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Cultivating Physiological Understanding and Innovation through Scientific Questions

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Abstract
Physiology is essential in medical education, linking basic and clinical medicine, and its teaching quality affects students' clinical reasoning and skills. Traditional methods promote passive learning, highlighting the need for effective teaching approaches. This study investigates the impact of scientific questions on enhancing the understanding and innovative thinking skills of medical students in the context of physiological education. A questionnaire was administered to 34 medical students after they engaged in scientific questions activity. The questionnaire focused on assessing the impact of scientific questions on knowledge acquisition and creativity enhancement. The findings reveal that 97.06% of participants found scientific questions beneficial for comprehending physiological knowledge, with 82.35% emphasizing their crucial role in the learning process. 67.65% of respondents reported that engaging with scientific questions enhanced their innovative capabilities, particularly in problem analysis and problem-solving, improvements in teamwork skills, broadened their knowledge and perspectives. 44.12% expressing strong interest in future similar engagements. The findings underscore the importance of integrating scientific questions into physiological education, as they not only foster deeper understanding but also contribute to the essential skills required in modern healthcare environments.
Keywords: physiological education, scientific questions, innovation, teamwork
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1. Introduction

Physiology is fundamental to medical education, providing a comprehensive framework that enhances our understanding of the human body and its various functions (Natochin Iu, 2008). Understanding the mechanisms of body functions at a cellular and systemic level is essential for medical students and healthcare professionals. Physiology enhances students' understanding of health and disease while establishing a crucial link between basic and applied sciences, which is vital for clinical practice (Wei, Xu, Guo, Tan, & Xin, 2024). However, simply memorizing physiological concepts is not enough; the real challenge lies in fostering the ability to innovate and think critically within the medical field (Wei et al., 2024) (Vykhrushch et al., 2021).

Innovative thinking and creativity have garnered increasing attention in modern medical education (Amiri, Khosravi, Chaman, Sadeghi, & Raei, 2020) (Song & Cai, 2024). The capacity to devise new solutions and tackle complex medical challenges is a skill that should be developed throughout training. Medical innovation can lead to better patient outcomes, the creation of advanced technologies, and the introduction of novel treatment methods (Vykhrushch et al., 2021) (Rathee, Sen, Pandey, & Jain, 2024). By highlighting the importance of innovation in education, we can equip future healthcare professionals to navigate the challenges of a constantly changing medical environment. Notably, innovative thinking can be fostered through inquiry-based learning, which encourages students to engage with scientific questions that promote critical thinking and creativity (Verma, Yacob, & Kirpalani, 2023).

Scientific questions is one of the ways to stimulate curiosity and enhance understanding. It is a method that encourages critical thinking and exploration within the field of science(Ke., Tong., Cheng, & Peng., 2025). These questions are typically open-ended, which means they invite various approaches and viewpoints. This format challenges students to actively engage instead of merely absorbing information. Moreover, these activities often blur the lines between traditional classroom learning and real-world application, prompting students to apply their physiological knowledge in genuine contexts. Interacting with peers during these activities fosters a sense of collaboration, which is vital for teamwork in clinical environments (Bordonaro, 2024). Additionally, these experiences enable students to explore their interests, and build the resilience needed to tackle the challenges they will face in the medical profession.

In this paper, we will explore the outcomes of a recent survey conducted among medical students who participated in extracurricular activities related to scientific questions.

2. Research Methodology

2.1 Sample and data collection

After studying physiology, we held an extracurricular activity. There are four scientific questions: 1. Do male mosquitoes really not suck blood? 2. Does winter swimming feel cold? 3. What effect does sand ginger juice have on the intestines? 4. How does electroencephalogram change under different states? Students could choose one of the questions based on their interests, research it uses their knowledge of physiology, and then design an experiment or organize the information they found to draw conclusions. After that they presented their findings and related content. Afterwards, we surveyed the participating students to assess a questionnaire. A total of 20 groups participated, with each group consisting of two to three people. In the end, 34 people took part in the survey.

2.2 Questionnaire

To assess the impact of the activity, we developed a questionnaire targeting several key areas: the effectiveness of scientific questions in enhancing the understanding of physiological knowledge, the contribution of these questions to the development of students' innovative thinking, and if the participants engaging in similar activities in the future. Finally, the questionnaire also highlighted certain areas for improvement, including the need for more structured guidance during the inquiry process, a high time cost, overemphasis on results, and others. The questionnaire survey was developed for this study (supplementary material).

3. Results

3.1 Enhancing Understanding of Physiological Knowledge through Scientific Questions

The first part of our study aimed to evaluate how scientific questions contribute to a better comprehension of physiological concepts among students. The survey results show that 97.06% of students indicated that scientific questions have been beneficial to their learning of physiological knowledge. Among this group, 52.94% reported feeling that such scientific questions provided substantial assistance, while 44.12% indicated that the support was somewhat limited, demonstrating that while the majority saw value, there remains a segment of students who felt the need for more robust interventions. Another 2.94% of participants reported that they did not find these scientific questions helpful in their studies (Fig. 1A). These results indicate that scientific questions play a pivotal role in deepening students' understanding of physiological principles.

In terms of the importance of scientific questions for physiological study, 82.35% of students articulated that they were crucial to their learning experience. Furthermore, 14.71% of respondents remained neutral, while only 2.94% of students perceived scientific questions as unimportant to their studies (Fig. 1B). This data suggests that scientific questions not only facilitate understanding but also engage students in active learning processes.

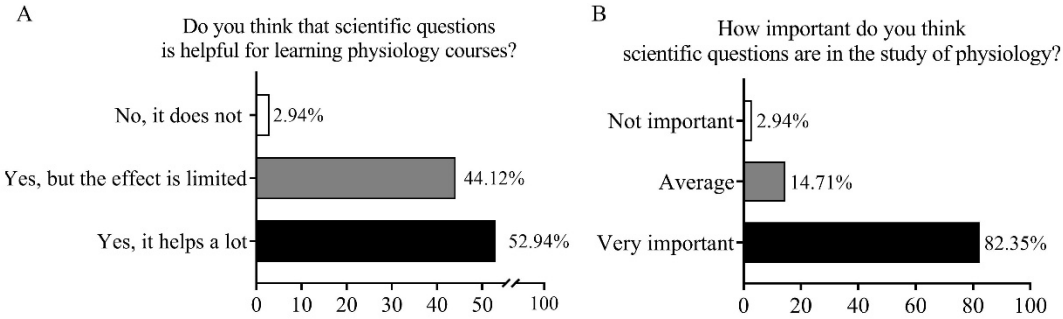

Fig. 1. The effect of Scientific Questions on understanding physiological knowledge. A. A survey questionnaire on the impact of scientific questions on physiological knowledge. B. A survey on the significance of scientific questions for the study of physiology.

3.2 Fostering Innovative Thinking through Scientific Questions

In addition to fostering understanding, scientific questions significantly contribute to the cultivation of innovative thinking skills among medical students. The survey results indicated that most students perceived a strong correlation between scientific questions and the enhancement of their innovative capabilities. Specifically, 67.65% of participants believed that engaging with scientific questions had effectively improved their innovation skills. In contrast, 26.47% of students remained neutral regarding the impact of scientific questions on their creative thinking, while 5.88% asserted that they found no significant benefit (Fig. 2A).

To delve deeper into the specific aspects of innovative thinking influenced by scientific questions, we included a multiple-choice question in our survey. The results show that over 80% of students reported improvements in both problem analysis and problem-solving capabilities, as well as in the cultivation of innovative thinking and practical skills (Fig. 2B). Scientific questions is not only merely academic exercise but is integral to

advancing teamwork, adaptability, and self-learning among students. The data is, 76.47% of students indicated that scientific questions enhance their teamwork abilities. Furthermore, 64.71% of participants felt that engaging in scientific questions broadened their knowledge and perspectives. However, it is noteworthy that only a modest number of students reported an improvement in self-learning skills (Fig. 2B). These findings highlight that the integration of scientific questions into physiological education plays a pivotal role in fostering innovation and contributing to essential skills needed in modern healthcare environments (Ten Haven, Pragt, Luijk, Dolmans, & van Mook, 2022) (Badowski, 2023).

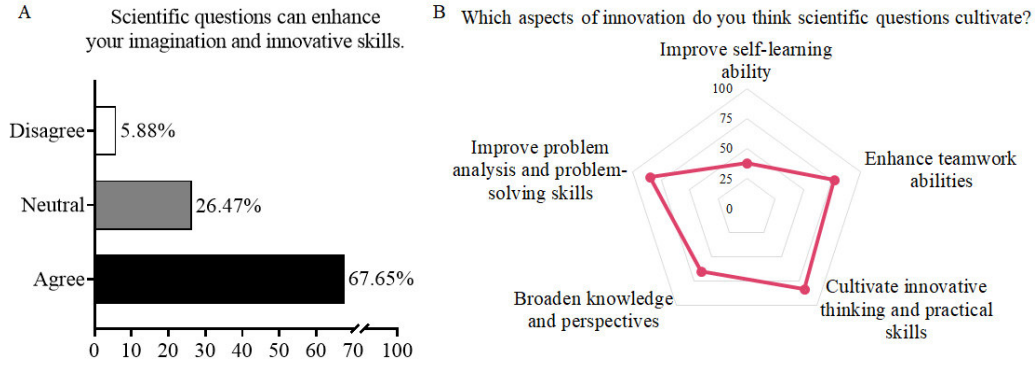

Fig. 2. The effect of Scientific Questions on enhancing innovation ability. A. Scientific questions fostering innovation skills. B. The aspect of innovative ability promoted by scientific questions.

The student feedback reveals a positive reception of the scientific questions activity. 44.12% of participants expressed a strong willingness to engage in similar activities in the future. Meanwhile, 52.94% of students indicated that their participation would depend on the specific circumstances, and 2.94% of students would not participate again (Fig. 3A). This data underscores that most students found the recent activity beneficial, reinforcing the efficacy of scientific questions in the educational environment. Moreover, we observed that many students identified specific physiological knowledge segments that left a substantial impact on their learning experience. The creation of a word cloud (Fig. 3B) visually demonstrates the terminology and concepts that resonated most with the students.

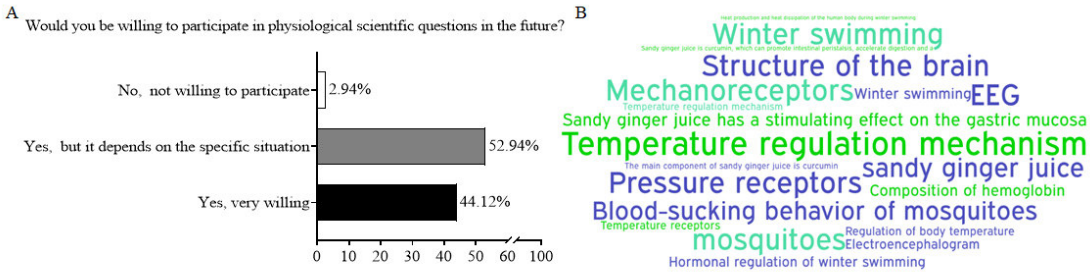

Fig. 3. The perspectives of Students on scientific question activities. A. Willingness to participate in scientific question activities in the future. B. Word cloud of the knowledge that left the deepest impression on students.

4. Discussion

In recent years, the integration of inquiry-based learning into the curriculum has been recognized as a vital approach to enhance student engagement and understanding, particularly in fields like physiology. This paper discusses the critical role that scientific questions play in fostering physiological knowledge and innovation among students.

Our research indicates that the use of scientific questions can significantly enhance the learning experience in physiology. Students acknowledge the importance of exploring scientific questions in their study of physiology (Fig. 1). The majority expressed a strong desire to participate in activities that promote this inquiry (Fig. 3A). It is clear that engaging in scientific questions activities is beneficial for medical students' learning of theoretical knowledge. This aligns with the findings that gamification can enhance learning outcomes, engagement, and collaboration through real-world applications (Krishnamurthy et al., 2022). Students view the exploration of scientific questions as a process similar to playing a game, which helps them better internalize knowledge. Additionally, a word cloud analysis based on student feedback highlighted the positive influence of scientific questions on their learning processes. Keywords such as "temperature regulation mechanism," "EEG" "sandy ginger juice" and "mechanoreceptors" emerged prominently (Fig. 3B), suggesting that students are more likely to

grasp complex physiological concepts when engaged through targeted inquiry. This form of active learning not only aids in the retention of knowledge but also fosters an awareness of active engagement in the learning process (Torralba & Doo, 2020).

The benefits of scientific questions extend beyond knowledge acquisition; it also significantly enhances students' innovation capabilities. Many students noted that engaging with scientific questions has significantly improved their ability to analyze problems and solving skills (Fig. 2B). This skill is essential in the field of medical, where the treatment of complex diseases often require critical thinking and innovative approaches (Araujo, Gomes, & Ribeiro, 2024) (Richards, Hayes, & Schwartzstein, 2020). At the same time, scientific questioning activities expanded students' knowledge, allowing them to integrate not only physiological concepts but also knowledge from other sciences and even information beyond books. Moreover, many students indicated that this activity significantly enhanced their teamwork skills. In the process of group discussions and collaboratively solving scientific problems, each participant played different roles and leveraged their unique strengths, which fostered collective thinking and creativity. Through collaboration, students not only learned how to communicate more effectively with their peers but also developed mutual trust and understanding. This practical experience in teamwork is crucial for medical students (Shaker et al., 2024), as many tasks in the medical field require interdisciplinary collaboration and strong communication skills. Being able to work effectively in a team will help them tackle complex medical challenges and meet the needs of patient care in their future careers (Eddy, Jordan, & Stephenson, 2016) (Lerner, Magrane, & Friedman, 2009). In contrast, researchers have emphasized the role of inquiry-based learning in cultivating students' critical thinking and collaborative skills (Verma et al., 2023), which is similar with this study. However, researchers also underlined the importance of self-directed learning for medical students (Lu, Ren, Xu, & Han, 2023), whereas the feedback on scientific questions did not have as significant an impact. This suggests a need for further refinement of teaching strategies to ensure that all students not only grasp the relevance of collaboration and practical application but also could seek knowledge independently beyond the curriculum.

In the activity of scientific questions, we also identified some drawbacks. 67.65% of students indicated a perceived lack of guidance throughout the inquiry process. Teachers providing students with certain guidance can help in formulating relevant questions and designing appropriate experiments. Additionally, 32.35% of students noted that the activity took too much time, which may be related to a lack of teacher's guidance and students' self-directed learning abilities (Ricotta et al., 2022). 23.53% of students expressed that an overemphasis on results could detract from the learning process itself (Fig. 4). This highlights a crucial gap where educators need to provide more systematic support to facilitate effective inquiry-based learning experiences. A clear mindset can help students tackle complex scientific problems and provide them with the necessary approaches to promote deeper understanding and innovation (Meyer et al., 2022). In conclusion, the integration of scientific questions in physiology education represents a powerful tool for cultivating not only knowledge but also innovation and creativity among students. While the positive impacts are clear, it is essential for us to be mindful of the challenges that students face and to implement strategies that will enhance guidance, manage time effectively, and promote a focus on the learning process.

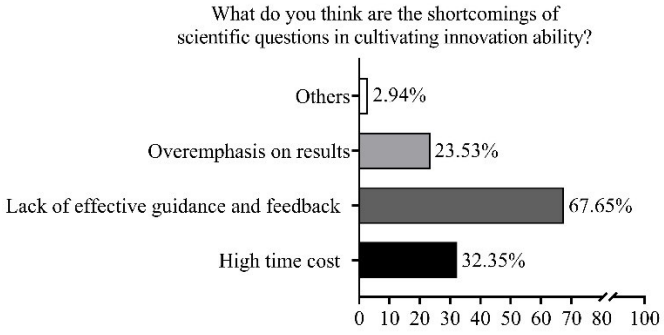

Fig. 4. The perspectives of Students on scientific question activities. A survey questionnaire on the shortcomings of scientific questions in cultivating innovation ability.

5. Conclusion

In conclusion, our study highlights the significant role that scientific questions play in enhancing both understanding and innovative thinking among medical students in the context of physiological education. The overwhelmingly positive feedback from students indicates that scientific questions not only contribute to their comprehension of complex physiological concepts but also actively engage them in the learning process. Promoting the ability to analyze and solve problems, as well as collaborating effectively within teams, reflects the multifaceted advantages of integrating scientific questions into educational practices. While a minority of students

expressed neutrality or dissatisfaction, the majority's response interest in future activities centered around scientific questioning. Overall, the integration of scientific questions into physiological education is crucial for cultivating essential skills in modern healthcare settings.

Future research could investigate the integration of artificial intelligence (AI) tools that generate scientific questions to promote clinical innovation among medical students in physiology education. Additionally, it may involve the use of AI-simulated clinical scenarios to assess how the combination of scientific questioning and AI-based teaching methods can improve the application of theoretical knowledge into innovative clinical practice.

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Data Availability Statement
The data utilized in this study were obtained through self-designed questionnaires. All relevant data supporting the findings of this article are available within the article itself.

Declaration of interest statement
The authors declare they have no conflicts of interest.

Ethics approval and consent to participate
The need of ethical approval was waived by the Ethics Committee of Hainan Medical University. All participating students voluntarily took part in the activity and filled out the survey questionnaire. The informed consent to participate in this study was obtained from each participant on the front page of the questionnaire.

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