

# The “P-5C” Model for Medical Education Reform in Frontier Regions: A Conceptual Framework and Narrative Review for Cultivating Innovative and Research-Oriented Physicians

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## ABSTRACT

In the context of rapid transformations in healthcare systems and medical knowledge, contemporary medical education faces increasing demands to cultivate physicians who are not only clinically competent but also innovative and research-oriented. Nonetheless, ongoing problems, such as a lack of teaching resources, unequal training infrastructures, and inadequate opportunities to conduct research, continue to hinder the quality of medical talent development at the frontier and in the underdeveloped areas. In order to tackle this challenge, this study put forth the P-5C model and structured educational framework to nurture physicians with 5C, namely: Cross-disciplinary Connections, Critical Thinking, Creativity, Communication and Collaboration. The “P-5C” model interates inquiry-driven learning, interdisciplinary training, and clinical practice, aiming to overcome the limitations of discipline-centered education while strengthening students’ research capacity, innovative thinking, and problem-solving skills in real-world medical settings. The implementation of the model aligns the educational goals with the healthcare needs of the region and adapting to complex clinical and public health issues. The analysis revealed positive effects of training using the “P-5C” model on students’ research competence, clinical competence, collaboration, and more. Besides, the increased innovation capacity, academic productivity, public health awareness and cultural competence also have improved employability and career development potential. The findings of the study indicate that “P-5C” model is a valuable educational strategy for frontier regions. The P-5C model can be successfully used to bridge the gap in most difficult medical education issues in the frontiers. Through a model that applies interdisciplinary collaboration with forward-thinking educational methods, specific to the needs of the regions in which we work, we provide a scalable path to train physicians able to address the complex health care needs of a variety of underserved populations.

**Keywords:** Frontier regions, Innovation-oriented education, Interdisciplinary learning, Medical Education, Outstanding physician cultivation, P-5C model.

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## INTRODUCTION

The focus of medical education has increasingly shifted towards the holistic development of medical students. It goes beyond the mere transmission of clinical knowledge and technical skills to emphasizing innovation, scientific literacy, critical thinking, and digital competence (Liu *et al.*, 2023). The analysis of scientific inquiry and critical thinking is not regarded as advanced or extra.

But it is now considered a core competency of undergraduate medical students (Arshad *et al.*, 2021; Ditta *et al.*, 2020; Ratte *et al.*, 2018; Zhou *et al.*, 2025). Research-oriented learning and systematic evaluation of the research ability must be integrated with the curriculum designs to set-up scientific training in medical education frameworks (Adebisi, 2022). In addressing complex clinical problems, enhancing students’ innovative capability can also enhance specific evidence-based and effective medical decisions, benefitting ultimately the quality of health care (Lopatto, 2007).

In tandem with these global tendencies, clinical institutions, and in particular leading teaching hospitals, are expected not only to have diagnostic and therapeutic means, but also to have independent research competence and translation of basic



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science into clinical work. A recent reform of medical education has focused on the gradual inculcation of research literacy, critical thinking and awareness of innovation among undergraduates. Nevertheless, regions are uneven in the implementation of such reforms.

Medical education within a frontier and underserved area is an essential part of a national medical education system, which is considerably contributing to the training of clinical medicine graduates. Despite being important, frontier medical education is limited by many structural constraints including educational resource limitation, research infrastructure limitation and uneven academic foundation. Numerous institutions still heavily depend on lecture-based teaching models that focus more on the transmission of knowledge and less on inquiry-based and innovative training. The development of students' research capacity, interdisciplinary integration skills and problem-solving abilities is severely constricted.

The need for medical education reform in frontier regions has become increasingly pressing. It is no longer enough to depend on memory-based learning and discipline-based curriculum to cater to healthcare needs. Medical schools on the frontier must rethink their educational objectives by focusing on students' capacities to identify significant clinical and public health problems, knowledge integration across disciplines, and creation of sustainable solutions. The challenge and strategic focus of medical education reform in frontier regions now boils to shift from passive acceptance of knowledge to initiative-driven and innovation-centered training.

In response to these problems, this study proposes the "P-5C" model of training physicians based on the development of multi-dimensional competencies. The model is based on five competency namely Cross disciplinary Connection, Critical Thinking, Creativity, Communication and Collaboration(5C). The "P-5C" model, which combines educational objectives with competency-based training and assessment criteria, serves as an informed framework to enhance the capacity of physicians with sound clinical acumen to address challenging medical problems in varied and underprivileged populations. Due to its flexibility and emphasis on integration across disciplines, model has great potential for implementation and easy spread in frontier areas of medical education.

## METHODOLOGY

### Literature Search Strategy

This narrative review was conducted through a comprehensive literature search to summarize current evidence regarding Competency-Based Medical Education (CBME), frontier medicine education, physician training in resource-limited settings, medical humanities, public health emergency preparedness, and innovative educational models. Electronic

databases including PubMed, Web of Science, Scopus, and China National Knowledge Infrastructure (CNKI) were searched for studies published between January 2000 and December 2025. The search strategy combined Medical Subject Headings (MeSH) and free-text terms, including: "competency-based medical education" OR "CBME", "frontier medicine", "physician training", "medical education", "medical humanities", "public health emergency", "innovation", "critical thinking", "communication", "collaboration", and "resource-limited regions". Additional relevant publications were identified through manual searches of the reference lists of selected articles. Publications were included if they addressed competency-based medical education, physician training models, educational innovation, or medical education in frontier or underserved regions. Articles not directly related to medical education, conference abstracts without sufficient methodological details, and duplicate publications were excluded. The selected literature was narratively synthesized to identify current challenges, educational strategies, and competency frameworks relevant to frontier physician training.

### Development of the P-5C Model

The P-5C model is a competency-based educational framework with five central competencies connections, critical thinking, creativity, communication and collaboration. It was devised following the principles of competency-based medical education that were adapted to meet the needs of resource-limited and multi-ethnic frontier regions.

### Evaluation

A multidimensional evaluation system has been set up to assess the students' knowledge, clinical competence, research ability, innovation ability and 5C competencies. The first year of the evaluation also included a written examination, a clinical skill assessment, Mini-CEX, research performance, performance in a competition, faculty assessment, peer assessment, and self-review.

### Outcome Measures

The assessment model adopted for evaluations and assessments is effective. This is evaluated based on indicators like scientific research outputs, innovation achievements, postgraduate admission rate, licensing examination success rate, employment outcomes, employer satisfaction, faculty development, and participation in community health services. Descriptive analyses were performed to assess implementation outcomes for the P-5C model.

## RESULTS

### Challenges in Medical Education in Frontier Regions

The quality of talent cultivation and educational outcomes is hampered by serious challenges in frontier medical education. Lack of geographic proximity, local economic development and

cultural diversity have structural handicaps. Additionally, the deficit of educational resources, skilled clinical educators, and accompanying infrastructure leads to differences present in frontier regions compared to more advanced ones. The following subsections detail the major difficulties in frontier medical education.

## **Lack of Educational Resources**

### ***Insufficient Teaching Facilities***

Medical education conditions in border areas are mostly poor. Numerous institutions are still using aging infrastructure with limited access to advanced laboratory equipment or clinical simulation and digital learning technologies. Outdated laboratories in fields like anatomy and pathology are running continuously, often not conforming with the needs of modern medical education. Moreover, curricula are often limited in scope and insufficiently tailored to regional disease patterns and the traditional medical practices of local ethnic groups. Teaching materials are not updated quickly enough for students to keep pace with advances in biomedical research and clinical practice. In addition, modern educational technologies are not fully utilized. The employment of online learning platforms and virtual simulation systems occurs in a decentralised fashion, often within a wider educational framework. Educational innovation and clinical competency development is limited by this. Access to scholarly materials is restricted, as indicated by the low number of library holdings and subscription to quality scholarly journals. The inadequacies notably harm the self-directed learning ability, critical thinking ability and research capacity of students.

### **Weak Faculty Support**

When teachers leave their jobs for better opportunities, there is brain drain and instability. Due to their established clinical/academic reputation, most experienced faculty members look for jobs at developed areas or high-level medical centers. Consequently, medical colleges and universities in border areas are perpetually facing shortage of qualified personnel and unevenness in faculty capacity. In addition, there is a specific lack of dual-qualified teachers who can undertake a clinical role while also conducting research. This discrepancy hampers the cohesive application of theoretical concepts and practical skills, consequently hampering the actual execution of practical training and research supervision. As a result, these institutions are limited in their ability to deliver an excellent, practice-oriented, and research-informed medical education.

### **Inadequate Practical Training Bases**

Across the frontier regions there is a troubling disparity in the distribution of high-quality medical education and clinical training resources. A shortage of good quality teaching hospitals adversely impacts the clinical training of medical students.

Healthcare units across border regions remain functionally limited due to a lack of medical equipment, limited case exposure and learning environment. Also, collaborative efforts among university-affiliated hospitals are disparate, limiting the economic exchange and sharing of superior educational resources. These inefficiencies lead to underutilization of current assets, duplication of infrastructure investment, and lost opportunities for coordinated improvements in the quality of medical training. As a result, clinical education is rendered inefficient due to deficiencies in structure and management. A few common challenges are a lack of planning these training programs, unequal participation from faculty members and inadequate assessment of clinical skills. Together, these factors compromise the quality and consistency of hands-on training and ultimately restrict the growth of competent medical professionals in frontier areas.

## **Insufficient Scientific Research and Innovation Capabilities**

Medical research in frontier regions is hindered by a lack of funding, less sophisticated infrastructure as well as a shortage of high-level research teams. Due to these limitations further innovations are prevented. The lack of solid research culture also weakens the coupling of medical research with building students' research competence and innovative capacity. As well as limited engagement with domestic and global institutions and industry partners has constrained academic outlook consultation and reduced incentives for research-driven innovations. Limited interaction prevents the flow of cutting-edge knowledge and technology across the spillover, as well as the transformation of discovery.

## **Lack of Medical Humanities Integration in Frontier Regions**

Contemporary medicine is gradually moving from a strictly biomedical approach to a biopsychosocial model. This model takes into account the patient's special needs and humanistic values. In China, medical humanities courses make up about 8% of the medical curriculum, considerably less than the 15%-20% usually seen in other countries (Isaac, 2023). Multiethnic frontier regions are home to a significant gap between medical professionals and patients, requiring stronger communication skills and greater cultural competence.

Inadequate cultural awareness on the part of medical students may impede physician-patient communication which can adversely affect the quality of care rendered, and undermine trust between patients and providers. In addition, a large number of ethnic minority communities still retain distinguishing medical traditions. Accordingly, medical education should not only be shaped by modern biomedicine, but also be molded and infused with relevant traditional medical knowledge systems. This means designing an integrated and culturally sound curriculum as well as adequate pedagogical strategies to train future doctors in the

delivery of scientifically sound, patient-centred, and culturally sound health care services.

### Inadequate Response to Public Health Emergencies

Increased public health risks are present in Frontier regions with greater risk of cross-border infectious diseases. Two or more people from different disciplines must work together. Many universities situated in frontier areas do not possess the synergy of interdisciplinary educational and research capacity, as well as communication and coordination mechanisms, to prepare students to deal with infectious diseases, international epidemic prevention and control, and emergence medical response. Moreover, the less than adequate public health education system and the absence of practical training venues, also affects the development of talents. It is hard to generate healthcare professionals who can cope with today's public health challenges without systematic training, experiential learning opportunities and interdisciplinary guidance.

### The Annotation of "P-5C" Model

The "P-5C" model features five interrelated capabilities, including interdisciplinary connection, critical thinking, creativity, communication, and cooperation, which constitute a framework for the all-round development of the medical major (Figure 1). Instead of proposing a new theory of competencies, the P-5C model is offered as a context-adaptive implementation framework grounded in Competency-Based Medical Education (CBME). The framework is based on established frameworks (CanMEDS, ACGME competencies, 21<sup>st</sup> century skills) but adapted for context of frontier and under-resourced medical education.

The innovation of our Curriculum lies in three areas: firstly, its incorporation of clinical competence, research literacy, digital literacy, innovation training, and humanistic communication into a single framework; secondly, its tailoring of these competencies to a resource-poor, multi-ethnic, digitally uneven frontier context; and lastly, its tying of each competence to educational activities and assessment indicators. Grounded in theories, the model draws from constructivism, experiential learning and systems theory (Blue *et al.*, 1998; Lehmann *et al.*, 2020). These views promote learner-centred inquiry, early exposure to clinical and research, simulation and community-based practice; and alignment of competency and curricula, institutional resources and regional health needs.

So, P-5C does not replace CanMEDS and ACGME. Rather, it presents a contextualized, CMBE-informed pathway for producing innovative and research-oriented physicians in resource-poor frontier regions.

### Development of the Frontier Outstanding Physician Training System Based on the 'P-5C' Model

In the digital age, to solve the problem of fragmentation of disciplines, inadequate training for advanced cognitive ability, integration of humanities and technology and so on in medical education an integrated "P-5C" medical talent cultivation model devised. The P-5C model encourages the integration of subjects and disciplines, with critical thinking and innovation as the core competencies supported further by communication and collaboration competencies. The framework is made up of five interconnected dimensions contributing to the holistic development of medical professionals of the future.

### Building an "Medicine +X" Interdisciplinary Education System

#### Curriculum Reconstruction and Integration

The system of the curriculum should extend beyond disciplines and establish an interdisciplinary "Medicine + X" system (Figure 2). The curriculum includes courses like Medical Ethics, Doctor-Patient Communication, etc., to strengthen the professional ethics and humanistic competencies of students through the integration of humanities and social sciences with medical education. The curriculum of the course also integrates emerging fields like Artificial Intelligence (AI) and big data analytics. Also, MedicNex, an AI-based medical assistant that increases students' ability to apply information technologies to solve clinical issues has been created. MedicNex can promote teaching effectiveness and foster student engagement as a personalized, all-weather learning and diagnostic tool.

In addition to technological integration, the curriculum fosters close links among basic medicine, clinical medicine, and bioinformatics. The multidimensional integration of these subjects helps students to develop systematic and holistic thinking to tackle the complexities of modern-day medical practice.

### Collaboration and Innovation in Research Platforms

In order for there to be sustained interdisciplinary collaboration, there is a need to develop teams of professionals and shared research platforms that link academic disciplines. An example is, joint research projects pooling scholars from basic medicine, clinical medicine, computer science, and chemistry together can yield complementary expertise to tackle common scientific problems (Arrasate *et al.*, 2018; Rockne *et al.*, 2019). Collaborations between anatomy and engineering work on creating new medical devices and improving existing ones, which builds the bridge between theory and applications even stronger. At the regional level, it is also necessary to organize the study, collection and utilization of ethnic medical resources in border areas. Efforts are made to document indigenous medical knowledge, pharmacological studies of native medicinal

plants, and extraction and characterization of their bioactive compounds. Efforts to make integration of ethnic medicine with modern science, standardization and innovation, and sustainable development of ethnic medicine.

### Virtual Expansion of Practical Scenarios

A virtual experimental platform provides “zero-risk, high-fidelity” training to students while simulating clinical environments (Yeung *et al.*, 2021). This method lessens the dependency on standard laboratory materials and considerably brings down the risk of safety hazards. It also helps in overcoming some of the limitations of the traditional model used for training. Further, it enhances the practical skill sets of students. Apart from simulation-based learning, the platform encourages interaction in clinical practice and public health projects. The centres for disease control and prevention have structured tie-ups with medical colleges and universities for involving the students during infectious disease prevention and outbreak, emergency preparedness and response and other public health activities jointly. Two experiences deepen students’ understanding of real-world practice and collaborative thinking often required to address complex health challenges.

### Deepening Problem-Oriented Critical Thinking Training

#### Implementation of Problem- and Case-Based Learning (PBL & CBL)

To provide students with a medium of structured instructional guidance to enhance critical thinking skills, Problem Based Learning (PBL) and Case Based Learning (CBL) are implemented. As a result of these pedagogies, students examine complex cases, engage in collaborative dialogue, and make evidence-informed decisions in response to clinical and public health problems (Figure 3) (Chen *et al.*, 2022; He *et al.*, 2023; Kühne-Eversmann *et al.*, 2008; Liu *et al.*, 2020; Yue *et al.*, 2025). Teaching in pathology education is focused on real-life medical cases for students to recognize significant issues and find solutions. Through both online and offline, critical thinking is further enhanced. In cloud classrooms and labs, students are encouraged to go beyond knowledge acquisition to see problems systematically and explore a solution through academic research. Through inquiry, reflection, and application, this educational design encourages deeper analysis and enhances students’ capacity for independent judgment.

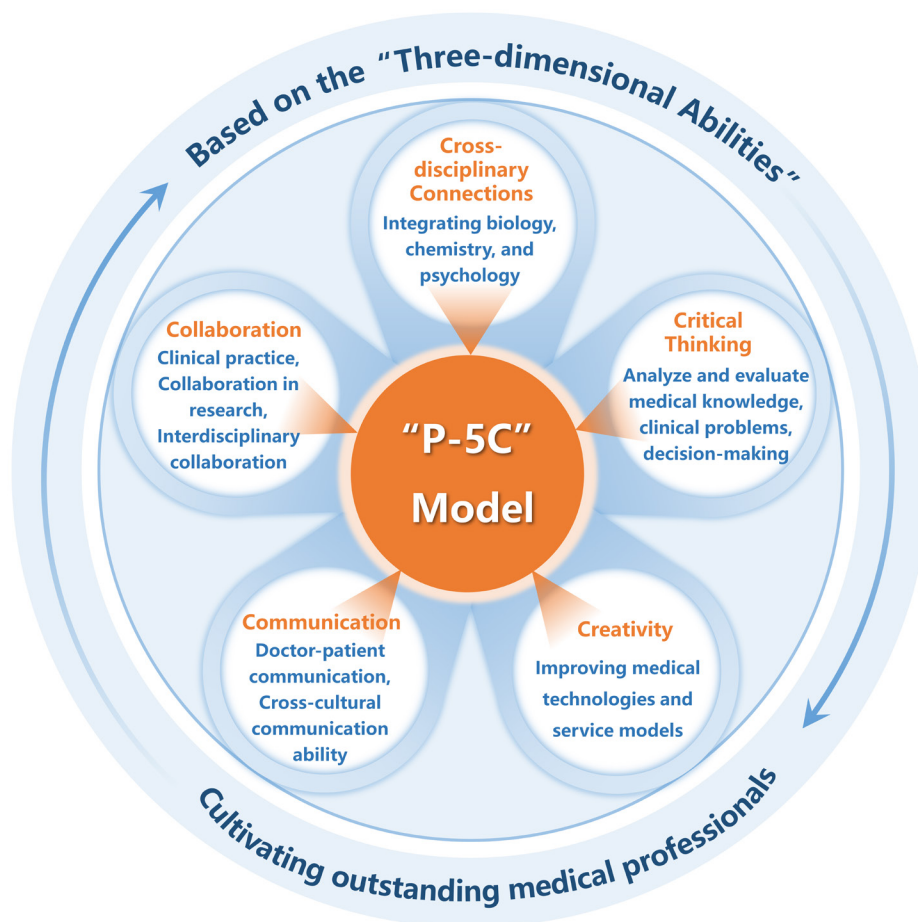


**Figure 1:** The composition of “P-5C” model.

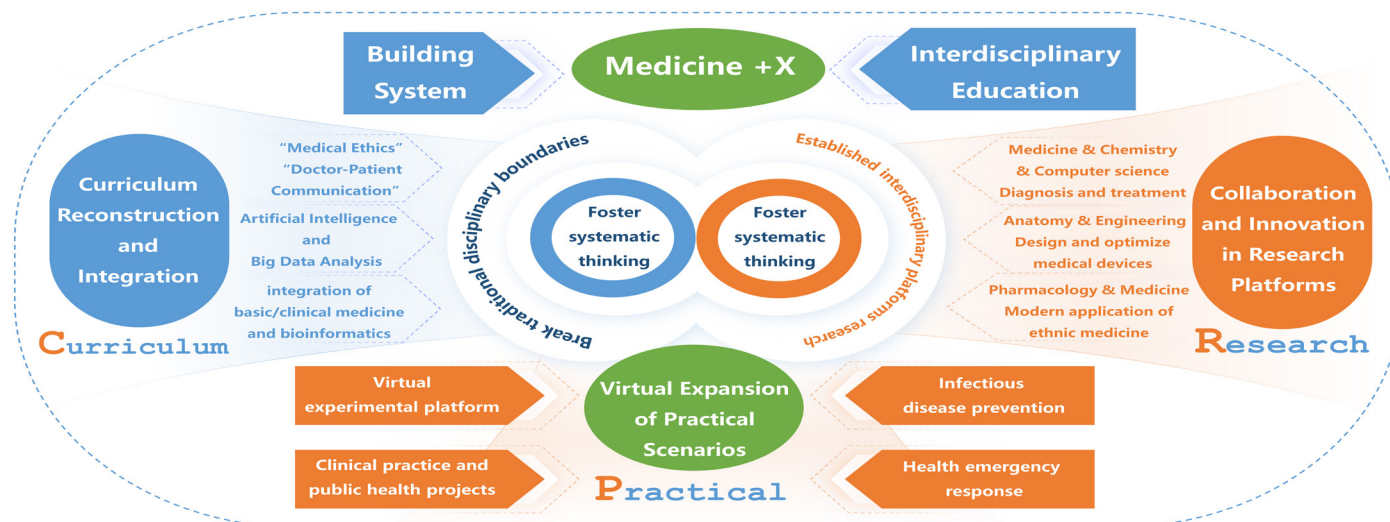


**Figure 2:** Model diagram for constructing an interdisciplinary education system of "Medicine+X".

### Creating a Culture of Academic Discussion and Debate

In order to create an environment for academic discussions, regular lectures, seminars and academic debates should be organized. Students engage with advances in medical science, ethical issues, and emerging controversies as part of these activities while analysing and critiquing them through the years of the medical curriculum. Affiliated hospitals' experienced clinicians can be invited to participate, sharing research findings and clinical insights, which can be supplemented by practical experience. By embedding theoretical knowledge within a real clinical context, these exchanges help students reflect critically and evaluate the applicability and limits of medical theories and technologies in practice (Gupta & Upshur, 2012; Harasym *et al.*, 2008; Jenicek *et al.*, 2011; Wang *et al.*, 2017). They also develop students' capacity for evidence-based reasoning and professional judgment through practice after theory to ensure applied learning.

### Strengthening Scientific Research Thinking

To develop students' research-oriented thinking, encourage them to take part in scientific research projects, academic writing, and other activities. As students increasingly participate in these activities, they improve key research skills such as study design, data analysis, and evidence evaluation. Furthermore, students are encouraged to apply for national innovation and entrepreneurship projects, where they take the lead on tasks such as designing experiments, analyzing data, and formulating problems. Such experiences not only enhance their understanding of research design but also their capacity for independent thought and analytical rigour (Mahomed & Van Wyk, 2021; Huang *et al.*, 2019).

### Innovative Ability Stimulation Mechanism Throughout the Entire Education Process

#### Integration of Innovation Education and Professional Education

The system of education for innovation and entrepreneurship is integrated into the talent training of basic medicine to form a three-level "one-two-three-four-five" model of innovation in basic medicine education (Figure 4). The model is developed with an integration from the disciplines and student-centered innovation platforms. The training model is a phased, modular designed model that consists of basic skill training followed by training in advanced practical. The combination of research and teaching along with the synchronization of curricular learning and co-curricular learning produces creative mind and application-oriented abilities. A New Medical Innovation Class has been set up to unleash the students' creativity potential. Students are encouraged to participate in thematic research challenges, innovation contests, entrepreneurial projects, and other experiential learning activities. The opportunities encourage converting theory into practice, thus boosting students' ability to innovate and solve problems (Duan *et al.*, 2025; Tan *et al.*, 2025).

#### Establishing Incentive Channels for Scientific Research and Innovation

To complement the training, a summer school program with competition orientation has been introduced to strengthen research and innovation practice. The program engages students in research projects or innovation challenges, thus allowing them to conduct detailed scientific studies and innovative problem-solving fields (Andolsek *et al.*, 2013; Shadiev *et al.*, 2022). To enable continuous and quality research experience for students, we provide targeted support for research funding, laboratory access, and sustained faculty mentorship. As a part of this framework, students are encouraged to take up an

interdisciplinary project like imaging the human body and studying anatomy. For instance, a three-dimensional data model of the upper and lower abdominal plexuses was created. Taking part in these kinds of projects will improve students' technical skills as well as instill a better understanding of the relationship between the human body and its functioning.

### Interdisciplinary Innovation Practice

Students should be encouraged to think out of the box through interdisciplinary projects to look at the emerging medical technologies with innovative healthcare solutions. Through partnerships with other leading research institutions, especially nanodrug delivery, nanoprobe technologies, immunotherapy-related science, and such other advances, innovations can be integrated in the curriculum itself. When students are exposed to such frontier developments, they stimulate their innovative thinking and strengthen their skills in harnessing emerging technologies to solve problems in medical research and practice.

### Strengthening Professional Communication Skills Centered on Empathy and Efficiency

**Systematic Construction of Doctor-Patient Communication Courses** Courses like *Medical Ethics*, *Doctor-Patient Communication* and *Labour Education* must be incorporated into the curriculum for ensuring a deep integration of professional ethics into medical education (Figure 5) (Gaber et al., 2022). We can also organize lectures on humanistic education for students and medical personnel, inviting physicians who have participated in healthcare assistance programs in Tibet and Xinjiang to share their professional experiences and reflections. Yanbian University School of Medicine has rolled out the Doctor-Patient Communication course, designed to boost students'

communication skills, empathy, and patient-centered care competencies through pedagogical approaches like case-based learning and role-playing.

### Social Practice and Volunteer Service Exercises

Students engage in grassroots free medical clinics, health education programs, and community service in which they interact directly with patients and community members to develop and practice communication. The Health Poverty Alleviation Youth Initiative operates 31 project bases and offers basic healthcare services and disease screening to some 5,000 underserved people each year. Students take part in these activities to improve their community service capacity, develop social responsibility as well as meet the healthcare demands of the area (Huang et al., 2025).

### Expansion of International Exchange Platforms

Colleges and universities use international exchange programs, academic conferences, and collaborative platforms to assist students in communicating with their classmates both at home and abroad to improve the cross-cultural communication skills of these students. Also, online cloud classroom and joint laboratory courses encourage students from different locations to interact and cooperate with each other.

### Developing Team Collaboration Skills in Diverse Environments

#### Team Infiltration in Clinical Practice

The multidisciplinary teaching team is composed of academics, not only from the medical but also from the humanities, social sciences, and engineering disciplines. Utilizing the clinical resources of hospital-affiliated hospitals, it runs a model characterized by "early clinical exposure, multiple clinical

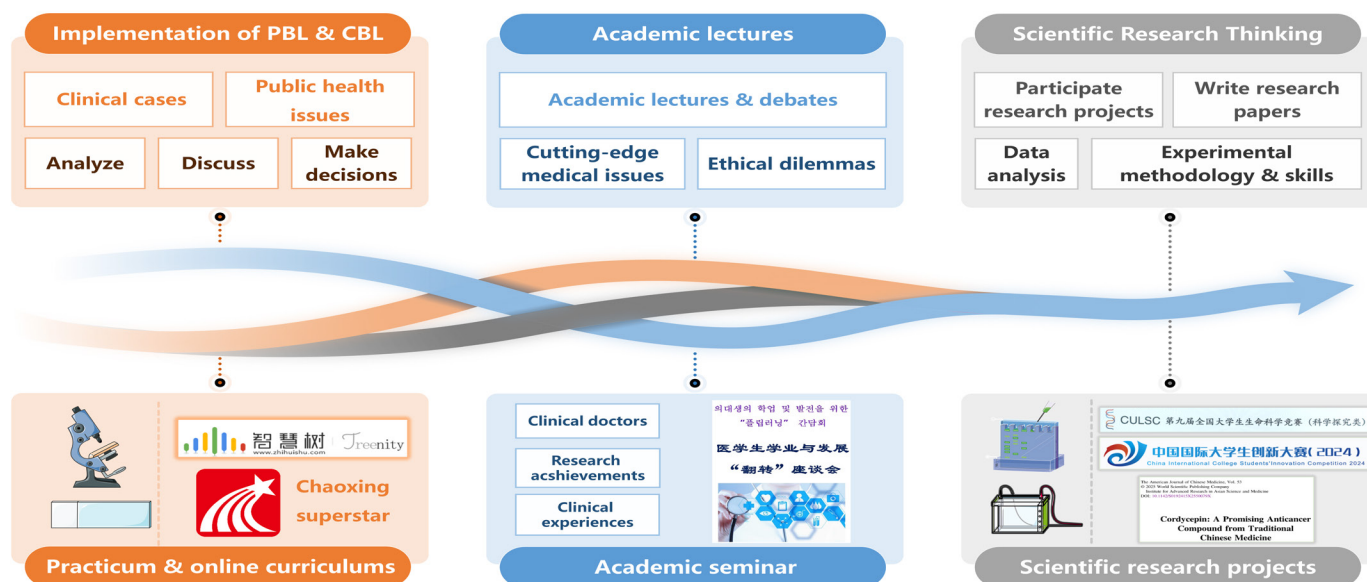


Figure 3: Model diagram for deepening problem-oriented critical thinking training.

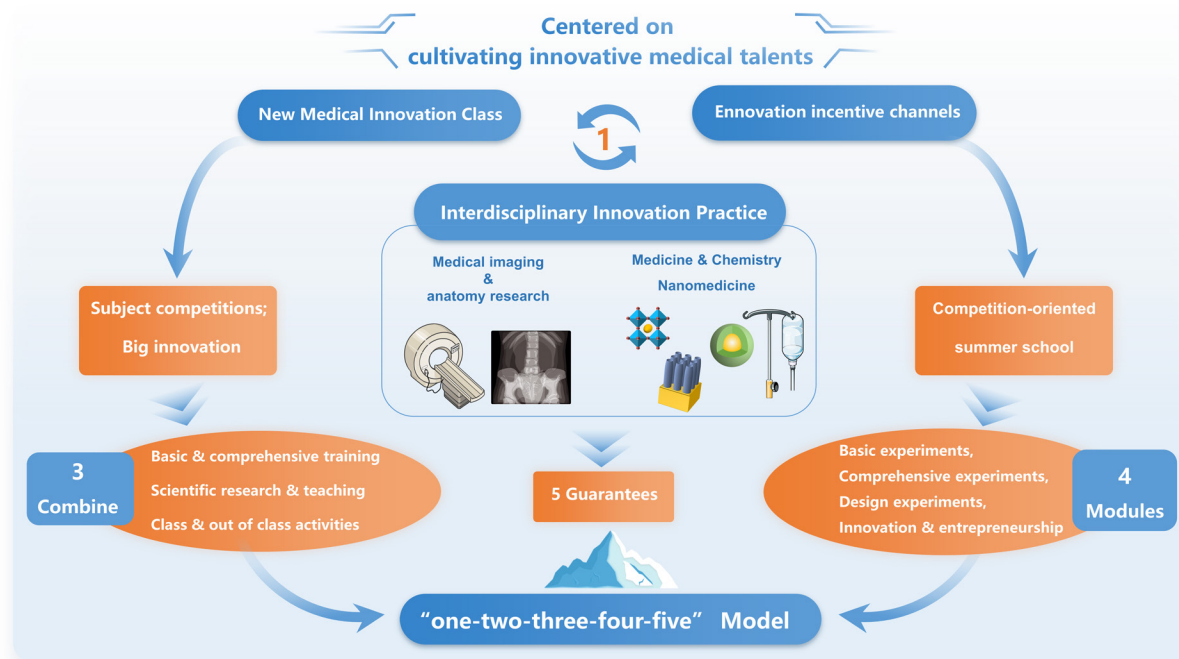


**Figure 4:** Pattern diagram of innovation capability incentive mechanism based on “one-two-three-four-five” system.

experiences, and repeated clinical practice” that give students authentic and progressive clinical learning opportunity (Brennan *et al.*, 2010; Chaou *et al.*, 2021). In their clinical placements and internships, students have the opportunity to work as part of a multidisciplinary team. Specifically, they engage in ward management, assists with surgeries, and helps in various emergency drills. As a result, they enhance their teamwork, communication and clinical practice skills.

### Team Building in Scientific Research and Competitions

The students should join the research teams and participate in various competitions. By undertaking project-based activities which stress task division and collaborative effective problem-solving, students learn teamwork and project management. For dealing with technical challenges in national and provincial innovative projects, cooperation is indispensable. Experiences of this kind sharpen students’ skills in scientific research, clinical practice, and public health, while assisting them to work in multi-disciplinary teams.

### Collaborative Innovation in Interdisciplinary Projects

It is crucial to establish a core interdisciplinary training framework surrounding “medicine + intelligence” to cultivate integrated Artificial Intelligence (AI) with clinical practice and develop students’ digital literacy and competency in new forms of medical technologies. Through interdisciplinary research and training activities, students are encouraged to think innovatively, work collaboratively, and develop solutions in teams to address complex

healthcare problems, thereby promoting team competencies in interdisciplinary collaboration. In addition, there is a need to promote the development and application of AI-based medical intelligent agents to enrich teaching and learning. These programs grow technologically sophisticated health professionals who can incorporate future technologies in research and practice (Gordon *et al.*, 2024; Han *et al.*, 2019; Jackson *et al.*, 2024; Li *et al.*, 2025; Nagi *et al.*, 2023; Tozsini *et al.*, 2024).

### Evaluation System

A multi-dimensional evaluation system must be established to evaluate the development of students in core domains such as knowledge, professional and technical capabilities and 5C literacy. The written test, classroom assessment, and online testing will be used to assess students’ mastery of basic knowledge and professional theories. The assessment of practical competencies such as clinical skills, diagnostic reasoning and treatment planning should employ skills examinations, simulated case analyses, Mini-CEX, and direct observation. The assessment of students’ research competence and innovation potential can be carried out through measurable academic achievements. In particular, these include participation in research projects, innovative product development, and success in academic competitions. Moreover, the involvement of students in primary health care services, public health action as well as community health education activities is an important indicator of student social engagement and ability to apply knowledge in practice. To ensure a balanced approach to evaluation and assessment in the university, faculty evaluation feedback, student self-evaluation,

peer reviews, and clinical and industrial assessment feedback should be included in the framework. Students' performance in the course of classroom discussions, application projects, case-based reasoning activities, collaborative tasks, etc., needs to be observed closely to capture the dynamic development of creativity, critical thinking, communication, teamwork, and cultural competence. In addition, a comprehensive evaluation system that incorporates formative and summative assessments should be implemented to monitor learning progress, provide timely feedback, inform instructional adjustments, and promote the continuous development of students' 5C competencies and overall professional literacy (Perkins *et al.*, 2020; Zikos & Sprague, 2022).

### The Effectiveness of Talent Development in the "P-5C" Model

The cultivation model P-5C improves students' scientific research and innovation capabilities. In the last three years, Undergraduates of the department has accomplished remarkable outcomes in academic and innovation competitions, published 84 papers that includes 11 SCI. In addition, the transition rate from undergraduate to graduate increased from 42.2% in 2022 to 53.4% in 2024. Moreover, through the early and extensive clinical exposure training approach, the clinical skills of students have experienced marked improvement. The pass rate of the National Medical Licensing Examination has increased by about 3%. Job-related statistics for the graduating class of 2023-24 suggest that over 85% of students managed to secure a job, above 90% of those found a job in their own field, and 96% of recruiting companies were satisfied. The overall teaching and research faculty capacity of P-5C has been significantly enhanced, which

has contributed to one national-level first-class course namely pathology and several provincial-levels outstanding courses such as Molecular pathology, and Histopathology. The model is efficient in organizing theoretical instruction and practical training through resources of affiliated hospitals. It has also organized student participation in about 100 grassroots medical activities, from free clinics to health education campaigns, thus helping mitigate shortages of medical resources in the frontier regions. Around a third of medical graduates with a master's and doctoral degree have started serving in frontier areas improving primary healthcare and enhancing the quality of medical education in the area. The numbers of physicians attending public health service departments in border areas has considerably increased as compared with the previous period (Kaduszkiewicz, 2018).

### The Multiplier Effect of the "P-5C" Model

Under the P-5C model, the online *Pathology* course has been incorporated into the online National Smart Education Public Service Platform, which mainly offers free medical education materials for the universities in central and western China. The organizing of a program contributes to the equitable, high-quality development of higher education and is evidence of social responsibility. The *Case-Based Forensic Pathology Virtual Simulation System* has tackled high-risk and high-cost experimental training problems, and had been implemented in other medical schools as a useful laboratory teaching tool. In addition, the P-5C model incorporated *Qiwen Xinglin* AI assistant for Bachelor Clinical Medicine which is an important implementation platform, enhancing the students' independent learning ability and critical thinking ability. The *Pathology*

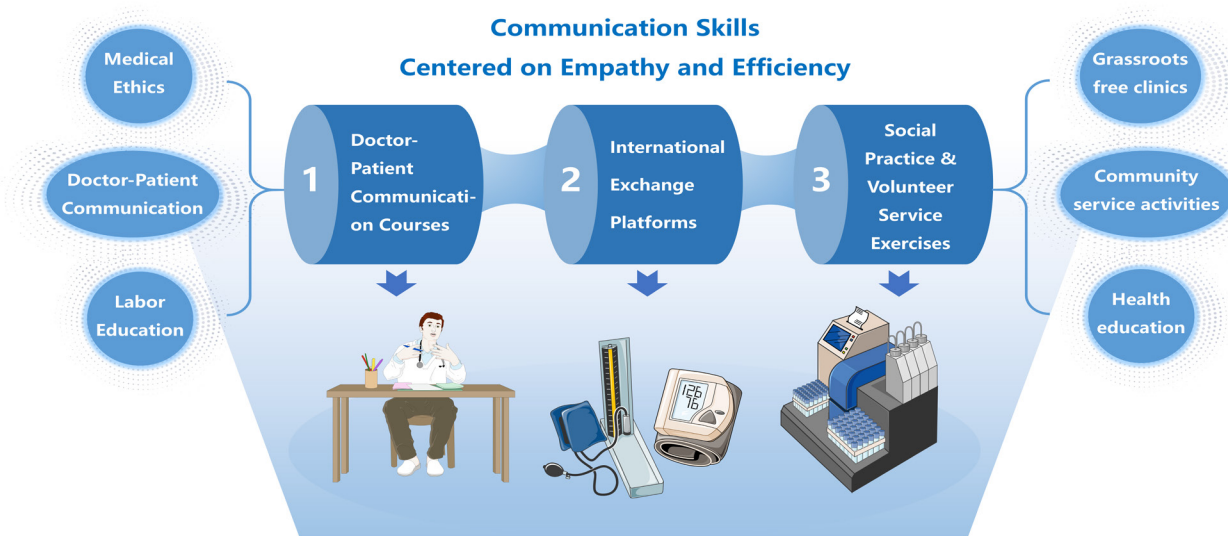


**Figure 5:** Strengthen professional communication skills centred on empathy and efficiency.

*Internship Guide* was reviewed three times during P-5C development and implementation and was designated as a major textbook of Jilin Province after that. It has turned out to be a mandatory reference for pathology internship teaching of several universities. The achievements of the P-5C model have also been presented as exemplary cases at national pathology education conferences. Subsequently, experts from prominent medical institutions evaluated them positively after extensive academic exchange. Furthermore, the model's "AI + Education" initiative was recognized by the Jilin Provincial Department of Education as a Typical Application Scenario Case of AI in Higher Education in Jilin Province, highlighting its pioneering role in the digital transformation of medical education. As a whole, the outcome shows that the P-5C model is innovative and practicable at large in the dissemination and social recognition.

## DISCUSSION

This article identified the major challenges facing physician education in frontier regions and proposed the P-5C competency framework as an integrated educational model to address these issues. Existing evidence suggests that frontier medical education is constrained not only by limited educational resources but also by insufficient research capacity, inadequate medical humanities training, and poor preparedness for public health emergencies. These findings indicate that physician training should emphasize comprehensive competency development rather than knowledge acquisition alone. The P-5C model extends the principles of competency-based medical education by integrating five core competencies: Connection, Critical Thinking, Creativity, Communication, and Collaboration. These competencies complement one another to promote interdisciplinary learning, evidence-based decision-making, innovation, effective physician-patient communication, and teamwork. Such an integrated framework is particularly relevant for frontier regions, where physicians are expected to manage diverse clinical conditions while adapting to multicultural healthcare environments and limited medical resources.

A major strength of the P-5C model is its emphasis on integrating research training, medical humanities, and public health preparedness into undergraduate medical education. Early participation in scientific research enhances students' analytical thinking and innovation capacity, while humanities education improves professionalism, empathy, and culturally competent care. Furthermore, incorporating emergency medicine and public health competencies into routine training can better prepare future physicians to respond to emerging health crises, an issue highlighted by recent global public health emergencies. At the same time, the multidimensional assessment system proposed within the P-5C framework also reflects the philosophy of competency-based education. By combining knowledge examinations, clinical skills assessments, Mini-CEX,

research performance, innovation activities, and multisource evaluations, the framework enables a more comprehensive evaluation of students' professional development than traditional examination-based approaches.

Nevertheless, this review has several limitations. As a narrative review, the literature selection process may be subject to selection bias. In addition, although the P-5C framework is supported by existing educational theory, further multicenter studies are required to evaluate its effectiveness using standardized educational outcomes. Successful implementation will also depend on institutional support, faculty development, and continuous curriculum improvement.

In conclusion, the P-5C framework provides a comprehensive competency-based approach for physician education in frontier regions. By integrating clinical competence, research capability, innovation, communication, collaboration, and public health preparedness, the model offers a practical strategy for strengthening medical education and developing physicians capable of addressing the evolving healthcare needs of resource-limited and culturally diverse communities.

## FUTURE DIRECTIONS

Future research should focus on validating the P-5C framework through multicenter, longitudinal studies involving medical schools from diverse frontier regions. Standardized assessment tools are needed to objectively evaluate the development of the five core competencies and to compare educational outcomes with those of conventional curricula. Further studies should also investigate the integration of emerging educational technologies, including artificial intelligence, virtual simulation, and digital learning platforms, to enhance competency-based training in resource-limited settings. In addition, faculty development programs and institutional support mechanisms should be strengthened to facilitate sustainable implementation of the P-5C model. International collaboration among medical schools may further promote the exchange of educational resources and best practices. By continuously refining the framework and evaluating its long-term impact on physician competence, healthcare quality, and community health outcomes, the P-5C model has the potential to serve as a scalable and adaptable approach for frontier medical education both nationally and globally.

## CONCLUSION

The P-5C model offers the most organized and competency-based solution to persistent issues in frontier medical education. These include the lack of appropriate resources, fragmented collaboration mechanisms, and insufficient capacity to innovate. The model aims at the digital transformation and modernization of medical higher education in frontier areas by making it possible interdisciplinary infusion of learning, research-oriented training, and use of digital teaching-learning approaches.

Medical education policy also presents a useful model for producing highly-skilled medical manpower, thus supporting the build-up of a more adaptive, inventive, and region-based medical education system. The framework also strengthens the development of a digitally intelligent curriculum framework for fundamental medical education while promoting the creation of interdisciplinary courses in frontier medical colleges and universities. Significantly, the P-5C model, instead of being prescriptive, acts as a flexible educational tool that aligns training goals with competency-based assessment and regional health needs. It offers important insights and useful guidance for medical education institutions that operate in similarly resource-poor environments (Noya *et al.*, 2024).

It is essential to note the limitations of the study. Primarily, the current evaluation mainly examines whether students develop 5C competencies over a short period of observation. Additionally, there are no long-term longitudinal tracking of educational and career outcomes. Moreover, the extent to which teachers' own 5C competencies affected the effective implementation of the model was not systematically explored, despite their potential to influence teaching quality and instructional innovation. Future studies should extend their follow-up duration, expand their evaluation indicators to different levels, and strengthen faculty development and capacity building.

The P-5C model has the capability to hone and suit any context or circumstance related to medical education, developing medical graduate's capacity for research and application in solving issues of varying discipline. Most significantly, it is able to provide a scalable and transferable framework to advance the reform of medical education. This will also support the sustainable development of health systems in the frontier and underserved regions.

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## ABBREVIATIONS

**ACGME:** Accreditation Council for Graduate Medical Education; **AI:** Artificial Intelligence; **CanMEDS:** Canadian Medical Education Directives for Specialists; **CBME:** Competency-Based Medical Education; **CBL:** Case-Based Learning; **Mini-CEX:** Mini-Clinical Evaluation Exercise; **PBL:** Problem-Based Learning; **SCI:** Science Citation Index.

## CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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## AUTHORS CONTRIBUTION

**YY:** Supervision, Conceptualization, Writing-review & editing, Writing-original draft. **TJ:** Data curation, Formal analysis, Writing-original draft. **XR:** Supervision, Writing-review & editing. **JP:** Formal analysis, Writing-original draft. **XZ:** Formal analysis, Supervision, Writing-original draft. **AJ:** Formal analysis, Writing-original draft. **SZ:** Formal analysis, Writing-original draft. **ZL:** Conceptualization, Investigation, Methodology, Supervision, Writing-original draft, Writing-review & editing.

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