Integration of Industry and Education Journal
Volume 5, Issue 2, 2026, Page 14–24
https://doi.org/10.6914/iiej.050202

Knowledge Construction and Value Internalization: An Educational Intervention Study Based on the 5E Model in Medical Science Communication Training

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Abstract

Objective: This study aimed to evaluate the effectiveness of a 5E-based educational intervention in promoting knowledge construction and value internalization in a medical science communication course.

Methods: This study was designed as a pilot educational intervention study. A total of 24 undergraduate medical students participated in a course integrating a 5E teaching model. The intervention incorporated elements of values-based education and professionalism development throughout the five phases (Engagement, Exploration, Explanation, Elaboration, and Evaluation). Pre- and post-intervention questionnaires and knowledge tests were conducted to assess learning outcomes.

Results: After the intervention, students' familiarity with key dimensions of medical science communication significantly improved compared with baseline ($P < 0.05$). Knowledge test scores also increased significantly ($P < 0.05$). More than 90% of students demonstrated high recognition of the core dimensions of professionalism, including scientific spirit, teamwork, and reflective spirit. The overall acceptance rate of the 5E model reached 91.66%.

Conclusion: The 5E-based educational intervention effectively enhances both knowledge acquisition and value internalization in medical education, and exerts a positive effect on fostering students' professionalism. This approach provides a feasible framework for integrating cognitive learning with the development of professionalism in medical training.

Keywords 5E teaching model; educational intervention; medical education; knowledge construction; values-based education; professionalism

1 Introduction

The Health Knowledge Popularization Campaign is one of the core tasks of the "Healthy China" strategy [1]. As the core reserve force for science popularization work in the future, medical students' awareness and capabilities of science popularization are directly related to the improvement of the national health literacy.

© The Author(s) 2026. **Article History** Received: June 2, 2026; Accepted: July 5, 2026; Published: August 15, 2026. ***Integration of Industry and Education Journal***, ISSN 2791–2671 (Print), ISSN 2791–268X (Online). Email: cpcl@cpcl.hk, https://iiej.net, https://cpcl.hk. Creative Publishing Co., Limited 2026. CPCL®. This work is licensed under a Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License.

Medical colleges and universities, as the main body responsible for cultivating and delivering high-quality medical talents for the country and society, shoulder the responsibility and mission of cultivating and improving medical students' science popularization literacy. At present, medical science popularization education is faced with two core challenges: first, how to help students construct a systematic and scientific theoretical knowledge system from fragmented and perceptual cognition; second, how to implicitly foster scientific integrity and professionalism in the process of knowledge imparting, and avoid the "labeling" style of values-based education and professionalism development. Existing studies have mostly focused on external approaches such as community activities, clinical practice and science popularization competitions to improve medical students' science popularization capabilities[2–6], while systematic exploration on the teaching model itself is relatively scarce, making it difficult to respond to the above two challenges simultaneously.

Proposed by the Biological Sciences Curriculum Study of the United States, the 5E teaching model is a progressive teaching strategy based on constructivist theory, which includes five core phases: Engagement, Exploration, Explanation, Elaboration and Evaluation[7]. This model has shown good application effects in various medical-related courses, which can effectively promote learners' knowledge construction and in-depth understanding, help them consolidate the foundation of theoretical knowledge, and improve their abilities of knowledge integration and transfer, serving as an effective strategy to optimize medical teaching and clinical tutoring [8–10]. Our research team has found in the course Fundamentals and Practice of Medical Science Popularization that the 5E teaching model is conducive to students' mastery of science popularization knowledge [11]. However, while consolidating the theoretical foundation of science popularization, can the 5E teaching model promote the integration of values education and professionalism development to realize value internalization? At present, there is a lack of relevant empirical support for this issue.

In view of the fact that values-based education emphasizes the integration of knowledge acquisition and professionalism development, and plays an important role in shaping noble medical ethics[12–14], this study takes the elective course Fundamentals and Practice of Medical Science Popularization of Sun Yat-sen University as the research platform, focuses on the fundamental proposition of "knowledge construction and value internalization", and attempts to construct and implement a professionalism education teaching intervention based on the 5E model. The study aims to systematically evaluate the practical effect of this model on medical students' mastery of scientific popularization theoretical knowledge and recognition of the core dimensions of professionalism, so as to provide a feasible path of cognitive construction and value shaping for science popularization education in medical colleges and universities.

2 Materials and Methods

2.1 Methods

2.1.1 Course Application

A total of 24 undergraduate students from the 2021, 2022 and 2023 cohorts of Sun Yat-sen University, who enrolled in the public elective course Fundamentals and Practice of Medical Science Popularization, were recruited as research subjects. This study was conducted as a pilot educational intervention in the 8th 135-minute session of the course (90 mins of theoretical teaching and 45 mins of practical teaching) themed Precision Science Popularization: Tailored to Different Crowds in April 2025, to explore the effectiveness of the 5E teaching model in medical education.

2.1.2 Teaching Design

The 5E teaching model was adopted in this teaching unit, which was divided into five phases: Engagement, Exploration, Explanation, Elaboration and Evaluation (Figure 1). The teaching process adhered to the student-centered principle and emphasized students' active participation and in-depth experience. The design of each phase is as follows: (1) In the Engagement phase, classic video clips were played to create problem situations, stimulate students' learning interest and guide them to enter the learning state. (2) In the Exploration phase, students independently analyzed cases around the question "What is precision science popularization" to cultivate their critical thinking and problem-solving abilities. (3) In the Explanation phase, students used mind maps to sort out the core elements of precision science popularization and their interrelationships, and elevated their perceptual cognition to rational cognition under the teacher's guidance. (4) In the Elaboration phase, students discussed in groups the differences in science popularization strategies for three groups of people: adolescents, young and middle-aged people, and the elderly, so as to deepen their understanding and application of precision science popularization. (5) In the Evaluation phase, mainly applied in the practical class, a diversified evaluation method combining student self-evaluation, peer evaluation and teacher evaluation was adopted to conduct a comprehensive evaluation of students' learning outcomes.

The integration of values-based education and professionalism development was embedded throughout the teaching process. In the Engagement phase, emotional engagement was used to stimulate interest and promote scientific integrity; in the Exploration phase, teamwork and collaborative skills were emphasized; in the Explanation phase, students were encouraged to develop independent thinking and innovation; in the Elaboration phase, a people-centered approach was reinforced; and in the Evaluation phase, reflective practice was promoted through self- and peer-assessment.

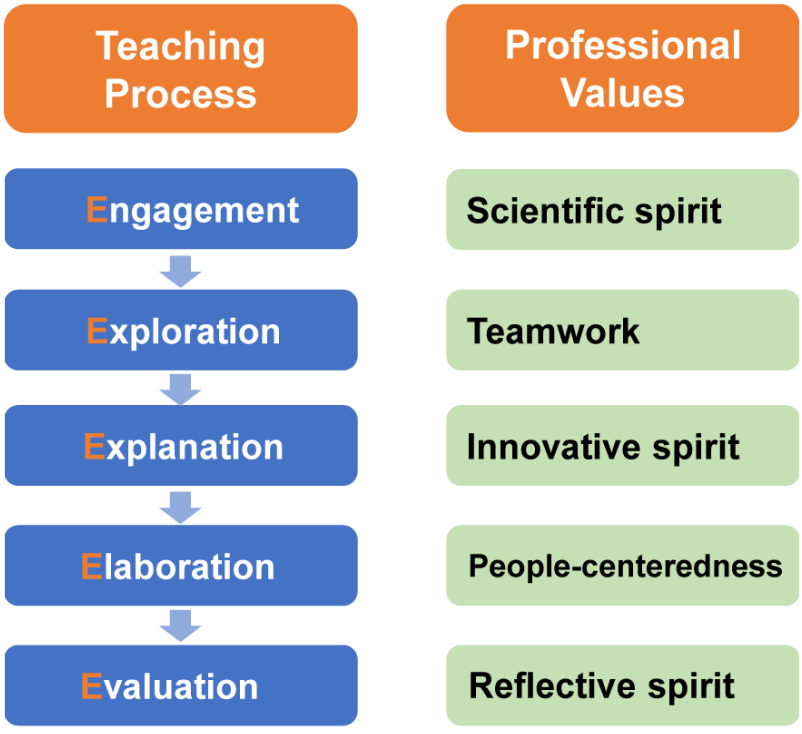


Figure 1: Integration of values-based education within the 5E teaching model.

2.2 Observation Indicators

Questionnaires and test questions were released through the online platform Questionnaire Star, and data were collected before and after the course respectively.

2.2.1 Students' Familiarity with the Core Content of Precision Science Popularization

A 4-level rating scale (very familiar, relatively familiar, generally familiar, unfamiliar) was used to assess students' mastery of the following six dimensions: (1) concept of precision science popularization (2) importance of precision science popularization (3) cognitive differences (4) needs differences (5) pain point differences (6) method preference. The impact of the teaching intervention on students' cognitive level was evaluated by comparing pre-course and post-course results.

2.2.2 Students' Mastery of Precision Science Popularization Knowledge

An objective test (6 multiple-choice questions, full score: 100 points) was administered, covering needs differences and pain point differences among different audiences. Teaching effectiveness was quantitatively evaluated by comparing pre-test and post-test scores.

2.2.3 Students' Recognition of the Core Dimensions of Professionalism

A 5-level rating scale (strongly agree, relatively agree, generally agree, not quite agree, strongly disagree) was used to investigate students' recognition of five practical principles of science popularization that represent the core dimensions of professionalism, including the scientific spirit, teamwork, innovative spirit, people-centeredness and reflective spirit. This indicator was designed to evaluate the actual effect of values-based education in fostering professionalism and value guidance.

2.2.4 Students' Acceptance of the Teaching Model

A 5-level rating scale (strongly agree, relatively agree, neutral, not quite agree, strongly disagree) was used to investigate students' acceptance of the 5E teaching model.

2.3 Statistical Methods

The statistical software SPSS 27.0 was used for data analysis in this study. The measurement data were tested by the Shapiro-Wilk test, and since they did not conform to the normal distribution, they were described by the median (M) and interquartile range (P25, P75), and the Wilcoxon signed-rank test was used for the comparison between groups. The enumeration data were expressed as n (%), and the Wilcoxon signed-rank test was also used for the comparison between groups. A two-tailed P value < 0.05 was considered statistically significant.

3 Results

3.1 Questionnaire Recovery Rate and Reliability and Validity Test

A total of 24 students participated in the questionnaire survey, and 24 valid questionnaires were recovered, with an effective recovery rate of 100%.

3.2 Students' Familiarity with the Core Content of Precision Science Popularization

As shown in Figure 2, the 5E teaching intervention substantially enhanced students' familiarity across all six evaluated dimensions of precision science popularization. Statistically significant improvements were observed for three core dimensions: the concept of precision science popularization ($P < 0.05$), its importance ($P < 0.05$), and the differences in science popularization pain points among different audiences ($P < 0.05$). For these three dimensions, the proportion of students reporting being "very familiar" increased

notably (by 33.33%, 25.00%, and 33.33%, respectively), and the "unfamiliar" group was completely eliminated after the course.

Although the remaining three dimensions—cognitive differences, needs differences, and method preference differences among audiences—also showed positive shifts in familiarity (e.g., increased proportions of "very familiar" and reduced "generally familiar"), these changes did not reach statistical significance (P = 0.17, P = 0.14, and P = 0.20, respectively).

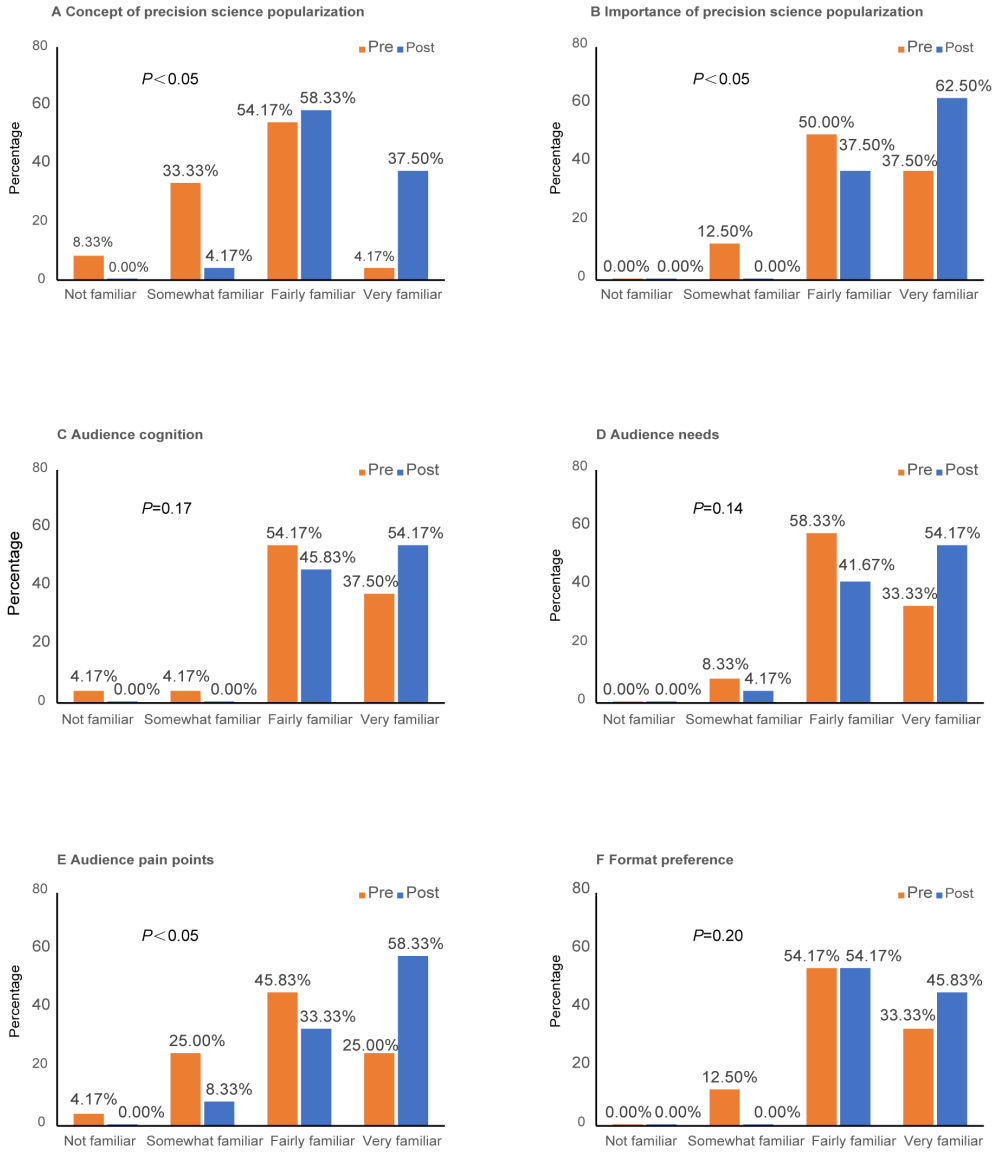


Figure 2: Comparison of student familiarity with six dimensions of precision science popularization before and after the 5E model-based teaching intervention. The horizontal axis lists the six investigated dimensions; the vertical axis shows the percentage of students in each familiarity category. Paired bars show pre-course (orange) and post-course (blue) distributions. P values are from Wilcoxon signed-rank tests.

3.3 Students' Mastery of Precision Science Popularization Knowledge

The median pre-test score increased from 58.33 to 70.83 after the course ($P < 0.05$), indicating that the 5E teaching model significantly improved students' mastery of precision science popularization knowledge (Table 1). Analysis by age group revealed different patterns: For adolescents, needs recognition improved significantly ($P < 0.05$), while pain point recognition showed a non-significant upward trend ($P = 0.08$). For young and middle-aged adults, both needs and pain point recognition improved significantly (both $P < 0.05$), representing the most pronounced effect. For the elderly, students had a high pre-course baseline, with post-course median scores reaching full marks for both needs ($P = 0.36$) and pain points ($P = 0.11$).

Table 1: Comparison of pre-test and post-test scores on precision science popularization knowledge (n = 24).

Dimension	Pre-intervention median(P25,P75)	Post-intervention median(P25,P75)	P-value
Total score	58.33(50.00, 66.67)	70.83(58.33, 83.33)	$P < 0.05$
Q1: Science popularization needs of adolescents	8.33(8.33, 8.33)	8.33(8.33, 16.67)	$P < 0.05$
Q2: Science popularization needs of young and middle-aged adults	8.33(8.33, 8.33)	8.33(8.33, 14.58)	$P < 0.05$
Q3: Science popularization needs of the elderly	16.67(10.42, 16.67)	16.67(16.67, 16.67)	P=0.36
Q4: Science popularization pain points of adolescents	8.33(8.33, 8.33)	8.33(8.33, 16.67)	$P = 0.08$
Q5: Science popularization pain points of young and middle-aged adults	8.33(8.33, 8.33)	8.33(8.33, 16.67)	$P < 0.05$
Q6: Science popularization pain points of the elderly	12.50(8.33, 16.67)	16.67(8.33, 16.67)	P=0.11

3.4 Students' Recognition of the Core Dimensions of Professionalism

After the course, students demonstrated a high level of recognition across all five core dimensions of professionalism (Figure 3). The recognition rates (combining "strongly agree" and "relatively agree") were as follows: scientific spirit (95.84%), teamwork (100%), innovative spirit (100%), people-centeredness (91.67%), and reflective spirit (100%). Among these, the proportions of students who selected "strongly agree" were 79.17% for scientific spirit, 45.83% for teamwork, 66.67% for innovative spirit, 75.00% for people-centeredness, and 66.67% for reflective spirit.

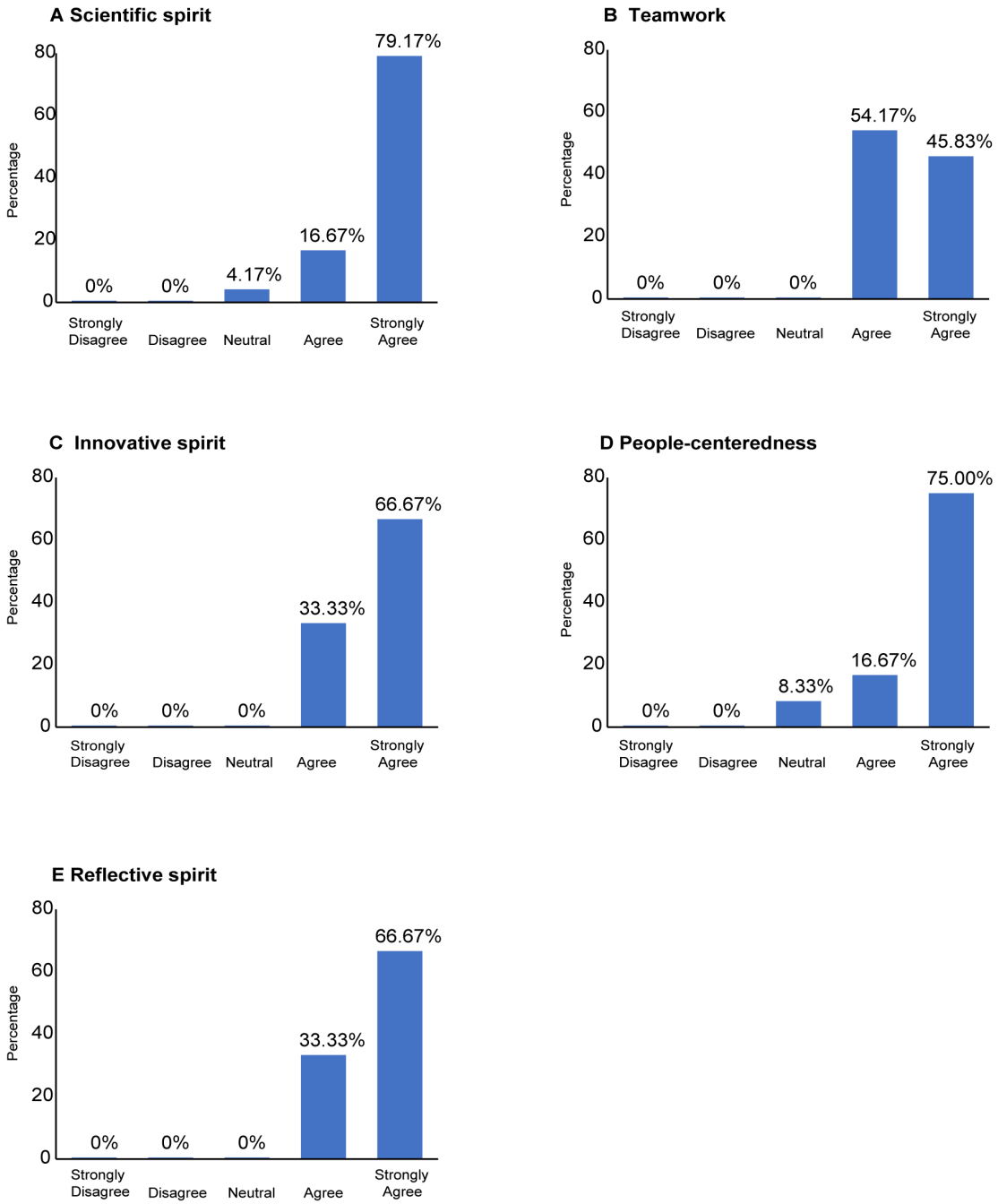


Figure 3: Students' recognition of five core dimensions of professionalism after the 5E model-based teaching intervention (n = 24). The panels show response distributions for scientific spirit, teamwork, innovative spirit, people-centeredness, and reflective spirit.

3.5 Students' Acceptance of the Teaching Model

Compared with the traditional teaching method, students were more willing to accept the 5E teaching model, among which 83.33% strongly agreed, 8.33% relatively agreed and 8.33% were neutral. There was no feedback of "not quite agree" or "strongly disagree".

4 Discussion

Under the background of the "Healthy China" strategy, the cultivation of medical students' science popularization literacy has become an important part of medical education and fostering professionalism is an

essential core goal in this process. Through offering the medical science popularization elective course, our research team has systematically explored the applicability of the 5E teaching model in medical science popularization courses, and focused on investigating its empowering effect in values-based education.

A needs survey on the improvement of science popularization capabilities showed that consolidating the theoretical foundation of medicine in a systematic way is the primary demand of students[15]. Relevant studies have pointed out that theoretical knowledge is a key factor affecting medical students' science popularization literacy[16]. The results of this study show that the 5E teaching model has shown significant advantages in the mastery of theoretical knowledge of science popularization. Students' familiarity with knowledge related to precision science popularization was improved after the course, especially in the dimensions of concept understanding, importance cognition and science popularization pain points, with statistically significant improvements ($P < 0.05$). In addition, the median post-test score of students increased from 58.33 points before the course to 70.83 points ($P < 0.05$), further verifying the positive role of this model in helping students construct a systematic knowledge framework and promoting in-depth internalization of knowledge.

4.1 Mechanism Analysis of the 5E Model Empowering Values-Based Education and Professionalism Fostering

In this study, students' recognition of the core dimensions of professionalism such as the scientific spirit (95.84%), teamwork (100%), and innovative spirit (100%) all reached a high level. This result reveals the unique advantage of the 5E model in embedding professionalism fostering into medical teaching. Through its progressive structure of "Engagement-Exploration-Explanation-Elaboration-Evaluation", the model implicitly integrates the core connotations of professionalism into teaching links. Zhang Lina pointed out that the high-quality development of values-based education should focus on realizing the unity of knowledge imparting and value shaping, as well as explicit education and implicit education[17]. The 5E model's approach to empowering values-based education precisely responds to the core requirement of values-based education to "avoid labeling and achieve implicit infiltration"[18], effectively addressing the problem of "separation between knowledge imparting and value shaping" in traditional teaching and providing an operable practical paradigm for values-based education in medical courses.

4.2 Reflection on Differences in College Students' Cognition of Characteristics of Different Science Popularization Audiences

The results of this study show that the 5E teaching model had the most significant effect on improving college students' grasp of the science popularization needs and pain points of young and middle-aged groups ($P < 0.05$). This is related to the fact that the age characteristics and health information acquisition habits of this group are close to college students' own life experiences, enabling them to better empathize with the perspective and understand core demands. Studies have shown that emotional value has a significant impact on college students' cognitive construction and value identification; when teaching content is highly relevant to students' own experiences, it is more likely to promote in-depth internalization of knowledge and shaping of professionalism through emotional resonance[19]. In contrast, the improvement in college students' cognition of the "science popularization pain points" of adolescent groups did not reach a statistically significant level ($P = 0.08$), reflecting certain cognitive barriers. Adolescents' health behaviors are intertwined with multiple factors such as peer influence and social media penetration, making their science popularization pain points more implicit and diverse. Further breakthroughs require more targeted case analyses or simulated practices to deepen students' understanding and foster their professionalism in targeted science communication. For the elderly group, college students already had a relatively high level of common-sense cognition (e.g., chronic disease management, digital divide) before the course, and

all achieved full marks in the post-course test. The teaching intervention only played a role in consolidation and systematization, elevating their fragmented experience into a theoretical system and reaching the cognitive "ceiling" in this dimension, which also laid a solid foundation for the cultivation of their professionalism in science popularization for the elderly.

4.3 Research Limitations and Future Prospects

This study still has several limitations: (1) The sample size is small (24 students) and the source is single (only Sun Yat-sen University), which may affect the generalizability of the results about the effect of the 5E model on knowledge construction and professionalism fostering. In the future, it is necessary to expand the sample size and conduct cross-university multi-center studies; (2) There is a lack of long-term follow-up data, failing to verify the sustainability of the teaching effect. Subsequent studies can further supplement this by recording students' performance in science popularization competitions and social practices; (3) Although the 5E model has unique functions and values in constructing students' new knowledge and cultivating their inquiry ability, it has deficiencies in the practical transformation link[20,21], especially for courses emphasizing operational capabilities such as medical science popularization. To address this issue, our research team has iteratively developed the A-SPIRE teaching model incorporating a "practice" link, and verified its effectiveness in improving science popularization practical ability in a larger sample [22], which provides a feasible path to make up for the practical shortcomings of the 5E model.

4.4 Research Value and Conclusion

This study demonstrates that a 5E-based teaching intervention can simultaneously promote knowledge construction and value internalization in medical science popularization courses, helping medical students systematically master theoretical knowledge while achieving implicit infiltration and deep recognition of the core dimensions of professionalism such as scientific spirit and people-centered service orientation. The model offers a practical pathway for integrating cognitive learning with professionalism fostering in medical education. This finding enriches the application scenarios of the 5E model and provides a practical solution to the two major challenges in science popularization education: "fragmented knowledge" and "formalized values-based education." In summary, the 5E-centered approach to medical science popularization teaching is an effective choice for enhancing medical students' science communication literacy and achieving the goals of values education.

Author Contributions

Liu Minling: Conceptualization, Methodology, Teaching practice, Investigation, Data curation and analysis, Writing – original draft. Dai Huiru: Teaching practice, Investigation, Data curation and analysis. Li Tingwei: Investigation, Data curation and analysis. Wang Jiancheng: Conceptualization, Methodology, Writing - review and editing, Supervision, Funding acquisition, Resources. Fang Shuo: Conceptualization, Methodology, Supervision, Writing - review and editing, Project administration, Funding acquisition, Resources.

Acknowledgements

The authors would like to thank DeepSeek and Doubao for their assistance in translating portions of the text from Chinese to English.

Funding

This study was supported by Guangdong Provincial Education Society "14th Five-Year Plan" 2024 Higher Education Research Project (24GYB05), Shenzhen Education Science "14th Five-Year Plan" 2025 Key Research Project (zdzz25026). Sun Yat-sen University Quality Engineering Project (Academic Affairs Document [2026] No. 36), and Sanming Project of Medicine in Shenzhen (No. SZSM202411015).

Competing Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical Considerations

Not applicable.

Data Availability

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding authors.

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