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PAPER

Influence of AI-driven Inquiry Teaching on Learning Outcomes

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ABSTRACT

In the field of educational informatization, the integration of information technology with education and teaching is deepening. Rich information technologies, such as artificial intelligence (AI), have provided efficient support for optimizing the teaching process and improving teaching quality. Inquiry teaching aims to cultivate students' learning abilities in all aspects. AI can assist teachers in organizing effective inquiry activities, formulating scientific explanations, highlighting the relationship between problems and assumptions, and utilizing empirical evidence to solve related problems, thereby enhancing the teaching effectiveness of the course. In this study, we comprehensively examined the teaching process of inquiry-based teaching. We analyzed the impact of four components of AI-driven inquiry teaching (questioning, evidence acquisition, explanation focus, and evaluation summary) on learning outcomes. Additionally, we investigated the variations in learning outcomes resulting from college students' familiarity with artificial intelligence. Results show that the Cronbach's α coefficient of the questionnaire is 0.863 and the KMO value is 0.865. The four components of inquiry-based teaching, namely questioning, evidence acquisition, explanation focusing, and evaluation summary, have been found to enhance learners' learning outcomes by 10%, 5%, 1%, and 10%, respectively. The level of familiarity of college students with AI displays a significance level of 0.05 ($F = 2.682$, $p = 0.032$). The study results have significant reference value for analyzing the appeal of AI-driven education and teaching reform, summarizing the process of AI-driven inquiry teaching, and assisting teachers in using AI technology to enhance classroom teaching and improve teaching effectiveness.

KEYWORDS

artificial intelligence (AI)-driven inquiry teaching, learning outcome, questionnaire technique, analysis of variance

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1 INTRODUCTION

Artificial intelligence (AI) visualization technology is developing rapidly, especially with the widespread use of 5G technology. This has effectively solved the delay problem of data interactions in key AI technologies, providing strong support for the visual presentation of university teaching content. Combining AI with virtual, augmented, and mixed reality can greatly enhance the visual presentation of specialized course teaching content in colleges and universities. This integration enriches the teaching material and provides students with a unique and immersive learning experience in a multi-dimensional visual environment [1]. As the primary driving force behind the new scientific and technological revolution and industrial transformation, AI offers new momentum for promoting the high-quality development of education. Today, with the development of new information technologies, especially AI technology, higher education is inevitably facing the trend of "intelligence" [2]. AI-driven wisdom teaching in colleges and universities integrates the advantages of traditional teaching methods with AI technology. This integration has become one of the most significant challenges in the current era of teaching reform and development in higher education institutions, particularly in the context of big data. AI is an important technical tool that supports the visualization of teaching content, enhances the sense of presence in teaching scenes, promotes an interactive teaching atmosphere, facilitates borderless teaching, significantly improves the immersion of university teaching, and provides a powerful boost for students to better understand the fundamental knowledge system of various professional courses in colleges and universities. Additionally, it enhances the teaching effectiveness of university teachers.

Currently, all colleges and universities in China prioritize the role of students and promote active teacher-student interaction in the teaching process. They emphasize that teaching should be beneficial for teachers and students. Teachers should properly manage the relationship between knowledge and ability in teaching. They should prioritize the development of students' independence and autonomy, guiding them to investigate and explore practical problems. Additionally, teachers should foster a spirit of inquiry and promote personalized learning [3]. Inquiry-based teaching can enhance and cultivate college students' learning abilities in all areas. University teachers should organize effective inquiry activities and develop scientific explanations prior to teaching scientific concepts. They should emphasize the establishment of relationships between problems and assumptions and utilize empirical evidence to solve related problems in order to complete the inquiry-teaching process. Inquiry-based teaching can significantly enhance students' knowledge construction and the generative nature of the teaching process. After engaging in continuous reflection and a spiraling process, teachers and students require ongoing feedback to address the challenges associated with inquiry teaching. This feedback is crucial for improving the effectiveness of inquiry teaching and enhancing learning outcomes. If teachers utilize AI technology, students can engage in inquiry-based learning with the guidance of their teachers. The future direction of education will be focused on providing an inclusive and stimulating learning environment where every student can study successfully and their abilities can be nurtured and developed. Therefore, AI-driven inquiry teaching can be a valuable instructional approach that aids students in learning through efficient data analysis and algorithmic decision-making. This method also allows for more classroom time to be dedicated to higher-level learning activities, thereby facilitating continuous improvement in college students' learning outcomes.

2 THEORETICAL BACKGROUND AND HYPOTHESIS DEVELOPMENT

2.1 Theoretical background

According to Piaget [4], the constructivist learning theory emphasizes that students do not learn information from teachers through classroom teaching but rather through their own efforts in the social environment, using their existing materials. Through mutual discussions with different groups, students continuously construct meanings to acquire knowledge. Constructivism holds that, in the teaching process, it is necessary to change the continuous knowledge imparted by teachers to students, facilitate and ensure students' active participation in classroom learning, and empower students to become the active constructors of their own understanding under the guidance and support of teachers. In this process, teachers should pay attention to the changes in their own identity and become guides for students' meaning construction instead of simply imparting what students have learned.

Gardner [5], an American psychologist, proposed the theory of multiple intelligences, theory which encompasses spatial intelligence, linguistic intelligence, and bodily kinesthetic skills. This theory emphasizes the abilities that learners need when encountering problems or creating works that exist independently. Therefore, this theory advocates various evaluation concepts to promote development through evaluation. It transcends the traditional testing-based evaluation orientation and shifts the focus from results to the procedural review of work. This theory enlightens the current author about the importance of science courses in colleges and universities in cultivating students' comprehensive abilities. It emphasizes the need to discover and affirm the advantages of college students during the university teaching process in order to promote their personalized development. In the teaching process of various university disciplines, teachers should carefully plan the main objectives of the task, assess the learning situation of college students, group them appropriately based on the principle of heterogeneous grouping, and assign tasks to team leaders in a rational manner. Teachers should prepare evaluation scales to comprehensively assess students' language expression, work, and logical thinking, thereby enhancing their self-confidence.

2.2 Research hypothesis

Artificial intelligence-driven inquiry teaching is an innovation in the teaching paradigm in colleges and universities, led by information technology. AI technology provides the necessary technical infrastructure and application methods for the new teaching paradigm of professional courses in colleges and universities. This is achieved through the embedding of teaching processes, the application of real-life scenarios, and technical support. AI technology enhances teaching methods across various disciplines in colleges and universities. As for the influence of inquiry teaching on learners' learning outcomes, Andrini [6] comprehensively summarized the effectiveness of inquiry teaching in improving students' academic performance. Sriarunrasmee [7] proposed a virtual field investigation-type learning model based on inquiry-based teaching to enhance the scientific learning outcomes of junior high school students. The comparative experiment shows that the significance level of virtual learning effectiveness based on inquiry teaching is less than 0.05, indicating that inquiry teaching can enhance learners' learning outcomes. Lotulung [8] argued

that inquiry-based teaching effectively enhances the learning outcomes of entrepreneurship education. Mäkitalo-Siegl [9] investigated the influence of computer-aided collaborative inquiry learning on the learning outcomes of 54 pairs of students in middle school science education. Results show that the inquiry mode significantly impacts learners' scientific process skills and learning outcomes. Bunterm [10] pointed out that students under guided inquiry conditions greatly improve their scientific content knowledge and process skills compared to structured inquiry conditions. Spronken-Smith [11] shows that courses that use discovery-oriented inquiry teaching receive higher ratings and comments compared to those that use information-oriented inquiry teaching. Kolloffel [12] stated that in inquiry-based teaching, collaborative learners perform better than individual learners, particularly in intuitive knowledge and situational knowledge. Manlove [13] believes that fully designated support tools can enhance learning outcomes and facilitate the implementation of an initial inquiry teaching plan. Sari [14] found that students who utilize inquiry-based mind mapping exhibit differences in critical thinking ability and learning motivation. Furthermore, inquiry-based mind mapping tools have a significant impact on enhancing learners' critical thinking skills and learning motivation. Aditomo [15] indicated that inquiry teaching is positively correlated with learners' learning outcomes. However, in the absence of teacher guidance, it is negatively correlated with learners' learning outcomes. This further proves that inquiry teaching must take into account the role of teachers, who should provide scientific and reasonable guidance in the inquiry learning process of learners. Lestari [16] demonstrated that the implementation of guided inquiry learning has a significant impact on students' cognitive achievement in understanding stoichiometry concepts. Sutiani [17] investigated inquiry-based teaching with the participation of 93 students from the Department of Chemistry at Medan University, Nigeria. The results revealed that a standard inquiry learning model with a focus on scientific literacy has been established for the discipline of chemical kinetics. This model demonstrates excellent feasibility, and the learning approach developed and implemented in teaching activities can enhance students' critical thinking abilities. Kitot [18] conducted an eight-week exploratory teaching experiment. The results showed that the critical thinking ability of the experimental group was higher than that of the control group, confirming the effectiveness of inquiry-based teaching and suggesting that the inquiry teaching approach should be emphasized in school instruction. Furtak [19] analyzed the effectiveness of an inquiry-based teaching method that encourages students to take the lead. The results showed that when implementing the inquiry teaching mode, teachers should scientifically guide students to participate in inquiry-based teaching and patiently explain students' questions about this teaching method. Keys [20] argued that teachers need to design the implementation processes of the inquiry teaching mode in order to ensure learners' learning outcomes. Lotter [21] found that teachers need to reflect at different levels in the inquiry teaching mode, which can provide a more realistic learning environment to enhance students' learning outcomes. Lin [22] investigated the influence of collaborative reflection on teachers' inquiry teaching practices. The comparative results showed that the interaction between teachers and peers, as well as the reflective observation of peer teaching, has enhanced the quality of teachers' instruction. Based on existing research literature, inquiry pedagogy centers around inquiry-based activities. Therefore, teachers should prioritize facilitating students' exploration of problems and assisting them in acquiring knowledge, developing proficiency in scientific research methods, and gaining a deep understanding of the principles of scientific inquiry through immersive inquiry-based learning. In recent years, AI has been widely used in education

and teaching. This has led to new transformation requirements for education and teaching objectives, resulting in the innovation of various classroom teaching models, including inquiry teaching. Guided by national policies, the implementation of AI-aided education and teaching reform is progressing steadily. Therefore, a questionnaire regarding the impact of AI-driven inquiry teaching was constructed. According to existing research literature, the AI-driven inquiry teaching process mainly includes four stages: questioning, evidence acquisition, explanation focusing, and evaluation summary. The following four hypotheses were proposed:

H1: The use of AI-driven inquiry teaching can enhance learners' learning outcomes.
H2: The evidence acquisition link of AI-driven inquiry teaching can enhance learners' learning outcomes.
H3: The explanation focusing on the link between AI-driven inquiry teaching can improve learners' learning outcomes.
H4: The evaluation summary indicates that AI-driven inquiry teaching can enhance learners' learning outcomes.

3 RESEARCH DESIGN

3.1 Questionnaire design

Based on existing research, a research questionnaire was developed to investigate the impact of AI-driven inquiry teaching on learning outcomes. The questionnaire focused on three main aspects: The second aspect was measuring the AI-driven inquiry teaching method. Based on the research conducted by Shore [23] and Zhang [24], 4, 5, 5, and 4 measurement questions were proposed based on aspects of inquiry-based teaching: questioning, evidence acquisition, explanation focusing, and evaluation summary. The third aspect was measuring learning outcomes. All the measurement questionnaires were assessed using the five-point Likert scale [25].

3.2 Questionnaire design and data collection

The questionnaire survey was conducted among civil aviation students from six universities in China, namely Zhengzhou University of Aeronautics, Civil Aviation University of China, Civil Aviation Flight University of China, Shenyang Aerospace University, Anyang Institute of Technology, and Nanchang Hangkong University. Questionnaires were divided into online and paper formats. Specifically, questionnaires were distributed on the spot to randomly selected college students from different grades during their spare time on Saturday and Sunday and collected promptly. As for the online questionnaire survey, a quick response (QR) code was generated on a popular questionnaire platform (www.wjx.cn) in China. Head teachers sent the questionnaire uniform resource locator (URL) to student groups from six universities, and students were asked to fill out the questionnaires on weekends. A total of 426 questionnaires were recovered. Invalid ones, which were randomly filled, partially filled, or unfilled, were subsequently excluded. Valid questionnaire information was entered into Excel for statistical analysis, and a total of 308 valid questionnaires were obtained, resulting in an effective recovery rate of 72.30%.

Table 1. Frequency analysis results

Name	Option	Frequency	Percentage (%)
Gender	Female	36	11.69
	Male	272	88.31
Grade	Freshman	39	12.66
	Sophomore	111	36.04
	Junior	111	36.04
	Senior	47	15.26
Major	Aviation service arts and management	48	15.58
	Safety engineering	53	17.21
	Transportation	58	18.83
	Flight technology	66	21.43
	Aircraft airworthiness technology	83	26.95
Familiarity with AI	Very unfamiliar	60	19.48
	Unfamiliar	30	9.74
	Ordinary	72	23.38
	Relatively familiar	78	25.32
	Very familiar	68	22.08

Table 1 shows that out of the respondents, 272 males account for 88.31%. This aligns with the current situation of civil aviation majors in colleges and universities in China, where males in engineering majors accounted for a relatively higher proportion. Moreover, sophomores and juniors make up a large proportion, while seniors and first-year students occupy a small proportion. More college students were relatively and ordinarily familiar with AI, and the two types accounted for 48.70%.

4 RESULTS

4.1 Reliability and validity tests

The reliability and validity of the questionnaire surveys should be measured first. The reliability test aims to determine whether the results obtained from repeated measurements of the same object using the same method are consistent. Reliability indicates whether measured data is reliable and is generally measured through internal consistency. A higher reliability coefficient indicates greater consistency, stability, and reliability of test results. This study utilized the widely used Cronbach's α coefficient to conduct the reliability test for the questionnaire.

Table 2. Cronbach α coefficient of the questionnaire

Variable Type	Variable Name	Number of Measurement Questions	Cronbach α Coefficient	Cronbach α Coefficient
Independent variable	Questioning	4	0.794	0.863
	Evidence acquisition	5	0.915	
	Explanation focusing	4	0.888	
	Evaluation summary	4	0.855	
Dependent variable	Learning outcome	4	0.903	

Table 2 shows that the overall Cronbach α coefficient of this questionnaire was 0.863, which is greater than 0.8. This indicates the high reliability and quality of the research data. The Cronbach α coefficients of all variables were higher than 0.794, indicating that the data for each variable was also high and suitable for further analysis.

After conducting the reliability analysis, it is generally necessary to perform a validity analysis. Validity refers to the extent to which a measurement tool or method can accurately measure the object, and it reflects the extent to which the investigated object is accurately captured. The higher the measurement result accords with the investigated content, the higher the validity, or conversely, the lower the validity. The validity requirement for questionnaires or scales as measurement tools is crucial in educational questionnaire surveys.

Table 3. KMO and Bartlett tests

KMO value		0.865
Bartlett sphericity test	Approximate Chi-square	3542.515
	D*f*	210
	P value	0.000

Table 3 shows that the validity of the questionnaire was verified through KMO and Bartlett tests. The KMO value was 0.865, which exceeded the threshold of 0.8. The corresponding P value was less than 0.01. These results indicate that the research data obtained from this questionnaire was suitable for information extraction.

4.2 Regression results

Table 4. Linear regression results

Variable Name	T Value	P Value	Collinearity Diagnosis	
			VIF	Tolerance
Constant	2.734	0.007***	–	–
Questioning	1.898	0.059*	1.023	0.978
Evidence acquisition	2.447	0.015**	1.098	0.911
Explanation focusing	4.445	0.000***	1.138	0.878
Evaluation summary	1.722	0.086*	1.163	0.860
Adjusted R^2	0.936			
F	F (4,303) = 13.061, p = 0.000			
D-W value	1.765			

Notes: ***means the significance level of %, **denotes the significance level of 5%, and *reflects the significance level of 10%.

Table 4 shows that the model passed the F test (F = 13.061, p = 0.000 < 0.05), indicating that at least one independent variable has a significant influence on the dependent variable. Moreover, the multicollinearity test of the model reveals that all VIF values in the model were smaller than 5, indicating the absence of multicollinearity. Moreover, the Durbin-Watson (D-W) value was close to 2, indicating

no autocorrelation in the model and no correlation between the sample data. This suggests that the model was favorable.

1. H1 holds. The role of AI-driven inquiry teaching in questioning will have a significant impact on learners' learning outcomes at a significance level of 10%. This is because questioning serves as the foundation of inquiry-based teaching activities and motivates college students to actively engage in teaching and critical thinking activities. With the assistance of various guiding questions posed by teachers, college students can identify gaps in their knowledge and stimulate their critical thinking skills. The questions that college students want to explore should be based on their existing knowledge and life experience and should be solvable and scientific. College teachers design specific teaching scenarios as a means of presenting questions. By embedding the teaching questions within these scenarios, they aim to ignite a strong curiosity in college students, encouraging them to explore comprehensively. In the process of teaching civil aviation courses in colleges and universities, it is important for college teachers to identify the key and challenging aspects of the curriculum. They should align their teaching with the content and objectives of the civil aviation courses, provoke cognitive conflicts among students, stimulate their curiosity, and encourage them to explore and question. Moreover, teachers and students can discuss and identify teaching questions related to inquiry values.
2. H2 holds. The link between evidence acquisition and AI-driven inquiry teaching significantly influences learners' learning outcomes at a significance level of 5%. Evidence acquisition is the fundamental connection between inquiry-based teaching and the development of critical thinking skills in college students. By engaging in effective communication with their teachers, college students can gain a comprehensive understanding of learning concepts and employ more systematic learning approaches to engage in inquiry-based learning activities. In the summary of civil aviation courses, college students can gather evidence through data surveys, basic experiments, scientific history, scientific research results, factual materials, and other sources. Regardless of the approach taken, various scientific thinking methods, such as comparative classification, analysis, synthesis, induction, and generalization, need to be comprehensively utilized. In inquiry-based teaching for college students, it is important for college teachers to emphasize the process of acquiring evidence for civil aviation engineering students. They should guide students in designing their thought process to obtain evidence for questions, stay updated on students' understanding of civil aviation knowledge, address and resolve issues, and direct students in using appropriate scientific thinking methods to solve problems in accordance with disciplinary logic.
3. H3 holds. The explanation focusing on the link between AI-driven inquiry and learners' learning outcomes will have a significant impact at the 1% significance level. The reason is that focusing on explanation is at the core of inquiry activities and the explicit process of thinking activities. By providing scientific explanations for problems, college students can make discoveries, especially in their scientific reasoning process. For example, they can explain how to present various images in 3D space and how to support initial test conclusions with evidence in civil aviation courses. This conclusion suggests that teachers in civil aviation colleges and universities should extensively utilize inquiry-based teaching methods. They should prioritize the student explanation process and enhance students' understanding of evidence. Additionally, they should guide students to reason

and present arguments based on facts and evidence. It is important to establish connections between factors, evidence, and conclusions and encourage students to independently construct the meaning of knowledge. This approach will help improve their logical thinking ability and language expression skills.

4. H4 holds. The evaluation summary indicates that AI-driven inquiry teaching has a significant impact on learners' learning outcomes at a significance level of 10%. The evaluation summary includes three aspects: students' self-evaluation, teacher evaluation, and peer evaluation of students. This link is a correction process for inquiry teaching and regulating college students' thinking activities. In the self-evaluation process, college students should fully utilize the important impact of critical thinking. In the teaching of civil aviation courses in colleges and universities, it is important for teachers to emphasize students' self-evaluation. They should guide students to engage in criticism and questioning while also training their critical thinking skills. Additionally, teachers should help students enhance their abilities in self-reflection and self-monitoring. Meanwhile, it is crucial to establish more scientific teacher evaluation index systems and guide more students to engage in peer evaluation. This practice holds significant value in regulating college students' thinking activities, correcting and refining explanations, accurately comprehending civil aviation-related concepts, principles, and laws, and understanding the internal logical relations of civil aviation courses.

4.3 Difference analysis

Table 5. Analysis results of variance

Learning Outcome	Familiarity with AI (Mean ± Standard Deviation)					F	P
	Very Unfamiliar (n = 60)	Unfamiliar (n = 30)	Ordinarily Familiar (n = 72)	Relatively Familiar (n = 78)	Very Familiar (n = 68)		
	3.95 ± 0.86	4.33 ± 0.51	4.35 ± 0.58	4.52 ± 0.42	4.46 ± 0.31	2.682	0.032**

Table 5 revealed that familiarity with AI had a significant impact on college students' learning outcomes (F = 2.682, p = 0.032) at a significance level of 0.05. Furthermore, noticeable differences were observed between groups in the average score. Students who are relatively familiar with AI may acquire higher learning outcomes more easily when participating in AI-driven inquiry teaching. A possible reason is that AI-driven inquiry teaching combines the advantages of college teaching and AI technology, making it one of the most significant practical challenges in the current reform and development of colleges and universities. This is particularly relevant in the context of big data and the need for innovative teaching methods. With the application of AI technology, teachers can proactively carry out educational activities and implement personalized teaching based on the unique characteristics of each student. Students who are more familiar with AI will be better equipped to grasp AI-related teaching technologies. They will also be more motivated to actively participate in the learning process and collaborate with teachers. This teaching method aligns with the autonomous learning needs of college students. This conclusion also reflects that when adopting the AI-driven inquiry teaching method, college teachers should consider learners' familiarity with emerging teaching information technologies. However, they should not blindly advocate using AI technology frequently through tedious

processes. Instead, teachers should fully consider the usability and accessibility of information-assisted teaching technologies when designing an AI-driven physical classroom environment. Moreover, they should carefully consider the technical requirements of the social environment and enhance intergroup communication efficiency and collaboration effectiveness. This can reduce learners' cognitive load, increase their interest in learning, enhance learning inputs, and ultimately improve learning outcomes.

5 CONCLUSION

Artificial intelligence technology has been an important tool for enhancing national competitiveness. College teachers have actively utilized AI technology to assist in their teaching process. The seamless integration of modern information technologies with college education and teaching is beneficial for the innovative development of education. More colleges and universities are advocating for AI-driven inquiry teaching to update and optimize the teaching model and achieve an organic combination of quality-oriented education and large-scale education. This study analyzed the degrees of influence of four components—questioning, evidence acquisition, explanation focusing, and evaluation summary—of AI-driven inquiry teaching on learning outcomes. Then, the study examined the variations in learning outcomes among college students based on their familiarity with AI. Finally, the study yielded the following three conclusions: (1) The overall Cronbach's α coefficient and KMO value of the questionnaire were 0.863 and 0.865, respectively, indicating good reliability and validity of the questionnaire. (2) The four components—questioning, evidence acquisition, explanation focusing, and evaluation summary—of AI-driven inquiry teaching significantly improved learners' learning outcomes at levels of significance of 10%, 5%, 1%, and 10%, respectively. (3) Students who were relatively familiar with AI tended to acquire higher learning outcomes more easily in AI-driven inquiry teaching. How to achieve the integrated development of education and teaching reform by leveraging the advantages of AI technology and enhancing the adaptability and effectiveness of AI-driven teaching models should be thoroughly explored.

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