DOI: 10.53469/jerp.2024.06(09).04

Generative Artificial Intelligence Empowering Inquiry-Based Learning: Strategy and Challenges

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Abstract: ***This paper explores the potential and challenges of generative artificial intelligence in empowering inquiry-based learning. Generative artificial intelligence can build personalized learning resources, promote collaborative learning, conduct learning evaluation and feedback, and establish a human-computer collaborative inquiry-based learning model. However, we should also be vigilant against drawbacks such as over-reliance, information bias, academic misconduct, and lack of deep learning. To meet the challenges, this paper proposes strategies such as including content that generative artificial intelligence cannot complete, strengthening process evaluation, formulating clear guidelines for the use of generative artificial intelligence, and improving students' understanding of generative artificial intelligence tools to promote the effective implementation of inquiry-based learning.***

Keywords: Generative artificial intelligence, Inquiry-based learning, Human-computer collaboration.

1. Introduction

Generative Artificial Intelligence (GAI) is an advanced technology that can automatically generate various types of content, including text, images, audio, and video, based on user needs. In recent years, with the rapid development of technology, the potential applications of GAI have garnered widespread attention and recognition across various fields. In the realm of education, GAI demonstrates immense potential; it not only provides personalized learning resources tailored to the specific needs of students but also engages in natural language dialogue with them, facilitating intelligent assessment and immediate feedback. Furthermore, GAI can assist educators in designing more precise and effective teaching strategies and evaluations (Liu Bangqi et al., 2024; Zong Kai et al., 2023). These applications significantly enhance the efficiency and quality of teaching, promoting the realization of personalized learning and the possibility of holistic student development.

Inquiry-based learning, as a student-centered approach, emphasizes the construction of knowledge through active discovery, exploration, and problem-solving. This learning model not only fosters students' critical thinking and creativity but also cultivates their autonomous learning abilities. It encourages students to actively ask questions, design experiments, collect data, and analyze results, thereby achieving deeper understanding and internalization of knowledge (Wang Hulin, 2017). Relevant research indicates that inquiry-based learning can significantly enhance students' motivation and engagement, demonstrating positive effects on academic achievement (Bruscia, 2020). This approach exhibits unique and profound value in promoting interdisciplinary knowledge integration and addressing complex real-world problems.

In the era of artificial intelligence, it has become increasingly important to cultivate students' innovative thinking, technological adaptability, autonomous learning capabilities, lifelong learning attitudes, as well as emotional and social skills (Liu Ming et al., 2024). The integration of generative artificial intelligence with inquiry-based learning allows educators to design more effective inquiry-based learning activities, creating richer and more diverse learning experiences for students. This combination not only enhances learning outcomes but also provides significant practical implications for fostering higher-order competencies. Therefore, a thorough exploration of the application of generative artificial intelligence in inquiry-based learning will offer new insights and inspirations for educational practice.

2. The Path of Generative Artificial Intelligence to Empower Inquiry-based Learning

2.1 Using GAI to Build Personalized Learning Resources

GAI significantly enriches the variety of learning resources available to students, addressing the diverse educational needs of different individuals by employing sophisticated algorithms to generate highly personalized learning content. At the forefront of its capabilities, GAI possesses the ability to meticulously analyze each student’s learning history alongside their personal preferences, thus enabling the customization of personalized learning paths and content tailored specifically for them. For instance, through examining prior performance metrics and engagement patterns, GAI can autonomously create exercises or case studies that correspond precisely with each student’s current knowledge level and learning style. This tailored approach to learning materials not only effectively enhances students' motivation and interest in academic pursuits but also permits them to delve into subjects and concepts at a pace that is optimal for their individual learning processes (Kumar et al., 2022).

Furthermore, GAI also offers a plethora of robust teaching resources to educators, which encompasses meticulously crafted teaching plans, interactive courseware, and comprehensive assessment tools. This wealth of resources helps alleviate the workload on teachers, allowing them more time to focus on direct student engagement. Teachers can utilize the data gathered from GAI to modify their teaching strategies in response to student feedback and progress metrics, thus ensuring that the learning resources provided remain both applicable and effective. The inherent flexibility and adaptability of GAI empowers learners to continuously refine and adjust their learning strategies throughout the

exploration process, consequently enhancing their ability to learn autonomously.

2.2 Using GAI to Promote Cooperative Learning

Cooperative learning plays a pivotal role in inquiry-based learning frameworks, as it emphasizes meaningful interaction and collaborative effort among students. GAI can effectively design team-oriented cooperative learning activities that not only facilitate communication between students but also encourage them to work collectively toward achieving set academic goals. For instance, GAI can generate engaging project titles, assist students in forming dynamic teams, and provide insightful suggestions for the distribution of various roles within those teams. This initiative fosters diverse forms of cooperative learning, allowing students to engage in collaborative endeavors in a structured manner. Through the capabilities of GAI, students can participate in discussions that take place within a virtual environment, utilizing references, reports, or insights generated by the AI to enrich their understanding and exchange ideas. The feedback generated through these interactions not only fortifies their collaborative abilities but also enhances their problem-solving skills in group projects, effectively preparing them for future teamwork scenarios (Kumar et al., 2022). Additionally, GAI can consistently monitor the dynamics of teamwork and provide timely feedback, which aids students in reflecting on their cooperation strategies and making necessary improvements as needed.

2.3 Using GAI for Learning Evaluation and Feedback

Within inquiry-based learning, the provision of timely and effective feedback is crucial for facilitating students' growth and development. GAI is capable of conducting a thorough analysis of students' learning processes and outcomes, offering personalized evaluations that cater to individual learning experiences. Traditional methods of evaluation tend to primarily focus on measurable outcomes, but GAI transitions this approach by continuously monitoring learning activities in real-time, enabling the nuanced analysis of students' performance and the provision of immediate feedback. By leveraging advanced GAI technologies, educators can receive comprehensive learning reports that identify specific weaknesses students may have in various knowledge areas and subsequently recommend appropriate remedial actions. For example, when a student completes a thematic report for a course, GAI can systematically analyze the report's structure, the data utilized, and the arguments presented. It evaluates the logical coherence of the report, the depth of data presented, and the persuasiveness of the arguments, ultimately providing constructive suggestions for enhancement. This real-time feedback mechanism not only fosters an environment conducive to student reflection and self-regulation but also empowers teachers with timely insights into students' learning statuses, allowing them to provide more effective support tailored to students' evolving educational needs.

2.4 Establish a Human-computer Collaborative Inquiry Learning Model

Integrating GAI into inquiry-based learning endeavors necessitates a focused consideration of the human-computer collaborative learning model (Hu Hang et al., 2024). The effectiveness of this educational approach hinges on meaningful interaction and collaboration among teachers, students, and AI systems. With the human-computer collaborative model, a synergy between human creativity, emotional intelligence, and the computational prowess and data-handling capabilities of machines is established. In this framework, educators evolve from mere knowledge transmitters into facilitators and organizers of the learning experience. They can harness GAI tools to provide students with the essential support needed to grasp complex concepts and ideas. Moreover, the interactions occurring between students and AI serve to stimulate critical thinking and inquiry, prompting students to constantly pose questions and authenticate information as they navigate their learning journeys. Accordingly, teachers play an indispensable role in this collaborative process, guiding students in effective strategies to interact with GAI, thereby optimizing their learning outcomes. This collaborative interaction not only boosts educational efficiency but also fosters a deeper, more nuanced understanding of the subject matter at hand, ultimately enriching the overall learning experience for students.

3. Learning Disadvantages of GAI

3.1 Over-dependence

The convenience of GAI often causes students to become over-dependent in the learning process. When faced with complex problems or tasks, students tend to rely on GAI tools to quickly get answers instead of thinking independently and solving problems on their own. This dependence not only weakens students' critical thinking and problem-solving abilities, but also directly affects their learning motivation and interest. Studies have shown that over-reliance on external tools may lead to a diminished intrinsic interest in learning content, resulting in students pursuing superficial efficiency rather than true understanding and mastery (Liu & Wang, 2020). This reliance can also create a detrimental cycle, where students increasingly turn to GAI for help, leading to further erosion of their self-efficacy in academic tasks. In addition, over time, students may develop a psychological dependence on GAI, causing feelings of helplessness and anxiety when faced with academic challenges. As they encounter situations that demand independent thought, these students may feel ill-equipped to manage without technological assistance. This over-dependence on technology may also pose challenges for them in their future careers, as a significant number of jobs require independent thinking and innovative capabilities that are ideally cultivated during the educational process. Hence, fostering independence in learning is crucial to ensure that students develop the necessary skills for future endeavors.

3.2 Lack of Deep Learning

While the instant feedback function of GAI has certain advantages in improving learning efficiency, it may lead to students developing a lack of deep thinking and exploration in the learning process. GAI tools often provide quick answers,

prompting students to remain on the surface level of understanding rather than engaging in in-depth analysis and discussion. This superficial engagement can hinder students' true comprehension and application of knowledge, which in turn affects their ability to innovate and solve practical problems (Holschuh, 2021). Deep learning emphasizes learners' intrinsic understanding and ability to apply knowledge thoughtfully, yet the ease of generating content with GAI may encourage students to overlook the critical inquiry process essential for mastering subjects. This trend not only compromises the quality of their learning but also cultivates a deficiency in vital skills such as critical thinking and creativity, making it difficult for students to navigate real-world challenges. Furthermore, this neglect of deep learning can lead students to develop a habit of seeking quick answers rather than investing the time and effort needed to explore complex topics thoroughly. Therefore, to harness the benefits of GAI effectively, educators need to guide students towards maintaining an in-depth exploration of knowledge while utilizing technology, encouraging them to ask thoughtful questions, engage in discussions, and think independently.

3.3 Information Bias

GAI models are trained based on large-scale data sets, which may introduce bias and discrimination into their output. The inherent selectivity and lack of representativeness in the training data mean that GAI models cannot fully encapsulate the complexity and nuance of the real world. When students use such tools, they may inadvertently accept incorrect or misleading information as factual. For example, the content generated by GAI may favor certain specific viewpoints or positions while neglecting alternative explanations or scenarios (Williamson & Piattoeva, 2020). This information bias not only adversely impacts students' cognitive development but may also exacerbate social prejudices and discrimination on a broader scale. When critical thinking skills are underdeveloped, students are likely to uncritically accept the information produced by GAI, thereby forming narrow perspectives that can limit their worldview. As a result, educators must prioritize teaching students how to recognize and manage these biases effectively. They should be encouraged to approach information with a critical mindset, fostering an ability to identify diverse perspectives and encouraging comprehensive understanding of various topics.

3.4 Academic Misconduct

The use of GAI has also raised significant concerns about academic misconduct. With the increasing accessibility of GAI tools, some students may exploit these technologies to engage in academic dishonesty, such as cheating and plagiarism. Papers and assignments generated by GAI can yield superficially "high scores" with little comprehension of the underlying learning material. This reliance on GAI for assignments could lead to a concerning trend wherein students prioritize grades over genuine learning, risking long-term detriments to their cognitive and intellectual development (Zheng & Zhang, 2022). The ramifications of academic misconduct extend beyond individual students; they compromise the integrity of educational institutions and challenge the fairness and credibility of the education system as a whole. As such, it is imperative that educational institutions take constructive measures to raise awareness surrounding academic integrity. This includes implementing educational programs and supervision mechanisms aimed at guiding students towards the responsible use of GAI tools. By emphasizing the importance of academic honesty and fostering an environment that encourages genuine learning, educators can help students develop a more ethical approach to their academic pursuits while leveraging GAI effectively.

4. Strategies for Designing Inquiry-based Learning Activities

4.1 Content That Cannot be Completed by Generative Artificial Intelligence

When designing inquiry-based learning activities, teachers must deliberately select tasks that cannot be fully replaced by generative artificial intelligence (Hodges et al., 2023). Activities such as oral presentations, group collaborations, and hands-on practical tasks serve as prime examples of effective engagement. These types of activities require students not only to participate actively in practical exercises but also to develop essential teamwork and communication skills, which will help mitigate over-reliance on text generated by GAI. For instance, in group collaboration tasks, educators can create complex problem-solving scenarios that necessitate leveraging the collective intellect and discussions within the team to arrive at solutions. This approach fosters a deeper understanding of the subject matter while honing practical problem-solving skills and enhancing communication abilities.

Furthermore, teachers can facilitate on-site experiments or organize field trips that require students to observe and gather data from real-world environments. Such activities not only increase the authenticity of the learning experience but also inspire a sense of exploration and curiosity among students. For example, students might be tasked with creating questionnaires related to their course topics, collecting firsthand data, and analyzing their findings. This hands-on experience encourages independent thinking and reduces reliance on GAI-generated results, reinforcing the value of personal engagement in the learning process.

4.2 Strengthen Process Evaluation

In inquiry-based learning, it is crucial to shift the focus of homework evaluation towards students' engagement throughout the process, rather than solely on the final products produced with GAI assistance (Li Haifeng et al., 2023). Teachers should closely observe student performance and attitudes during inquiry activities. By monitoring students' participation in group discussions, experimental implementations, and problem-solving endeavors, educators can gain a holistic view of their learning progress and capabilities. This method effectively encourages genuine engagement and discourages students from merely seeking shortcuts through GAI.

For instance, during thematic research projects, teachers can implement mid-term feedback sessions where students present their research progress and share challenges or

breakthroughs with their peers. Through these sharing sessions, students explore their comprehension of the topic, detail their methodological journeys, and discuss their interactions with GAI. Such peer interactions not only deepen their understanding of the content but also help them avoid the pitfalls of directly utilizing GAI outputs. Additionally, these sessions allow students to recognize their strengths and weaknesses, motivating them to reflect on their learning approaches and make necessary adjustments for future endeavors.

4.3 Establish Clear Guidelines for the Use of GAI

To effectively manage student interactions with GAI throughout the learning process, teachers need to create and disseminate clear guidelines regarding GAI usage. These guidelines should articulate acceptable and unacceptable behaviors, helping students understand the framework for responsible tool use. For example, educators might require students to disclose specific segments of their submitted homework that were generated using GAI tools and to evaluate and modify the content in question. This practice not only cultivates critical thinking regarding the GAI outputs but also enhances students' sense of accountability (Richardson, 2020).

Moreover, it is essential for teachers to establish clear consequences for violations of these guidelines in order to uphold academic integrity and fairness. Whether imposing temporary point deductions or requiring resubmission of work, it is important that the consequences are transparent and equitable. Maintaining consistency in enforcement will help diminish students' dependence on GAI while encouraging them to adopt proactive and independent learning strategies.

4.4 Improve Students' Understanding of GAI Tools

Educating students about the advantages and potential drawbacks of GAI tools is crucial when designing inquiry-based activities. Teachers should help students recognize how these tools can serve as effective learning aids, all while making them aware of associated risks such as plagiarism, superficial understanding of academic content, and the erosion of analytical thinking skills (Jiao Jianli, 2023). Facilitating class discussions where students can share their experiences and perspectives on GAI use fosters a reflection-oriented mindset and increases their understanding of these tools' applications.

Additionally, educators must emphasize the significance of academic integrity, nurturing students' sense of responsibility in both knowledge creation and its application. Through targeted lectures or seminars, teachers can lead discussions on the implications of GAI in academic research and learning while highlighting ethical considerations. This educational approach not only equips students with a broader understanding of GAI tools but also instills healthy academic attitudes and behavioral norms throughout their usage, ultimately promoting a more sustainable and responsible integration of technology into their educational pursuits.

5. Case Analysis

5.1 Assignments and Issues Before Optimization

In order to get a deeper understanding of students' performance and thought processes when using GAI for learning, we assigned an exploratory after-class task with the topic: "What changes have occurred in the number and industries of multinational companies in China over the past 20 years?" Students were informed that they could utilize GAI to assist in their responses. An analysis of the submitted assignments revealed several noteworthy phenomena.

Firstly, regarding the submission of assignments, over half of the students opted to use GAI as an GAId. This trend reflects an increasing reliance on GAI among students; however, the overall quality of the assignments was generally low. Most students' responses consisted primarily of qualitative analyses, lacking specific data support. While GAI can generate text and provide some background information, it currently cannot directly supply precise data, leading to a deficiency in necessary quantitative analysis within the assignments. This outcome not only affects the overall quality of the work but also exposes some issues students face when utilizing GAI tools.

Secondly, many students tended to simply pose questions to GAI and then copy the generated responses. This approach not only lacks a process of critical thinking and analysis but also causes students to lose agency in their learning. There were very few responses that integrated GAI-generated answers with relevant data and conducted in-depth analyses, indicating a widespread lack of academic integrity awareness among students. They often do not recognize that direct reliance on GAI-generated content may lead to academic misconduct. Furthermore, students clearly lack the skills to collaborate with GAI effectively to promote high-quality responses.

This simplistic interaction model hinders the effective development of students' deep learning capabilities, potentially leading them to become overly dependent on GAI in their thought processes. When faced with complex problems, students frequently choose to rely on GAI outputs rather than seeking answers through their own critical thinking and research. This trend not only negatively impacts students' academic capabilities but may also pose greater challenges in their future learning and professional endeavors.

5.2 Assignment Optimization Plan

To address these issues, we can improve this assignment based on the strategies outlined in Part 4.

Firstly, the exploratory task needs to be further clarified and specified. Educators could require students to select several representative multinational companies, collect relevant data from the past 20 years, such as sales figures, employee numbers, and primary business sectors, and analyze the changes in these companies over specific years. This process would encourage students to engage in more in-depth research and cultivate their data analysis skills.

Secondly, incorporating process assessments is essential. Educators could ask students to describe how they selected

sample companies, the data collection process, and the challenges encountered along the way, along with their solutions. This would not only help students reflect on their research process but also enhance their problem-solving abilities and critical thinking skills.

Thirdly, educators should emphasize the tasks that GAI cannot accomplish. Specifically, students could be required to organize a class presentation after completing their reports to explain their research findings. In this process, students would need to share their research with others, which would not only improve their communication skills but also foster discussion and interaction among classmates, thus enhancing the overall learning experience.

Fourthly, it is crucial to establish clear guidelines for the use of GAI. Educators should inform students that when submitting their final reports, they must declare whether they used generative GAI tools and provide a brief explanation of their usage. This measure will help raise students' awareness of academic integrity and encourage them to be more cautious when utilizing GAI tools.

Finally, to improve students' understanding and skills in using GAI tools, a discussion session could be organized. During this session, students could share their experiences and thoughts on using GAI for this assignment, exploring how to utilize these tools more effectively. Through this exchange, students would not only get insights in GAI and advice from others but also stimulate new ideas and perspectives in the discussion.

6. Conclusion

In summary, while the application of artificial intelligence in the educational field provides convenience for students, we must not overlook the challenges it presents. By refining exploratory assignments and guiding students in their use of GAI, we can help them make better use of these tools while fostering their independent thinking abilities and academic integrity awareness. This approach will not only enhance the quality of educational activities but also lay a solid foundation for students' future learning and development.

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