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Research on the Multidimensional Empowerment Mechanism of Smart Learning Engagement in Medical Education Based on NSSE-China

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Abstract: In response to the requirements for medical talent training set out in *Healthy China 2030*, this study addresses the issues of inadequate adaptation between traditional medical education and smart learning, as well as the fragmentation of learning engagement empowerment mechanisms. Drawing on theories such as NSSE-China, we analyzed the current status of smart learning engagement in medical education and constructed an empowerment mechanism through a questionnaire survey (n = 520) and in-depth interviews (n = 30). The results showed that the average score of smart learning engagement in medical education was 2.84 (slightly below moderate), with issues including dimensional imbalance, group differences, and dislocation of teachers' and students' perceptions. The verified "cognitive-behavioral-emotional-environmental" four-in-one empowerment mechanism increased learning engagement in the experimental class by 24.6%, and the academic performance and higher-order abilities of students in the experimental class were significantly superior ($P < 0.01$). This study provides a scientific scheme for the intelligent reform of medical education.

Keywords: NSSE-China; Medical education; Learning engagement; Multidimensional empowerment

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1. Introduction

The *Healthy China 2030 Planning Outline* emphasizes strengthening medical-education integration and reforming medical education, putting forward high requirements for the quality of medical talent training. As the core of talent supply, medical education faces the challenge of adapting traditional models to the precise and personalized needs of the new era. Smart technologies such as artificial intelligence and virtual reality are rapidly penetrating the field of education. According to the *China Smart Education Development*

Report (2024–2025), by the end of 2024, 89.2% of medical colleges and universities had built smart teaching platforms, promoting the composite reconstruction of learning scenarios into "online + offline" and "simulation + practical operation" models, which provide technical support for improving learning outcomes [1]. As a core indicator of educational quality, learning engagement directly determines the depth of knowledge mastery and the cultivation of practical abilities of medical talents, and its performance and improvement paths in the smart learning environment have become a focus of academic research.

2. Research status at home and abroad

Research on learning engagement originated in the 1990s, and the "three-dimensional theory" (cognition, emotion, behavior) proposed by Schaufeli *et al.* [2] laid the foundation for subsequent research, and the applicability of this theory in the field of medical education has been verified by a number of empirical studies. Research on the application of smart education in the medical field mostly focuses on technology implementation, such as the application of VR surgical simulation systems at Peking Union Medical College and AI-aided diagnosis teaching at Xiangya School of Medicine. However, a 2024 survey published in *Medical Education Management* showed that 65.4% of such studies only remain at the "technical demonstration" level, with insufficient discussion on the empowerment logic of learning engagement [3].

Since its launch in 2000, the NSSE framework has formed a mature evaluation system. NSSE-China, revised locally by the Institute of Education, Tsinghua University, has been used in surveys at more than 100 universities. However, research shows that only 8.7% of existing NSSE-China application studies focus on the field of medical education [4], and there is an obvious gap in the analysis of its adaptability in the evaluation of clinical practice teaching. Most studies only focus on the single dimension of teacher empowerment, lacking a systematic discussion on "multidimensional collaborative empowerment" in the context of smart learning in medical education. In summary, existing research has not formed a complete research chain of "framework guidance–problem diagnosis–mechanism construction–practical verification," which provides the core entry point for this study.

3. Research methods

3.1. Literature research method

We combed literature themed on "medical smart education" in CNKI, screened core journals, CSSCI journals, and degree papers from 2020 to 2025, excluded non-empirical studies, included 87 core journal papers and 42 degree papers, and extracted influencing factors and research gaps through content analysis to lay a theoretical foundation.

3.2. Questionnaire survey method

Based on the core dimensions of the NSSE-China scale, we added sub-dimensions of "clinical practice engagement" and "frequency of smart tool use" to design a 28-item questionnaire. A pre-survey was conducted among 50 clinical medical students, and the questionnaire was officially distributed after reliability and validity tests ($\alpha = 0.89$, KMO = 0.82).

3.3. In-depth interview method

Ten teachers and 20 students from three medical colleges and universities of different levels were selected by

stratified sampling, covering multiple disciplines and grades. A semi-structured interview outline was designed, focusing on the themes of tool use experience, barrier perception, and empowerment needs to explore the reasons for insufficient engagement.

4. Investigation on the current status of smart learning engagement in medical education

To accurately identify the quality shortcomings and optimization directions of smart learning engagement in medical education, Guangdong Medical University conducted a special survey from April to June 2024. This survey adopted a mixed research method of "scale + semi-structured interview": the scale referred to the core dimensions of NSSE-China, and added a secondary indicator of "depth of practical training participation" combined with the "practice-oriented" characteristics of medicine. Reliability and validity tests showed that Cronbach's α coefficient was 0.89 and the content validity index was 0.93; the sampling covered five majors, including Clinical Medicine, Basic Medicine and Nursing, including 320 undergraduates, 100 postgraduates, and 100 full-time teachers. A total of 520 valid questionnaires were recovered (effective recovery rate 90.91%), and 30 typical samples were interviewed (half teachers and half students). Survey data and interview information were triangulated to ensure the reliability of conclusions. The core data and in-depth analysis are shown in **Table 1**.

Table 1. Analysis of smart learning engagement in medical education (n = 520)

Indicator type	Specific indicator	Score (5-point Likert scale)	Statistical test result
Dimension score	Behavioral engagement	3.05	Significant differences among dimensions (F = 12.36, P < 0.01)
	Cognitive engagement	2.88	
	Environmental support	2.79	
	Emotional engagement	2.65	
Academic difference	Postgraduate cognitive engagement	3.24	t = 5.12, P < 0.01
	Undergraduate cognitive engagement	2.76	
Major difference	Clinical major behavioral engagement	3.18	t = 3.07, P < 0.05
	Basic medicine major behavioral engagement	2.92	
Teacher-student difference	Teachers' satisfaction with environmental support	2.68	t = 2.89, P < 0.05
	Students' satisfaction with environmental support	2.93	

Analysis of the data in **Table 1** shows that:

(1) Imbalanced engagement across dimensions, with emotional engagement as the shortcoming: Smart learning engagement in medical education shows a stepped distribution of "behavioral engagement > cognitive engagement > environmental support > emotional engagement," with an overall average score of 2.84 (slightly below moderate) on a 5-point scale. Among them, behavioral engagement scored the highest (3.05), indicating that students can complete basic learning behaviors such as online course learning and virtual practical training; however, there are significant differences among dimensions (F = 12.36, P < 0.01), resulting in uneven engagement quality. Emotional engagement scored the lowest (2.65, only at the "general" level). Combined with interviews, this is related to the virtualization of

teacher-student interaction and the single motivation incentive in smart learning. 72% of students reported that online learning lacks classroom atmosphere, making it difficult to maintain sustained learning enthusiasm.

(2) Significant group differences in engagement, with prominent academic and professional orientation: At the academic level, postgraduates' cognitive engagement score (3.24) is significantly higher than that of undergraduates (2.76), which is related to postgraduates' research training and clinical practice experience—they are better at using functions such as literature retrieval and case analysis on smart platforms for in-depth learning, while undergraduates mostly stay at the level of knowledge reception. At the professional level, clinical majors' behavioral engagement score (3.18) is higher than that of basic medicine majors (2.92), with a significant difference ($t = 3.07$, $P < 0.05$); the core reason is that smart learning resources for clinical majors are more closely combined with practice (such as virtual diagnosis and treatment, remote consultation simulation, etc., which are in line with post requirements), which can stimulate students' initiative to participate, while smart resources for basic medicine majors are still dominated by theoretical courseware with insufficient practice orientation.

(3) Dislocation of teachers' and students' perceptions of the environment, and supply-demand mismatch in the support system: There is a significant difference in satisfaction with smart learning environmental support between teachers and students ($t = 2.89$, $P < 0.05$), with students' satisfaction (2.93) higher than that of teachers (2.68). Students pay more attention to the "accessibility" of the environment (such as access to online resources), while teachers focus on "adaptability"; 68% of teachers reported that "the compatibility between smart teaching platforms and medical professional software is insufficient, and the efficiency of courseware upload and correction is low." This perceptual difference reflects that the current support system has a tendency to "emphasize the convenience of student use while neglecting the adaptability of teacher teaching," failing to balance the two-way needs of teachers and students.

In summary, the current smart learning engagement in medical education is characterized by "superficial behavioral participation, hierarchical cognitive engagement, weak emotional engagement, and dislocated environmental support" [5]. These problems provide a clear direction for the targeted design of the subsequent multidimensional empowerment mechanism.

5. Construction of the multidimensional empowerment mechanism for smart learning engagement in medical education

5.1. Core framework of the multidimensional empowerment mechanism

To intuitively present the core logic of the multidimensional empowerment mechanism and the correlation between various dimensions, a core framework diagram of multidimensional empowerment is constructed, as shown in **Figure 1**. The framework diagram takes the four core dimensions of the NSSE-China framework as the underlying support and builds a "cognitive-behavioral-emotional-environmental" four-in-one collaborative empowerment system. Each dimension not only focuses on specific goals independently but also forms a closed loop through resource flow and feedback regulation, jointly promoting the core goal of improving learning engagement [6].

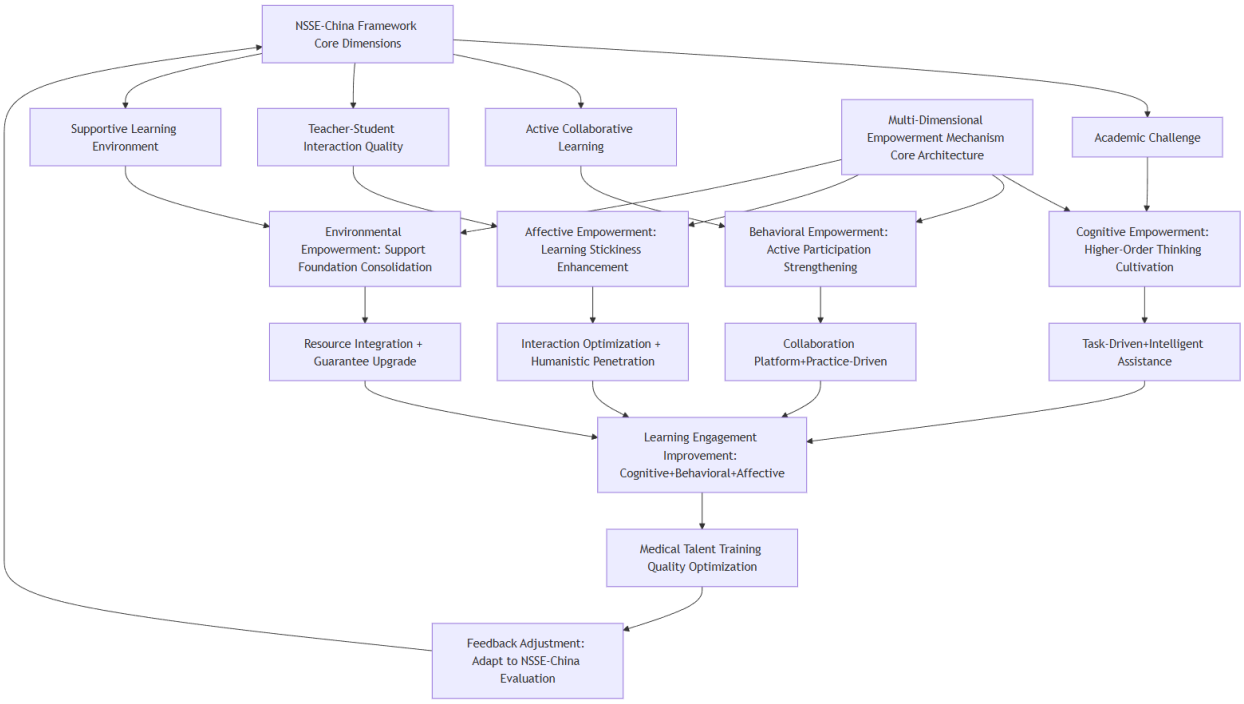

Figure 1. Core framework diagram of multidimensional empowerment

5.2. Design of empowerment paths for each dimension

(1) Cognitive empowerment: Focusing on the cultivation of higher-order thinking, a "task-driven + intelligent assistance" path is constructed. Drawing on the experience of the Clinical Medicine major at Guangdong Medical University, first, combined with the NSSE-China academic challenge indicator, a three-level cognitive task system of "basic theory–case analysis–clinical decision-making" is designed; second, an intelligent cognitive assistance platform is built, which parses case analysis reports through natural language processing, marks thinking loopholes and gives improvement suggestions; third, a higher-order evaluation system of "case defense + thinking visualization" is established to replace the traditional evaluation model dominated by written examinations [7].

(2) Behavioral empowerment: Strengthening active participation, a "collaborative platform + practice-driven" path is constructed. Relying on the NSSE-China active collaborative learning dimension, a cross-university medical smart collaboration platform is built, and multi-professional groups are formed to complete practical tasks such as "joint diagnosis and treatment of complex cases" [8]; a closed-loop process of "online preview–simulated practical operation–offline review" is designed to improve the participation in practical operation with the help of VR simulation systems; a learning behavior monitoring system is established to record collaboration contribution and practical operation quality, and generate personalized behavior improvement reports.

(3) Emotional empowerment: Enhancing learning stickiness, a "interaction optimization + humanistic infiltration" path is constructed. Based on the NSSE-China teacher-student interaction quality dimension, a mixed interaction space of "online exclusive Q&A area + offline tutor salon" is built to ensure high-frequency and in-depth interaction between teachers and students; a medical humanistic wisdom cultivation module is developed to cultivate professional identity by reproducing doctor-patient communication scenarios through VR; a diversified incentive mechanism is established, setting

up emotional incentive awards such as "Collaboration Star," and generating personalized growth files combined with data [9].

(4) Environmental empowerment: Consolidating the foundation of support, a "resource integration + guarantee upgrading" path is constructed. Aligned with the NSSE-China supportive learning environment dimension, resources from universities, hospitals and enterprises are integrated to build an integrated smart resource library of "basic medicine–clinical skills–professional literacy," regularly updating typical clinical cases and operation videos; technical support is optimized, and a rapid response mechanism of "teacher feedback–technical response–iterative optimization" is established; institutional guarantee is improved, and documents related to smart teaching quality evaluation and teacher ability training are issued to clarify department responsibilities [10].

6. Case verification of the multidimensional empowerment mechanism

Two parallel classes of the 2024 Clinical Medicine major at Guangdong Medical University were selected as research objects. The experimental class (32 students) adopted the multidimensional empowerment mechanism for teaching, while the control class (30 students) adopted the traditional smart teaching model. The implemented course was Internal Medicine (16 weeks, 64 class hours), with the core teaching content being the diagnosis and treatment of cardiovascular system diseases. A "pre-test–mid-test–post-test" evaluation design was adopted, and the effect was comprehensively evaluated by combining the revised NSSE-China scale, course score analysis, and teacher-student interview feedback.

To quantitatively present the practical effect of the multidimensional empowerment mechanism, the core evaluation data of the experimental class and the control class are sorted out in **Table 2**. From the data, the experimental class is significantly superior to the control class in all dimensions of learning engagement and academic performance, verifying the effectiveness of the mechanism.

Table 2. Comparison of core data between experimental class and control class

Evaluation indicator	Experimental class (n = 32)	Control class (n = 30)	Improvement range	Statistical test result
Overall learning engagement	3.65	2.93	24.6%	t-values > 3.5, P < 0.01
Cognitive engagement	3.51	2.86	22.6%	
Emotional engagement	3.48	2.62	32.8%	
Behavioral engagement	3.72	3.05	22.0%	
Final case analysis questions	86.7 points	72.8 points	19.1%	t = 4.21, P < 0.01
Course pass rate	100%	91.1%	8.9%	χ^2 = 4.32, P < 0.05

Qualitative interviews showed that 87% of students in the experimental class believed that "the thinking annotation function of the AI case system helps me sort out diagnostic ideas, especially in the differential diagnosis link," and 76% of students said that "cross-university collaboration tasks allow me to contact case characteristics in different regions, and my team diagnosis and treatment ability has improved significantly"; teachers feedback that "hierarchical training and standardized processes enable me to quickly design smart teaching activities, no longer limited to simple courseware playback." The verification results show that the

multidimensional empowerment mechanism can effectively improve the level of smart learning engagement and learning effects in medical education.

7. Research conclusions and prospects

7.1. Research conclusions

(1) The NSSE-China framework has high adaptability to smart learning engagement in medical education. Its core dimensions, such as academic challenge, can accurately cover the key evaluation indicators of medical smart learning, and it is more in line with the characteristics of medical majors after adjusting for "practice teaching participation."

(2) At present, the overall level of smart learning engagement in medical education is moderate, with core problems including insufficient depth of cognitive engagement, insufficient stickiness of emotional engagement, unbalanced participation in behavioral engagement, and a lack of environmental empowerment guarantee. The root cause is the fragmentation and insufficient pertinence of the empowerment mechanism.

(3) The constructed "cognitive-behavioral-emotional-environmental" multidimensional empowerment mechanism is scientific and effective. Through specific paths such as task-driven, collaborative platform, interaction optimization, and resource integration, it can systematically improve the level of each dimension of learning engagement, among which emotional empowerment has the most significant driving effect on overall engagement.

(4) Case verification shows that the multidimensional empowerment mechanism can significantly improve the learning engagement level and academic performance of medical students, especially in the cultivation of higher-order thinking and collaborative ability, providing an effective practical scheme for the intelligent reform of medical education.

7.2. Research limitations and prospects

Research limitations: The samples are concentrated in provincial medical universities, and the applicability of the conclusions in top medical universities and higher vocational medical colleges needs to be further verified; the implementation cycle is limited to a single course, and the long-term empowerment effect needs to be tracked; the differentiated design of empowerment mechanisms for different majors (such as Basic Medicine and Nursing) has not been thoroughly discussed.

Future prospects: Expand the scope of research samples to cover medical colleges and universities of different levels and majors, and refine differentiated empowerment paths; extend the research cycle to the entire training process to explore long-term empowerment mechanisms; optimize the intelligent assistance module combined with deep learning technology to improve the accuracy of empowerment; strengthen interdisciplinary cooperation, integrate theories and methods of education, computer science and medicine to enrich the connotation of the mechanism.

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Disclosure statement

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