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Enhancing innovation in medical students through imaginative driven models

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Chinese medical students lack innovation skills due to traditional teaching systems. To enhance innovation skills, the present study aims to develop a new learning model. This study develops an Imaginative Activity-Based Model by employing the Design and Development Research (DDR) approach to enhance Innovation for Chinese Medical Students. For the need analysis, data from 150 students were surveyed and thereafter analyzed through SPSS. Whereas data from 9 experts were collected to develop the design of the DDR model. The Fuzzy Delphi Method has been employed to test the data. The findings of the first phase, through 6 experts, confirm the need for the development of this new model. Findings of the design phase through identified 19 activities confirm the design of the new model. The third phase of evaluation evidence through defuzzification values ranged from 33.6 to 42.0, confirming the moderating level of experts' agreement on the usability of the model. Finally, it should be concluded that this model has potential for developing innovation in Chinese medical students.

Keywords Innovation, Medical student, Learning model, Fuzzy delphi method

In recent years, innovation has emerged as a strategic pillar in China's national development agenda, necessitating the cultivation of a skilled workforce capable of driving forward this agenda[1]. As part of this broader vision, China has significantly reformed its medical education system. During the 2018–2019 academic year alone, 420 institutions offered medical education programs, enrolling over 14,000 PhD candidates, 81,000 master's students, and more than 286,000 undergraduates[2]. Despite this expansion, the dominant pedagogical model in Chinese medical schools remains rooted in traditional lecture-based approaches, which emphasize rote memorization at the expense of critical thinking and creative problem-solving[3]. In an era where healthcare demands are evolving rapidly, the ability to innovate is increasingly critical, not only for integrating emerging technologies but also for enhancing patient-centred care. Yet, innovation remains an underdeveloped competency within Chinese medical curricula[4], underscoring the need for systemic educational reforms.

Several structural and institutional barriers hinder the development of innovation skills among Chinese medical students. These include inflexible curricula, limited opportunities for interdisciplinary collaboration, insufficient exposure to clinical innovation settings, and a shortage of faculty equipped to guide innovation-related learning[5]. Findings from a recent multi-institutional study involving 35 students revealed that, while Innovation and Entrepreneurship Education (IEE) initiatives are available, they are often overly theoretical and disconnected from real-world medical practice[6]. Furthermore, disparities in funding and institutional support, particularly in lower-tier institutions, further limit students' ability to engage meaningfully in innovation activities[7]. These challenges contribute to an educational environment where innovation is neither systematically taught nor institutionally prioritized.

Although existing research has examined individual components of innovation in medical education, such as entrepreneurial modules or collaborative learning strategies, much of the literature remains descriptive and lacks validated frameworks for skill development[5]. Moreover, few studies have employed rigorous expert-driven methods, such as the Fuzzy Delphi Method[8], to systematically assess and structure innovation-related learning activities based on their educational value. A recent review of innovation interventions in Chinese medical institutions found that most programs were short-term, lacked empirical evaluation, and were not underpinned by robust pedagogical models[6]. Addressing these gaps, this study employs a Design and Development Research

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(DDR) methodology to construct a structured learning model aimed at enhancing innovation competencies among Chinese medical students. DDR is particularly appropriate for educational research that seeks to both design practical solutions and evaluate their effectiveness within authentic learning environments. Unlike conventional theoretical or experimental approaches, DDR emphasizes iterative development, incorporating empirical data and expert input throughout the process. This is especially important in the context of educational innovation, where proposed interventions must be not only conceptually robust but also adaptable to the realities of classroom and clinical settings. The adoption of DDR thus reinforces the model's academic validity and its relevance for real-world application[9].

Therefore, the primary aim of this research is to construct a validated educational framework designed to enhance innovation capabilities among Chinese medical students. Specifically, the study pursues three objectives: (1) to gather expert insights on the essential components of innovation-oriented learning, (2) to identify and prioritize 19 core learning activities using the Fuzzy Delphi Method, and (3) to analyze the significance of each activity based on defuzzification scores ranging from 33.6 to 42.0. This research seeks to answer two central questions: What are the most critical activities for fostering innovation in Chinese medical education? And how can these activities be quantitatively ranked to inform evidence-based curricular reforms?

This study offers several key contributions to the advancement of innovation training within medical education. First, it introduces a structured learning model specifically designed to cultivate innovation competencies among Chinese medical students, developed through expert consensus and the application of the Fuzzy Delphi Method. Second, the research identifies and prioritizes 19 core innovation-focused learning activities using defuzzification analysis, providing a clear set of actionable elements for curricular integration. Third, by combining expert insights with a rigorous, data-driven approach, the study effectively translates the often theoretical discourse on innovation into a practical framework suitable for implementation. Lastly, the relevance of this model extends beyond academic settings, offering potential utility for healthcare organizations, professional training institutes, and industry stakeholders interested in fostering innovation capabilities within the medical workforce.

The remainder of this paper is structured as follows: a review of relevant literature; an outline of the research methodology, including expert selection and data analysis procedures; presentation of the study's findings; conceptual framework; discussion of key findings; and a conclusion offering recommendations for policy and future research directions.

Literature review

Innovation competencies and their relevance to medical education

Chinese medical education has the potential to equip them with essential skills and knowledge, enabling them to drive advancements in fields such as medical science, biotechnology, energy, and environmental sustainability[10]. China is advanced in genome sequencing, precision medicine, and genetic engineering. The China Precision Medicine Initiative (CPMI) project aims to leverage genomic data for personalized healthcare[11]. Chinese researchers and companies are at the forefront of integrating AI into medical studies and healthcare delivery. In healthcare departments, doctors are using (AI) for medical imaging analysis, drug discovery, disease diagnosis, and patient management. Therefore, technology giants are investing substantially in AI-driven healthcare solutions[12].

Medical education reform is growing in China, aiming for global comparability and enhancing ever-changing healthcare requirements. This effort seeks to enhance quality education for medical students, refine clinical skills, and promote multi-disciplinary teamwork among healthcare professionals. Chinese institutions and researchers have always actively participated in medical cooperation with their international counterparts to seek progress on all fronts of medical studies, including joint research projects, academic exchanges, and participation in global clinical trials and scientific initiatives. Consistent with this approach, we have developed an Imaginative Activity-Based model to Enhance Innovation for Chinese Medical Students. In this study, we have used the DDR method developed by[9], which consists of three phases. The first phase identifies the need for model development. In the first phase, once the need for model development is confirmed based on experts' consensus, the design and development of the model will start in phase 2. Finally, in phase 3, we evaluate the effectiveness of the new model. Detailed objectives of the DDR model are illustrated below.

Objectives of the first phase study

Identifying the development needs of an Imaginative Activity-Based Model to enhance Innovation for Chinese Medical Students.

Objectives of the second phase study

Designing and developing an Imaginative Activity-Based Model to enhance Innovation for Chinese Medical Students.

Objectives of the third phase study

Evaluating the Usability of an Imaginative Activity-Based Model to Enhance Innovation for Chinese Medical Students.

Collaboration, experimentation, and empathy are the critical factors of problem-solving and design thinking methodology. Design thinking integrated into innovation courses for medical students offers an interactive, explorative classroom environment. The student will benefit from applying knowledge to real-world challenges while further developing their innovation competencies. Traditional medical education has emphasized rote memorization and application of established concepts and procedures. Traditional education teaches fundamentals well and prepares students for standardized exams[13]. However, this methodology may not thoroughly equip students with the required skills to compete in a rapidly changing environment.

In recent years, medical students have learnt how to think critically and come up with creative solutions to problems. This is because people want to try new things in many areas[14]. say that these creative people are needed to solve world problems, especially in the medical field, which is a key part of meeting the Sustainable Development Goals' main goals by 2030. The SDGs include goals for developing nanotechnology, switching to green energy, building smart cities, encouraging creative businesses, and dealing with social and environmental problems. An imaginative model is purposely made to help students develop their imaginations, come up with new ideas, solve tough problems, and look for ways to be more creative.

Both educational policymakers and scholars realize that to compete in a rapidly competitive environment, medical students should learn innovative competencies. Enhancing these competencies is crucial for improving scholars' critical thinking, effective problem-solving, and creativity. The importance of innovation is further emphasized by making innovation competence a key focus area in the national action plan on STEM 2017–2025[15]. The Chinese Ministry of Education and Higher Education, in collaboration with the Federal Ministry of Science, Technology, and Innovation, is working on an initiative to promote research and increase the quality of learning and teaching from the perspective of innovation[16].

The literature evidenced that many educators have prioritized establishing an innovation competence model consisting of real-world problem-solving content in STEM education. The implications of the Imaginative Activity-Based Model in enhancing innovation among Chinese medical students entail not only innovation education but also extend beyond[17]. The emphasis will, therefore, be firm on innovation competencies in preparing students for challenges and opportunities brought about by a rapidly changing world where creativity, critical thinking, and collaboration are highly valued.

The potential of design thinking in stimulating innovation competencies

Competencies of innovation can be developed by creating a high-quality learning environment that nurtures the students to solve real-world problems with curiosity and an open-minded approach[18]. An important question is how integrating innovation competence and digital technology using one approach or the other affects the innovative capabilities of students. Scholars have suggested several ways to implement design thinking as a new school learning model. For example, it has been proven that design thinking among teachers in developing learning materials and delivering lectures tends to enhance students' learning outcomes further and complement the classroom environment[19].

Design thinking, therefore, has to be one of the fundamental approaches that empower students to solve problems and develop innovative capacities. The approach provides a structured process of five stages comprising empathy, definition, ideation, prototyping, and testing, leading students in building innovation competencies[20]. Learners can adopt a disciplined attitude towards problem-solving through this step-by-step process. This attitude is imperative for developing innovation competencies.

In China, the applicability of the design thinking model in education, especially in mathematics and science, remains underdeveloped. Several educators are still unaware of the principles of this model and its practical implementation in classroom settings to enhance the innovation competencies of students. Without a clear understanding of this approach, teachers face challenges in incorporating it into their teaching practices to promote innovation skills among students effectively.

Research gap and theoretical framework

However, existing literature underscores the importance of integrating innovative teaching approaches within health professions education, there remains a notable absence of a comprehensive, empirically validated model that combines imaginative activities with design thinking—particularly one tailored to the context of Chinese medical education. Prior initiatives have largely focused on isolated strategies or adaptations of Western pedagogical models, often without accounting for local cultural norms, institutional practices, or curricular structures. Additionally, few studies have employed systematic, expert-guided development processes or adopted structured methodologies such as Design and Development Research (DDR) to inform model creation.

This study seeks to address these gaps by introducing and validating an Imaginative Activity-Based Learning Model through the DDR framework. The model is grounded in a theoretical foundation that draws upon both design thinking principles and constructivist learning theory, emphasizing imagination, collaborative learning, and scaffolding as core components of creative development. Influential contributions from[21] on social interaction and[22] on educational imagination form the conceptual underpinnings of this work. By building upon these frameworks, the study offers a context-sensitive, expert-informed pedagogical model that directly responds to the unique challenges and needs articulated by Chinese medical educators.

Methodology

Research design

This study adopted a Design and Development Research (DDR) methodology to develop and validate an imaginative activity-based learning model aimed at enhancing creativity among Chinese medical students. DDR is particularly suited for educational research that involves the creation of practical instructional models through the integration of theoretical foundations and iterative validation processes. The present study focuses on Phase 1 of the DDR process, which involved conducting a needs assessment through expert input using the Fuzzy Delphi Method (FDM).

Participant selection and expert panel

Participants are selected through purposive sampling to ensure the inclusion of individuals with substantial expertise in medical education and curriculum development. The following are the inclusion criteria for each expert. First expert possesses a minimum of five years' teaching experience in higher medical education. Second, experts should be actively involved in curriculum design, educational reform, or academic leadership related to innovation. Third, the expert holds at least the academic rank of associate professor or an equivalent position. Finally, an expert demonstrates relevant expertise through scholarly publications or institutional initiatives related to innovation in education. Therefore, a total of six experts who met these criteria were invited to participate in the Delphi process. Their academic specializations included clinical medicine, health professions education, and educational technology.

Instrument development and validation

The initial pool of items for the proposed learning model was generated through an extensive literature review and informal consultations with medical educators. These items represented potential activities aligned with creativity and innovation in medical education. Hence, to ensure the content validity, three external experts, not involved in the Delphi rounds, reviewed the items. Moreover, the Content Validity Index (CVI) for the items ranged from 0.83 to 1.00, reflecting high levels of clarity and relevance. Finally, the reliability of the Delphi responses was assessed using Cronbach's alpha, resulting in a coefficient of 0.87, indicating satisfactory internal consistency.

Data collection procedures

Data collection took place over three months from September to December 2024, and involved two rounds of Delphi-based expert evaluation. The timeline was as follows:

- Weeks 1–2: Expert recruitment and dissemination of the first-round questionnaire.
- Weeks 3–4: Analysis of Round 1 feedback and refinement of items.
- Weeks 5–6: Distribution of the second-round questionnaire.
- Weeks 7–8: Final data analysis and consensus evaluation.

Data analysis

Data were analyzed using the Fuzzy Delphi Method (FDM) to assess consensus levels among experts and determine the relative importance of each item within the proposed model. The following key steps were followed to reach the result. First, expert ratings were translated into Triangular Fuzzy Numbers (TFNs) using predefined linguistic variables. Second, defuzzification was carried out using the Center of Gravity (COG) method to compute weighted scores for each item. Third, items were retained if the defuzzification value and the Expert agreement level were greater than or equal to 0.60 and 75%, respectively. Finally, the SPSS software has been employed to analyzed the data collected through survey from 150 students.

Modified design and development of an imaginative innovation model

The coherent idea for the present study is described in the following conceptual framework (Fig. 6). Furthermore, the present research also elucidates how the research design's conceptual framework pilots the design and successful execution of this research. The development of a model for the present study (i.e., an Imaginative Activity-Based Model to Enhance Innovation for Chinese Medical Students) is based on the Design and Development Research (DDR) approach, which was introduced by[23].

Prior literature evidenced that DDR is classified into product-based and model development design studies[23]. Product-based research focuses on decision-making and assessing whether the product meets its intended purpose and requirements[24]. In contrast, model development design studies focus on decision-making processes, procedures, and the supporting context for developing a model.

Design interventions

In the present study, we have followed[25] modified DDR research approach to classify our model into three stages, including (1) need analysis, (2) design and development, and (3) implementation and evaluation of the proposed model. Furthermore, a detailed illustration of this study is presented in Figure 1.

Phase 1: need analysis

The needs analysis part is the first step in the DDR research method. This step is important because it helps the researcher narrow down every research question that is relevant to the model development study[26,27]. This step looks at whether or not Chinese medical students need to be taught in a creative, activity-based way in order to encourage them to come up with new ideas. To find the desired results, this step involves figuring out what the study subjects need and evaluating those needs[26,28,29]. During this phase, the researcher performs a comprehensive requirements analysis guided by an extensive literature review[24]. To set goals, check progress, and solve problems, the McKillip discrepancy model for needs analysis in educational studies should be used.

In this study, a needs analysis was used to gather information about the need for an "imaginative activity model to enhance innovation among Chinese medical students," as described by a teacher of these students who specializes in innovation. It depends on the questions that come next. Q1: To find out why it's important to make an Imaginative Activity-Based Model to encourage creativity among Chinese medical students from the point of view of experienced teachers. Q2: Finding out what teachers think about the topic requirements for creating the Imaginative Activity-Based Model to encourage creativity among Chinese medical students.

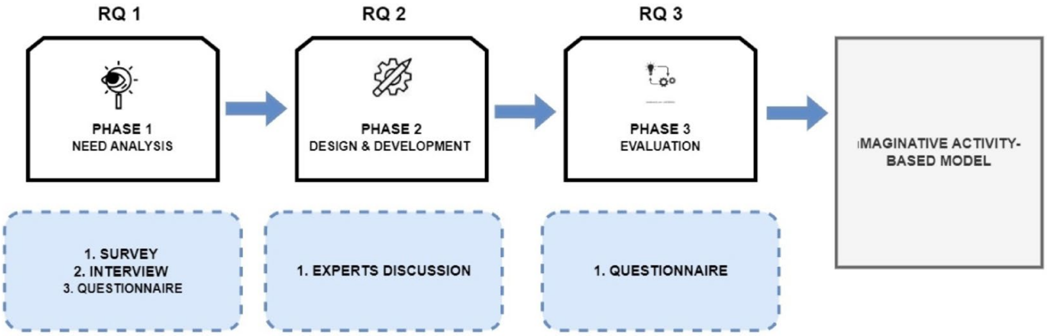

Fig. 1. Research flow Chart.

Mean Score	Mean interpretation
1.00–2.00	Low
2.01–3.00	Average
3.01–4.00	Intermediate
4.01–5.00	High

Table 1. Interpretation mean score Scale. Note: Own calculation.

Interviews and survey forms were used in both qualitative and quantitative research methods in this study. Six experienced innovation educators with at least 10 years of experience in the field were asked open-ended questions as part of the qualitative method. When a researcher wants to learn more about a new subject, they should use open-ended questions in talks[26]. Also, the interview method lets you get a more in-depth view from the subject and helps you understand the situation better[30,31].

Similarly, in the quantitative approach, data about need analysis is also calculated through survey questionnaires[25]. recommend that for a comprehensive needs analysis for developing an activity model, a survey questionnaire is the best option to collect data from a large sample. Furthermore, the following researchers advocate a quantitative approach[27,31,32]. Purposive sampling has been used because detailed information about the design and content requirements of the activity model can only be obtained from innovation educators or experts teaching medical students[33].

In the present study, data from 150 participants have been collected through a survey questionnaire. The participants were selected from three medical institutes in China (North Sichuan Medical College, Chengdu Medical College, and South West Medical University) on the approval basis of the Ethics Committee (EC)/ Institutional Review Board (IRB) with ethics code No. (2024-080, ER202402-006, 20241017-01), respectively. The questionnaires were provided in person to the participants of each institute.

Informed consent was obtained from all participants before their inclusion in the study. Participants were informed about the study's purpose, procedures, and their right to withdraw at any time without penalty. In addition, all the methods in this research have been performed in accordance with the relevant guidelines and regulations.

The collected data ware analyzed using descriptive statistics in SPSS software. The results evidence that innovation in terms of the Imaginative Activity-Based model is very important for medical students from the perspective of teachers. This result is consistent with the prior literature, which acknowledges that education is pivotal in improving students' innovation competencies[34]. Similarly, in response to the second research question, six experienced innovation educators with at least 10 years of experience recommend the need for innovation in medical education, along with 17 key activities. Table 1 indicates low, average, intermediate, and high mean interpretation.

Phase 2: design and development

The second phase is the design and development phase of an Imaginative Activity-based Model to enhance innovation among Chinese medical students based on the views and decisions of 9 experts. Resultantly[35], emphasize that this phase is very important in product, curriculum, and module development. In phase 2, gathering and making decisions based on expert opinion is carried out using the Nominal Group Technique (NGT) and Interpretive Structural Modeling (ISM). According to[36], NGT is a structured method for small group discussions to reach an agreement[37]. This aligns with[38] view that NGT involves face-to-face small-group discussions[39]. also noted that NGT is highly suitable for studies requiring consensus and evaluation, as it can provide a high level of agreement[37]. Figure 2 indicates the implementation phases of NGT.

Similarly, In this study, we also used Interpretive Structural Modelling (ISM) in this work. The Warfield introduced ISM in the middle of the 1970 s as a way to look at complicated social and economic processes[32]. Warfield says that ISM involves people and groups using computers to make models based on their experience

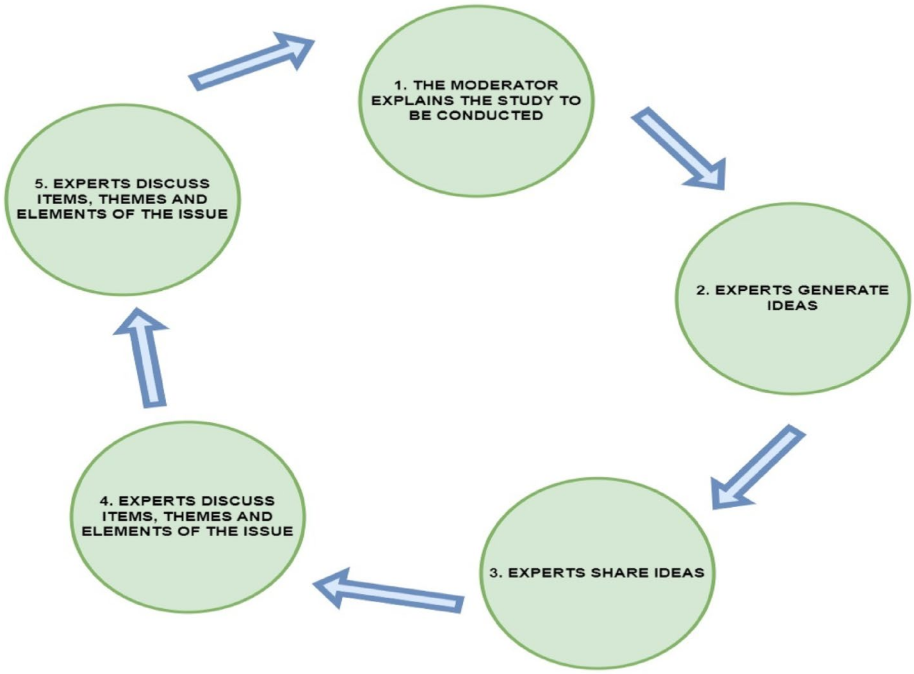

Fig. 2. The five phases of NGT implementation.

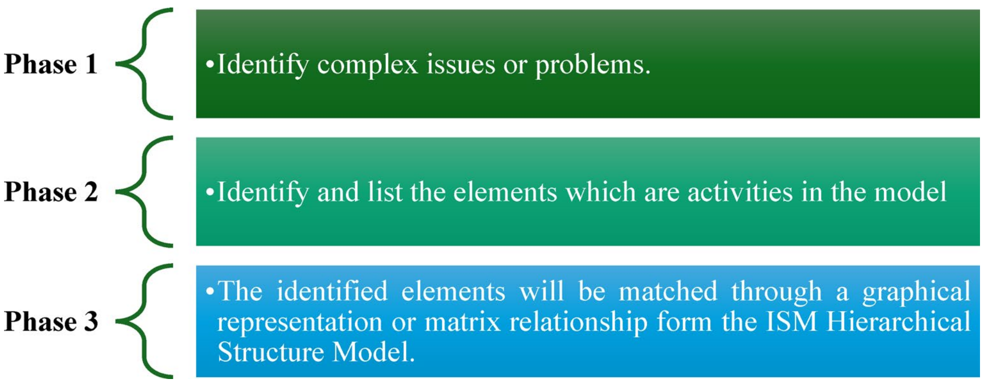

Fig. 3. Interpretive structural modeling process.

and professional knowledge[4041]. agree with this point of view. They define ISM as a computer-assisted interaction process that helps people or groups build models based on the parts that are relevant to the topic being studied[42]. says that ISM is a methodical, computer-assisted approach that can be used in a variety of situations and environments and is a useful tool for making models. According to these explanations, ISM is used to build an activity model in a planned way, showing how each part fits into the bigger picture that experts find during the planning and development process. There are three main steps in the ISM process. According to[43], the three phases of the ISM process have been followed, illustrated in Fig. 3.

The study sample for the NGT and ISM approaches in the data collection should consist of 5 to 9 people[3644]. suggests that an expert group should be between 6 and 10 members, as larger groups tend to weaken the quality of debate. Therefore, in the present study, 9 experts have been involved in the design and development phase of the NGT and ISM processes.

For NGT, an initial list built based on previous studies continued from the questionnaire in the first phase. However, this initial list went through two rounds of face validity before the initial list was produced to be discussed in the NGT session. At the end of the NGT session, a questionnaire consisting of the activity elements decided in the previous NGT session was made into a 5 Likert scale item to get personal feedback from each expert involved for each activity element that had been agreed upon. Similarly, the instrument in the ISM software developed by Sorach Incorporation is the Concept Star software. This software facilitates the discussion and the process of making a consensus or decision among the experts involved in the NGT workshop to determine the relationship of each element in the model included in the ISM software.

Step	Activity
Step 1	Identifying the Elements of Problems and Issues • Each element of the model activity was presented to experts, who decided on the appropriateness of an aspect that should be included in the final list. • In the final stage of the NGT, the final list was given to each expert to vote and select the appropriate activity element by ranking each element. • A scale of 1 to 5 determines the ranking items the ISM experts choose were involved.
Step 2	Establishing the context of the relationship between variables • The relationship of contextual phrases was determined by how the activities are to be connected. • Contextual relations and relational phrases had been determined by expert opinion on how activities are connected.
Step 3	Develop a self-interaction structure matrix. • ISM was developed based on the elements of activities that show the relationship between the elements.
Step 4	Generating the ISM Model • The software generated the ISM model in pairs.
Step 5	Model Presentation • Experts studied the generated model to check and make necessary modifications, if any.
Step 6	Presentation and Modification of Models • The final model should be presented if any amendments were made; the next step, 7 to 9, is the analysis of the results of the final model.
Step 7	Distribution of the Reachability Matrix • Activites were classified at different levels.
Step 8	Activity Cluster • Activities in the model were also classified according to clusters driving power and dependence power.
Step 9	Activity Analysis and Interpretation • Activities were analyzed and interpreted according to the importance and hierarchy of relevant activities.

Table 2. Procedure and data Analysis.

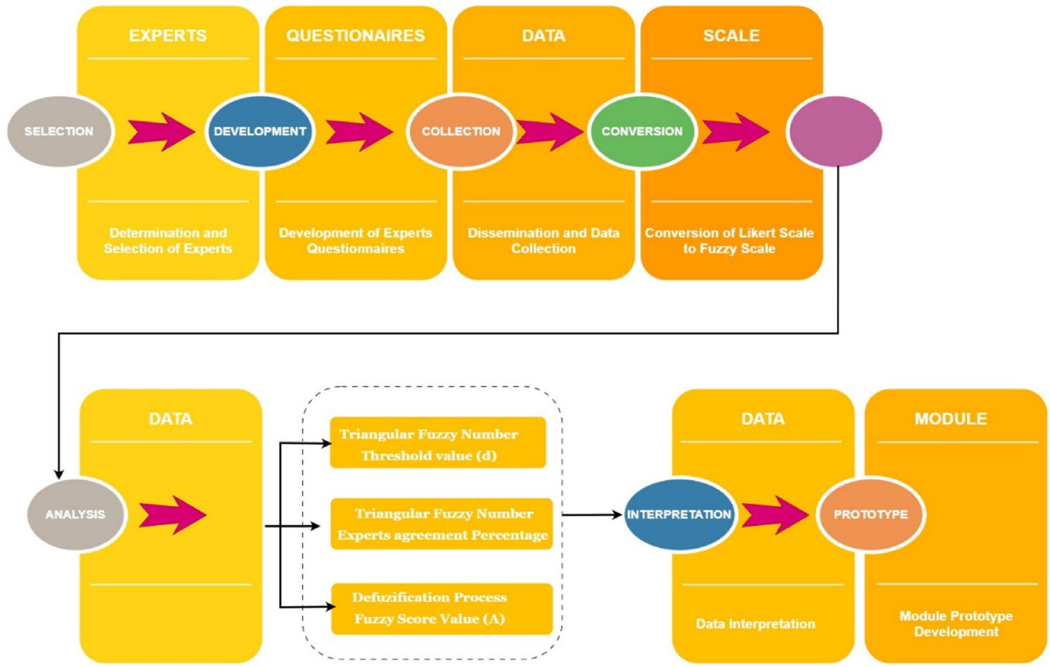

Fig. 4. Process of Fuzzy Delphi Method.

The following 9 steps have been taken in the present study to develop an Imaginative Activity-Based Model to enhance Innovation for Chinese Medical Students, as shown in Table 2.

Phase 3: evaluation

The purpose of phase 3, which is model usability evaluation, is to evaluate the model developed in phase 2[24]. The third phase evaluates the model using the Fuzzy Delphi technique. This phase aims to obtain the usability of the Imaginative Activity-Based Model to enhance Innovation for Chinese Medical Students. This model is evaluated by experts selected based on several criteria. The study for phase 3 uses the Fuzzy Delphi method to obtain expert views in validating the developed activity model.

The fuzzy Delphi method (FDM) was used in the present study to design and develop the imaginative activity-based model to enhance innovation for Chinese medical students, as illustrated in Fig. 4. The Fuzzy Delphi Method, introduced by Kaufmann and Gupta in 1988, combines fuzzy set theory with the Delphi Method introduced by[45]. FDM is the modified or updated version of the Delphi method. Consequently, FDM is not the latest method; it has been widely used and accepted by prior education literature since 1988[46–48]. Hence, based on earlier literature, we have chosen FDM in the present study to select elements in the model based on expert consent effectively. Furthermore, the FDM process strengthens the effective selection of experts and agreement to confirm, evaluate, and add elements[49]. Hence[50], have evidence that FDM can reduce uncertainties and inaccuracies in the research.

In the present study, we have followed the following steps in the FDM to ensure the empirical results.

Selection of experts
In the present study, following[46], we have selected experts based on individuals having (1) more than 5 years of experience[51], (2) various areas of expertise (Somerville, 2007), (3) high knowledge and skills in a particular field[52], (4) willingness to provide their views[53], (5) commitment to revise findings[54,55], and (6) ability to appreciate the views of other experts. Following[56,57], achieving a high level of agreement is essential. A pilot study of 15 innovation experts, each with over five years of experience, was conducted for the Delphi technique.

Development of questionnaires for experts
We have developed questionnaires based on the experts' discussion and a literature review following[58] methodology. Prior studies[27,48] evidenced that the 7-point Likert scale achieves superior accuracy compared to the 5-point Likert scale. Hence, we have utilized a 7-point Likert scale to reduce ambiguity and enhance experts' agreement in this study.

Distribution and data collection
The data about the present study was collected from the required experts by meeting face-to-face with each expert and physically disseminating the questionnaire.

Conversion of scale into fuzzy from likert
In this step, all variables are transformed into Fuzzy triangular numbers, allocating a fuzzy RLM number to each criterion, indicating the N experts.

$$\mathrm{L} = 1 \ldots .\mathrm{u},\ \mathrm{m} = 1, \ldots\ \mathrm{v}, \qquad \mathrm{N} = 1 \ldots .., \mathrm{n\ and\ rlm} = \frac{1}{N\left(r^1 lm\ \mp\ r^2 lm \mp\ r^k lm\right)}\ I = 1$$

Furthermore, the average data value of Delphi Fuzzy analysis in this research was calculated in MS Excel.

The data analysis began with calculating the threshold value (d) to see the expert's level of agreement on the usability evaluation of the activity model, according to[59], the threshold value of (d) must be less than or equal to 0.2, which indicates that all the experts are assumed to have consensus and agreement in determining the decision. The dispersion between two Fuzzy number, u = (u1, u2, u3), and v= (v1, v2, v3) are estimated using following calculation.

$$d\left(u,v\right) = \sqrt{\frac{1}{3}\left[\left(u1 - v2\right)^2 + \left(u2 - v2\right)^2 + \left(u3 - v3\right)^2\right]}$$

Based on the percentage of the expert's consent
In this step, the percentage value of the expert group's agreement must be equal to or exceed 75% to determine whether the item is accepted or rejected[46,60,61]. Hence, any item should be dropped if it does not reach the 75% threshold.

Defuzzification score
Finally, in this step, a group of experts whose (d) values and percentages exceed 0.2 and 75%, respectively, and then we proceed into the defuzzification process to identify the fuzzy score value. According to[40,62], the value of the (A) score should be greater than 33.6 and less than 46.8. This range (33.6–46.8) indicates the agreement among the experts' opinions about the items. The formula for estimating the (A) value is illustrated below.

$$A = \frac{1}{3} \times\ \left(u1 + u2 + u3\right)$$

Hence, based on the experts' consent, we developed the prototype of the Imaginative Activity-Based Model to Enhance Innovation for Chinese Medical Students. Furthermore, we restructured organizational charts, screen design, content program, evaluation process, storyboard, and repetition in this phase. Finally, we conducted the pilot testing on 15 students before implementing the model to identify any issues or errors that arose during model development.

Results

This section presents the research results gathered and analyzed following each study stage.

Result for phase 1: need analysis

The experts' data was collected through interviews and questionnaires to identify the need for an imaginative activity-based model to enhance innovation for Chinese medical students. The findings of the interviews were used to construct items for the questionnaire in addition to material collected from the highlights of previous studies. The conclusion of 6 experts' interviews shows that the learning scenario for Chinese medical students is very dense and requires full concentration. The level of imagination of Chinese medical students is at several levels, according to the observations carried out by experts. However, most experts stated that students' imaginations were at a moderate average level. Even so, students use their imagination during the learning process. This can be seen when they complete the tasks given. Many characters related to imagination have been outlined by the experts involved. Among them is innovation, which is seen as important in determining the direction of the student, not only in learning but also in the future. The experts also strongly agree that developing a guide for developing and enhancing innovative Chinese medical students is necessary. The model should include individualized education, adaptability, comprehensive training, and guidance.

Furthermore, to determine the validity and reliability of the questionnaire for identifying a need for an Imaginative Activity-Based Model to Enhance Innovation for Chinese Medical Students, data from 30 participants were collected as a pilot study. The reliability of the 30 collected questionaries was analyzed by determining the Cronbach's Alpha value. A summarizes the face validity report can be seen in Table 3 below.

Based on Table 3 above, the Cronbach's Alpha value for all 34 items is 0.977, including items for demographic data. The obtained value of 0.977 indicates that the reliability level of the questionnaire is very high. Therefore, the questionnaire can be used for data collection without needing modifications.

Result for phase 2: design and development model

The result illustrated in Table 4 indicates that the NGT process highlights 19 learning activities as key components for developing an innovation model. The table also presents the ranking scores assigned by the experts for each learning activity. The lowest score was two (2) for 'Disagree,' while the highest was five (5) for 'Strongly Agree.' The cumulative scores establish the priority ranking for each learning activity.

Furthermore, the relationships between activities selected through the NGT in Step 1, the contextual and relational phrases in Step 2, and the ISM process, the content of the Imaginative Activity-Based Model to enhance innovation for Chinese medical students can be developed through the collective decisions of experts with the support of ISM software, as illustrated in Fig. 5.

Result for phase 3: model usability evaluation

We have utilized the Fuzzy Delphi method in the present study to analyze pilot and actual study data. A pilot study was conducted to test the questionnaire's usability before implementation for actual model evaluation. The questionnaire's Cronbach's alpha value, calculated from data analyzed through SPSS, is 0.982, greater than the standard 0.80.

After successfully testing the reliability and validity of the questionnaire, data from 50 actual respondents are collected to evaluate the "Imaginative-Based Model to Enhance Innovation for Chinese Medical Students." Based on (d) value, percentage, and defuzzification value (A), the successful evaluation of the model can be justified. Table 5 indicates the estimated result of the (d) value for the usability factor of the first model. The result shows that there are 6 respondents in BA3 whose (d) values exceed the standard value of 0.2. Similarly, 3 respondents of items BA1, BA4, and BA5 exceeded the threshold value (d) 0.2. Finally, only 2 respondents assigned a threshold value (d) above 0.2 for item BA2.

Table 6 indicates the percentage of each item for the element usability construct evaluated based on the threshold value (d) in Table 5. The result reveals that all items in Table 6 are above the standard 75%, advocating that all items are better for evaluation and that there is no need for repeated items.

Based on the result illustrated in Table 7, the (A) values of items BA1, BA2, and BA5 moderately agree because these values are within the standard range (i.e., 33.6–46.8). In contrast, the (A) values of items BA3 and BA4 are 31.53 and 31.15, respectively, slightly agree because the defuzzification value obtained is 24 to 33.6. This shows that the usability factor of the element gets expert approval because it exceeds the minimum value of the agreement range, which is 24. The results of all other items are presented in Appendix A.

Conceptual framework

DDR's systematic and evidence-based nature is entitled to an extensive understanding of the design and development process[25]. The engagement of experts in the design consensus increases the relevancy and quality of the "Imaginative Activity-Based Model." Consistent with prior literature regarding the benefit of DDR research in educational design and development, the present study expands the contribution in this field. The present study provides a robust, practical approach to instructional design in medical studies. The final model, the "imaginative activity-based model to enhance the innovation of Chinese medical students," was developed after successfully carrying out three phases. The baseline model representing Fig. 6 was produced after going through several processes in the study: the production of elements, the grouping of elements, and the naming of elements. The output of this final model is based on previous surveys and feedback shared and received from all the experts involved from the first phase of the study up to the third phase.

Furthermore, the development of this methodology is grounded in disruptive innovation theory, Kieran Egan's imaginative education, and the Kolb learning model. The Disruptive Innovation Theory tells us a lot about how changes in technology and the way markets work can cause big changes in businesses and markets. It gives us a way to think about how businesses might move and respond to these disruptive forces. The healthcare

N	Cronbach Alpha
35	0.977

Table 3. Validity result.

	Teaching Activities	EP 1	EP 2	EP 3	EP 4	EP 5	EP 6	EP 7	EP 8	EP 9	Total	Priority	Ranking
1.	Gather students in an environment conducive to creative thinking.	5	5	4	4	5	4	5	4	4	40	6	15
2.	Introduce the innovation concept in medicine and its importance in improving patient outcomes and medical delivery.	5	5	5	4	4	5	5	5	5	43	3	3
3.	Brainstorm a list of current challenges or areas for improvement in healthcare.	3	5	5	5	3	5	5	5	5	41	5	12
4.	Choose one or more challenges from the brainstorm list.	4	5	5	4	3	5	5	3	5	39	7	16
5.	Encourage students to delve deeper into the chosen challenge to understand the underlying issues and identify specific problems that must be addressed.	4	5	5	4	4	5	5	4	5	41	5	13
6.	Divide students into small groups or pairs.	2	3	4	4	4	5	5	5	5	37	9	19
7.	Each group/pair chooses a specific problem to solve.	2	5	4	4	5	5	5	4	5	39	7	17
8.	Give them time to think of potential solutions to the identified problems. Please encourage them to think outside the box and consider innovative approaches.	4	5	5	5	5	5	5	4	5	43	3	4
9.	Please encourage students to create detailed sketches, diagrams, or even prototypes of their innovative solutions.	5	5	4	5	4	5	5	4	5	42	4	7
10.	Please provide a brief description of how their solution addresses the identified problem.	5	5	4	4	4	5	5	4	5	41	5	14
11.	Invite each group to present their innovative solution to the rest of the class.	5	5	4	4	4	5	5	5	5	42	4	8
12.	Encourage constructive feedback and discussion from peers. Questions can focus on the feasibility, effectiveness, and potential impact of the proposed solution.	5	5	5	5	4	5	5	4	5	43	3	5
13.	Facilitate a reflection session where students discuss what they learned from the activity and how they can apply creative thinking and innovation in their future medical practice.	5	5	4	4	5	5	5	4	5	42	4	9
14.	Encourage interested students to continue developing and refining innovative solutions outside the classroom.	5	5	5	5	5	5	5	5	5	45	1	1
15.	Provide resources or support to help students implement their ideas, such as connecting them with mentors, industry experts, or relevant organizations.	5	5	5	5	4	5	5	5	5	44	2	2
16.	Foster a supportive and non-judgmental environment where students feel comfortable expressing their ideas.	5	5	4	4	4	5	5	5	5	42	4	10
17.	Emphasize the importance of collaboration and interdisciplinary thinking in healthcare innovation.	5	5	5	4	3	5	5	5	5	42	4	11
18.	Highlight real-world examples of successful healthcare innovation to inspire and motivate students.	3	5	4	4	3	5	5	4	5	38	8	18
19.	Encourage students to continue exploring and experimenting with new ideas even after the activity is over.	5	5	5	5	4	5	5	4	5	43	3	6

Table 4. Findings of NGT: ranking and prioritization of teaching Activities.

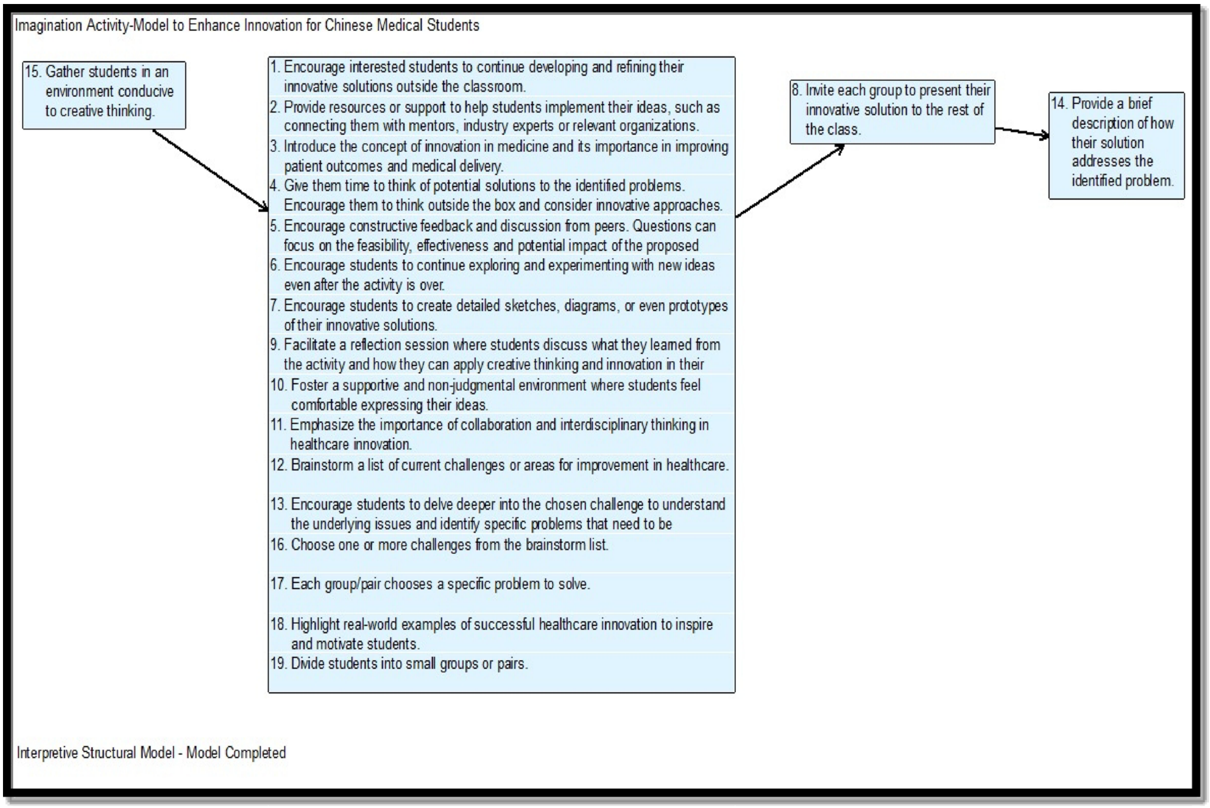

Fig. 5. Prototype Imaginative Activity-Based Model to enhance Innovation for Chinese Medical Students based on Interpretive Structural Modeling (ISM).

industry in China is currently being changed by disruptive innovation[63]. If medical students understand and accept these changes, they can change healthcare for millions of people, making it easier for them to get care, making it more affordable, and improving the quality of care.

Similarly[22], made important advances to the growth of thinking and creative learning. His method makes the very important role of imagination in education clear and gives teachers a way to make learning experiences that are both fun and useful. In medical studies, Kieran Egan's Imaginative Education Theory can help students learn by helping them remember and understand complicated medical ideas. By using this method, teachers can improve the learning setting and prepare their students to be caring and knowledgeable healthcare professionals.

In 1984, David A. Kolb came up with the Kolb learning model, also known as the experience learning theory[64]. This model includes four ways of learning: direct experience, thinking about what you see, doing things yourself, and making up ideas. This idea says that learning happens in steps, and each stage fits a different way of learning[65].

Discussion

This study set out to design and validate an imaginative activity-based learning model intended to foster creativity within Chinese medical education, using a structured three-phase Design and Development Research (DDR) framework. The discussion below interprets the findings from each phase in relation to existing literature and identifies key implications and limitations of the study. The first (Need analysis) phase of the research focused on assessing the perceived need for creative, activity-oriented pedagogies in medical education. Results indicated that 92% of expert participants acknowledged the necessity of integrating imaginative, student-centered approaches. This strong consensus marks a notable departure from the traditionally rigid, exam-driven instructional models that have long dominated Chinese medical education[66]. The prevailing emphasis on rote memorization and authoritative teaching is increasingly viewed as insufficient for preparing students for today's dynamic healthcare environment.

The experts' support for pedagogical innovation aligns with growing international recognition of the value of experiential learning, adaptability, and interdisciplinary collaboration in medical training[4,67]. Their perspectives reflect not only a local demand for reform but also resonance with global shifts in health professions education, where fostering critical thinking, creativity, and teamwork has become essential for professional readiness in complex clinical settings.

The second (activity identification) phase involved the identification and categorization of 19 core learning activities using the Nominal Group Technique (NGT). These activities were analyzed in relation to the design thinking framework, which served as the conceptual foundation of the model. Activities such as clinical simulations, interdisciplinary projects, and role-play closely align with key design thinking processes, including

Respondents	Usability of Elements				
	BA1	BA2	BA3	BA4	BA5
1	0.0072	0.0456	0.1153	0.0158	0.0228
2	0.0386	0.0456	**0.3767**	0.0158	0.0481
3	0.0099	0.0736	0.1167	**0.2417**	0.1748
4	0.0099	**0.4023**	**0.2573**	0.0158	**0.3414**
5	0.0072	0.0456	0.1167	0.1052	0.0014
6	0.0386	0.0456	0.0520	0.1052	0.0014
7	0.0072	0.0736	0.0207	0.0158	0.0481
8	0.0386	0.0736	0.0207	0.0158	0.0481
9	0.0386	0.0069	0.0207	0.0158	0.0014
10	0.0386	0.0103	0.0047	0.0598	0.0014
11	0.0072	0.0069	**0.2573**	0.0158	**0.3414**
12	0.0099	0.0103	0.0047	0.0598	0.0014
13	0.0072	0.0069	**0.2573**	0.0158	0.0228
14	**0.2366**	0.0736	0.0207	0.1052	0.0481
15	0.0386	0.0103	0.0047	0.0065	0.0708
16	0.0386	0.0456	**0.2573**	**0.2417**	0.0228
17	0.0072	0.0069	0.0520	0.0065	0.0228
18	0.0099	0.0103	0.0207	0.0158	0.0228
19	0.0099	0.0069	0.0207	0.1052	0.0014
20	0.0386	0.0456	0.0520	0.0598	0.0228
21	0.0099	0.0069	0.0047	0.0065	0.0014
22	0.0072	0.0103	0.0207	0.0065	0.0014
23	0.0386	0.0103	0.1153	0.1278	0.0708
24	0.0072	0.0103	0.0047	0.0598	0.0228
25	0.0386	0.0456	0.0520	0.1278	0.0708
26	0.0099	0.0103	0.1167	0.0158	0.0014
27	0.0832	0.0736	0.0207	0.0065	0.0014
28	0.0099	0.0069	0.0047	0.0065	0.0014
29	0.0099	0.0069	0.0047	0.0065	0.0014
30	0.0386	0.0456	0.1153	0.1278	0.0708
31	0.0072	0.0103	0.0520	0.0598	0.0228
32	0.0072	0.0456	0.0520	0.0065	0.0708
33	0.0099	0.0069	0.1153	0.1278	0.0708
34	0.0832	0.0069	0.0207	0.1052	0.0481
35	0.0386	0.0456	0.0047	0.1052	0.0014
36	**0.4239**	0.0736	0.0047	0.0158	0.0481
37	0.0386	0.0456	0.1153	0.1278	0.0708
38	0.0099	0.0069	0.0047	0.0065	0.0014
39	0.0099	0.0069	0.0047	0.0065	0.0014
40	0.0099	0.0069	0.0047	0.0065	0.0014
41	0.0386	0.0456	0.0520	0.0065	0.0228
42	0.0386	0.0456	0.0520	0.0598	0.0708
43	0.0099	0.0069	0.0047	0.0065	0.0014
44	**0.5686**	**0.4023**	**0.2573**	**0.2417**	**0.3414**
45	0.0099	0.0456	0.0207	0.0158	0.0014
46	0.0099	0.0069	0.0047	0.0158	0.0014
47	0.0386	0.0456	0.0047	0.0598	0.0228
48	0.0386	0.0456	0.1153	0.1278	0.0708
49	0.0072	0.0069	0.0047	0.0065	0.0014
50	0.0832	0.0069	0.0047	0.0065	0.0014

Table 5. Threshold value (d) for usability of Elements.

Usability of Elements	Percentage (%)
Elements can be easily mastered by the user.	94.0%
Elements meet the high productivity expectations of users.	96.0%
Users are still good at implementing elements after a certain period of time without having to learn them again.	88.0%
Users do not easily make many mistakes while implementing elements, and in case of mistakes, users can deal with them easily.	94.0%
Users get satisfaction and pleasure while implementing elements.	94.0%

Table 6. Expert's agreement percentage for usability of Elements.

Usability of Elements	Defuzzification Value (a.i.)
Elements can be easily mastered by the user.	39.35
Elements meet the high productivity expectations of users.	38.63
Users are still good at implementing elements after a certain period of time without having to learn them again.	31.53
Users do not easily make many mistakes while implementing elements, and in case of mistakes, users can deal with them easily.	31.15
Users get satisfaction and pleasure while implementing elements.	35.90

Table 7. Defuzzification value for usability of Elements.

empathy, ideation, and prototyping[5,68]. These methods aim to activate learners on emotional, cognitive, and collaborative levels conditions widely recognized as conducive to creativity and innovation.

Additionally, several activities particularly those emphasizing reflection, scenario-based problem-solving, and collaborative inquiry—are consistent with constructivist educational theory, which posits that learners build knowledge through active engagement and social interaction[21]. This theoretical alignment reinforces the pedagogical soundness of the model and provides a strong foundation for its proposed structure.

In the final phase (evaluation), expert evaluations were analyzed using the Fuzzy Delphi Method (FDM) to establish consensus on the importance and relevance of each activity. Most items received high defuzzification scores, indicating strong agreement among experts. However, a few activities—those with defuzzification values between 31.15 and 31.53 were categorized under "slightly agree," reflecting moderate consensus. These lower values may point to concerns about practical implementation challenges, such as time constraints, technological demands, or the need for cross-disciplinary coordination.

Such findings suggest that while the overall model is well-supported, certain components may require contextual adaptation or piloting before being integrated at scale. This is consistent with previous applications of the FDM, where borderline items often highlight areas in need of further refinement or institutional alignment[8].

Conclusion

This model development study was produced based on the research problems that the researcher identified at the beginning of the study. It starts with the issues that led to the formation of objectives and research questions. To meet and achieve the goals and questions of this study, the researcher has determined the use of Design and Development Research as a methodology used to obtain information and feedback. This DDR approach combines three phases: need identification, development and evaluation analysis.

The first phase of this study set out to investigate the insights of experienced medical educators concerning the development of an Imaginative Activity-Based Model intended to cultivate creativity among Chinese medical students. Framed by two guiding research questions, the study first examined the rationale for introducing such a model and then explored the thematic components necessary for its effective design. The findings from the needs assessment indicate a clear inadequacy in traditional instructional approaches, which often rely on passive learning, memorization, and limited interdisciplinary interaction. These methods fall short in preparing students for the complex, innovation-driven demands of contemporary medical practice. Educators consistently underscored the importance of integrating imaginative, activity-centered learning methods to enhance creativity, critical thinking, and problem-solving capabilities. This directly affirms the relevance and urgency of the proposed model, addressing the first research question.

In addressing the second question, the study identified several key thematic elements deemed essential by educators for the model's construction. These include clinical simulations, case-based discussions, reflective learning, interdisciplinary collaboration, and project-based activities. Together, these components align with current best practices in educational design and offer a validated framework for building a model that is both pedagogically sound and practically applicable.

Overall, this research confirms both the necessity for and the foundational structure of a creativity-oriented learning model in Chinese medical education. By drawing on expert perspectives and employing a rigorous design and development research methodology, the study contributes a contextually relevant and empirically grounded approach to innovation in medical training offering valuable direction for ongoing curricular reform in China and similar educational contexts.

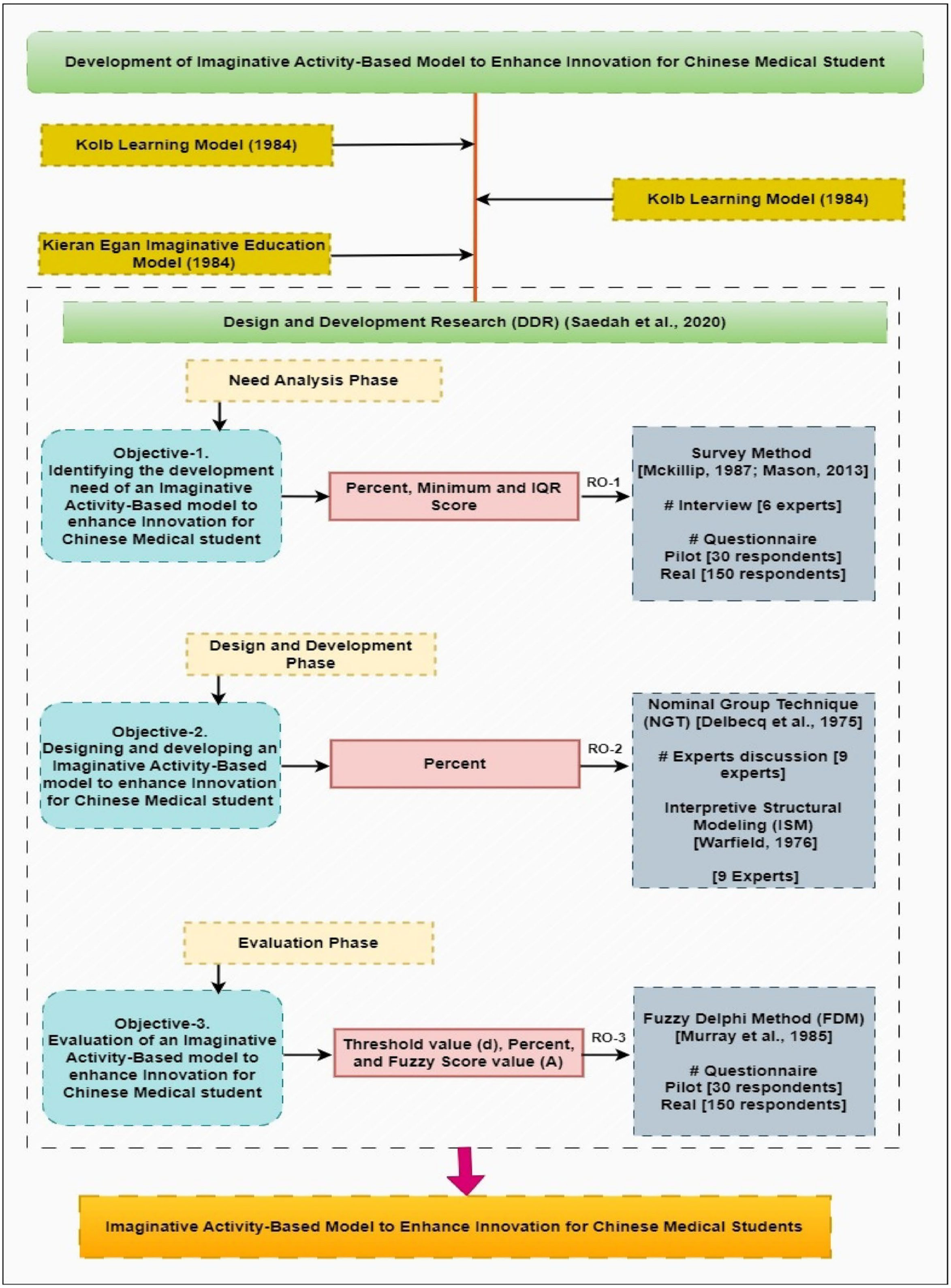

Fig. 6. Conceptual framework.

Policy implications

The findings of the present study contribute both practically and theoretically. Integrating imaginative activities to enhance innovation among Chinese medical students holds several practical implications that can significantly enrich their educational experience and prepare them for future challenges in healthcare.

Practical implications for students
Firstly, the imaginative activities help students develop the ability to generate novel ideas, adapt existing concepts, and approach challenges with creativity. This fosters a mindset of innovation that is essential for addressing complex healthcare issues and improving patient care outcomes. Secondly, imaginative activities actively engage students in problem-solving; through creative activities, students learn to identify root causes, evaluate multiple solutions, and implement effective strategies, which is crucial for navigating the dynamic and challenging healthcare landscape. Thirdly, this prepares them to work effectively in multi-disciplinary healthcare teams and tackle complex healthcare challenges holistically. Fourthly, this enhances the focus of medical students on understanding patient needs, preferences, and experiences through empathy-building exercises, patient simulations, or user-centered design approaches. Fifthly, students will gain hands-on experience with cutting-edge technologies and innovation tools increasingly shaping modern healthcare practices such as virtual reality (VR), artificial intelligence (AI), medical simulations, and digital health platforms.

Practical implications for innovation educators
Firstly, Innovation educators should encourage students to take risks, try out new ideas, and be open to failing as normal parts of the learning process. They should create a safe space for students to look into unusual answers and new ideas without worrying about being judged. Secondly, innovation educators should encourage students from a wide range of fields, not just the medical field, to work together. By working together, students learn from each other's ideas, which improves their ability to deal with complex healthcare issues in a complete way and come up with new ideas effectively in multidisciplinary teams. Thirdly, innovation educators should use new technology and tools in creative activities to make learning better. For example, they should use medical models, virtual reality (VR), and artificial intelligence (AI) to make learning more like real life. Fourthly, innovation educators should help students think of themselves as always learning and changing. Students are encouraged to stay up to date on changes in medical research, technology, and healthcare policies by taking advantage of chances for professional and ongoing learning.

Theoretical implications
Putting together the Kolb Learning Model, Kieran Egan's Imaginative Education, and the Disruptive Creativity Theory to make a model for creative activities that are meant to encourage creativity among Chinese medicine students could have big effects. Chinese medical students get a well-rounded and interesting education when Kolb's experiential learning, Egan's creative methods, and disruptive innovation theory are all used together. It combines learning useful skills with thinking outside the box and finding creative solutions to problems. The idea gives students the skills and mindset they need to deal with difficult problems in modern healthcare situations. By combining old knowledge with new tools, they learn how to be innovative and get ready to improve medical science and patient care. By adapting tasks to the Chinese culture, the model will be in line with the students' backgrounds and the rules of Chinese society. It encourages inclusion and relevance, which makes educational approaches more likely to lead to new ideas in Chinese medical education.

Implications for educational practices and Polices
The outcomes of this study hold significant implications for curriculum developers, medical educators, and educational policymakers. By presenting a systematically validated and hierarchically ranked set of innovation-oriented learning activities, this study provides a concrete framework for embedding innovation into existing medical curricula. Distinct from prior research that often rests on conceptual propositions, this study employs expert consensus and quantitative analysis specifically the Fuzzy Delphi Method to establish an evidence-based foundation for curriculum design. Consequently, the proposed model functions as a strategic tool for academic institutions seeking to cultivate essential competencies such as creative problem-solving, interdisciplinary collaboration, and entrepreneurial thinking among future healthcare professionals. Moreover, the model offers valuable guidance for faculty development, student assessment methodologies, and broader educational reform efforts across both academic and clinical training environments.

Recommendations
This study can be extended with a comprehensive literature review. This can be done using diverse sources and conducting a thorough literature review that includes Western and Chinese educational theories and practices. This ensures a well-rounded understanding of existing models and their effectiveness. It also can consist of literature from various fields, such as psychology, education, design thinking, and medical education, to provide a holistic view of how imaginative activities can foster innovation.

Contextual relevance in this study also can vary. It should consider the cultural sensitivity. Researchers need to ensure that the model is culturally sensitive and aligns with the values, traditions, and learning styles prevalent in Chinese education. Incorporate traditional Chinese educational philosophies alongside modern pedagogical approaches. It can use case studies and examples from Chinese medical schools with successful implementation of similar methods.

Limitations and future research directions
Despite the valuable insights gained from this study, several limitations should be noted. First, the expert panel comprised only six participants drawn from three medical institutions within a single region of China. Although these individuals were purposively selected for their expertise in medical education and curriculum development, the limited geographic and institutional scope may constrain the broader applicability of the findings. Second, the model has not yet been tested in real-world classroom or clinical settings. Without implementation and

feedback from medical students, the practical effectiveness and pedagogical impact of the proposed activities remain unverified. Third, the model was conceptualized within a specific cultural and educational framework, which may present challenges when transferring it to international contexts or institutions with different teaching philosophies and curricular structures. To build on these findings, future research should aim to pilot the model with student populations and assess its impact on measurable creativity outcomes. Longitudinal studies could further evaluate its effectiveness over time. Additionally, comparative studies across diverse institutional and cultural settings would help determine the model's adaptability and relevance beyond the Chinese medical education system. Such research would contribute to refining the model and supporting its integration into broader educational reform efforts.

Data availability
Data will be provided by the corresponding author upon reasonable request.

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References
1. Chen, J., Yin, X. & Mei, L. Holistic innovation: an emerging innovation paradigm. *Int. J. Innov. Stud.* **2** (1), 1–13 (2018).
2. Gong, X. et al. Developing a competency model for Chinese general practitioners: a mixed-methods study. *Hum. Resour. Health.* **22** (1), 31 (2024).
3. Li, X. et al. Comparison of the effects of different teaching methods on the effectiveness of teaching neurology in china: a bayesian network meta-analysis and systematic review. *BMC Med. Educ.* **24** (1), 1560 (2024).
4. Hu, X. et al. Medical education challenges in Mainland china: an analysis of the application of problem-based learning. *Med. Teach.* **47** (4), 713–728 (2025).
5. Wang, Y. et al. Integrating experiential learning theory with innovation and entrepreneurship education: a qualitative study on Chinese medical students. *BMC Med. Educ.* **25** (1), 1–16 (2025).
6. Santana, A. L. M. & Lopes, R. D. Using real-world problems and project-based learning for future skill development: an approach to connect higher education students and society through user-centered design, in Creating the University of the Future: A Global View on Future Skills and Future Higher Education. Springer. 393–417. (2024).
7. Ocansey, D. K. W. et al. Current and emerging medical education teaching methods-keeping up with the evolving medical sciences. *Revista De Educación*. **392** (5), 51–105 (2021).
8. Okoli, C. & Pawlowski, S. D. The Delphi method as a research tool: an example, design considerations and applications. *Inf. Manag.* **42** (1), 15–29 (2004).
9. Richey, R. C. & Klein, J. D. *Design and Development Research: Methods, strategies, and Issues* (Routledge, 2014).
10. Dahlman, C. J. & Aubert, J. E. *China and the Knowledge Economy: Seizing the 21st Century* (World Bank, 2001).
11. Chaudhary, A. & Chadha, R. *Analyzing Blockchain in Healthcare* (BPB, 2022).
12. Javanmard, S. Revolutionizing medical practice: the impact of artificial intelligence (ai) on healthcare. *OA J. Appl. Sci. Technol.* **2** (1), 01–16 (2024).
13. Okuda, Y. et al. *The utility of simulation in medical education: what is the evidence?* Mount Sinai journal of medicine: A journal of translational and personalized medicine. *J. Translational Personalized Med.* **76** (4), 330–343 (2009).
14. Adenle, A. A. et al. Global UN 2030 agenda: how can science, technology and innovation accelerate the achievement of sustainable development goals for all? *PLOS Sustain. Transformation*. **2** (10), e0000085 (2023).
15. Costello, E. et al. *Government responses to the challenge of STEM education: case studies from Europe.* (2020).
16. Ismail, N. et al. *From innovation to market: Integrating university and industry perspectives towards commercialising research output*. in *Forum Scientiae Oeconomia*. (2020).
17. Chen, R. et al. STEM teaching for the internet of things maker course: A teaching model based on the iterative loop. *Sustainability* **12** (14), 5758 (2020).
18. Keinänen, M. *Educating innovative professionals: a case study on researching students' innovation competences in one Finnish University of Applied Sciences.* (2019).
19. Thai, N. T. T., De Wever, B. & Valcke, M. The impact of a flipped classroom design on learning performance in higher education: looking for the best blend of lectures and guiding questions with feedback. *Comput. Educ.* **107**, 113–126 (2017).
20. Yeung, W. L. & Ng, O. L. Using empathy maps to support design-thinking enhanced transdisciplinary STEM innovation in K-12 setting. *Int. J. Technol. Des. Educ.* **34** (4), 1325–1350 (2024).
21. Vygotsky, L. S. *Mind in Society: the Development of Higher Psychological Processes* Vol. 86 (Harvard University Press, 1978).
22. Egan, K. Imagination and learning. *Teachers Coll. Record*. **87** (2), 155–166 (1985).
23. Richey, R. C. & Klein, J. D. Design and development research, in Handbook of Research on Educational Communications and Technology. Springer. 141–150. (2013).
24. Chang, A. & Ariffin, A. The Application of Fuzzy Delphi Technique in Evaluating the Appropriate Arrangement of the Teaching Activity Model Elements using I-Think Maps in the Development of Future Thinking Skills. *Journal of Contemporary Social Science and Education Studies (JOCSSES)* E-ISSN-2785-8774, **3**(1): 148–158. (2023).
25. Saedah, S., Muhammad Ridhuan, T. & Rozaini, M. *Pendekatan Penyelidikan Rekabentuk Dan Pembangunan (PRP): Aplikasi Kepada Penyelidikan Pendidikan* (Universiti Pendidikan Sultan Idris (UPSI), 2020).
26. Ramlan, M. *Reka Bentuk Model Integriti Akademik Berasaskan Penghayatan rohani/Ramlan Mustapha* (University of Malaya, 2017).
27. Jamil, M. R. M. *Pembangunan Model Kurikulum Latihan Skives Bagi Program Pengajian Kejuruteraan Pembelajaran Berasaskan Kerja* (University of Malaya (Malaysia), 2016).
28. McKillip, J. *Need Analysis: Tools for the Human Service and Education* (Applied Social Research Methods Series, 1987).
29. Mason, D. *Voluntary Nonprofit Enterprise Management* (Springer Science & Business Media, 2013).
30. Creswell, J. W. & Poth, C. N. *Qualitative Inquiry and Research Design: Choosing among Five Approaches* (Sage, 2016).
31. Merriam, S. B. & Grenier, R. S. *Qualitative Research in Practice: Examples for Discussion and Analysis* (Wiley, 2019).
32. Saleh, M. P. *Model Pengajaran M-Pembelajaran Berasaskan Kaedah Inkuiri Mata Pelajaran Sejarah Peringkat Menengah* (University of Malaya (Malaysia), 2016).
33. Baltes, S. & Ralph, P. Sampling in software engineering research: A critical review and guidelines. *Empir. Softw. Eng.* **27** (4), 94 (2022).
34. Malagrida, R. et al. Towards competencies and methods to support responsible research and innovation within STEAM secondary education–the case of Spain. *Res. Sci. Technological Educ.* **42** (3), 678–698 (2024).
35. McKenney, S. & Reeves, T. C. Educational design research, in Handbook of Research on Educational Communications and Technology. Springer. 131–140. (2013).

36. Delbecq, A. L. & Van de Ven, A. H. A group process model for problem identification and program planning. *J. Appl. Behav. Sci.* **7** (4), 466–492 (1971).
37. Ahmad, A. M. et al. *Masalah Etika Dan Akhlak Pelajar Kemahiran Kejuruteraan: Analisis Keperluan* Vol. 5, p. 34–45 (Jurnal Kurikulum & Pengajaran Asia Pasifik, 2017). 2.
38. Mohd, A. *Nasurdin, Intan Osman & Zainal Ariffin Ahmad.(2006).* Pengantar pengurusan.
39. Pokorny, M. L., Blom, D. H. & Opmeer, C. H. Effects of work and Orcadian rhythm on bus drivers' oral temperature. *Chronobiol. Int.* **5** (4), 425–432 (1988).
40. Mohd Jamil, M. et al. *Pengenalan Asas Kaedah Fuzzy Delphi Dalam Penyelidikan Dan Pembangunan* (Minda Intelek, 2014).
41. Abd Rashid, M. N. et al. Model authentic learning Bagi program Kejuruteraan Politeknik malaysia: Aplikasi interpretive structural modelling. *Malaysian J. Learn. Instruction.* **13** (2), 227–251 (2016).
42. Nurulrabihah, M. N. *Pembangunan Model Pengajaran Pemikiran Reka Bentuk Sekolah rendah/Nurulrabihah Mat Noh* (Universiti Malaya, 2020).
43. Hansen, J. V., McKell, L. J. & Heitger, L. E. ISMS: Computer-aided analysis for design of decision-support systems. *Manage. Sci.* **25** (11), 1069–1081 (1979).
44. Janes, F. Interpretive structural modelling: a methodology for structuring complex issues. *Trans. Inst. Meas. Control.* **10** (3), 145–154 (1988).
45. Murray, T. J., Pipino, L. L. & Van Gigch, J. P. A pilot study of fuzzy set modification of Delphi. *Hum. Syst. Manage.* **5** (1), 76–80 (1985).
46. Jamil, M. R. M. & Noh, N. M. *Kepelbagaian Metodologi Dalam Penyelidikan Reka Bentuk Dan Pembangunan* (Qaisar Prestige Resources, 2020).
47. Cone, C. & Unni, E. Achieving consensus using a modified Delphi technique embedded in lewin's change management model designed to improve faculty satisfaction in a pharmacy school. *Res. Social Administrative Pharm.* **16** (12), 1711–1717 (2020).
48. Yaakob, M. N. *Pembangunan model kurikulum m-pembelajaran kursus teknologi dalam pengajaran dan pembelajaran di institut pendidikan guru.* Unpublished doctoral dissertation, Universiti Utara Malaysia, (2017).
49. Siraj, S., Abdullah, M. R. T. L. & Rozkee, R. M. *Pendekatan Penyelidikan Rekabentuk Dan Pembangunan: Aplikasi Kepada Penyelidikan Pendidikan* (Nur Niaga Sdn. Bhd, 2020).
50. Zhu, M. et al. Evaluating the renewal degree for expressway regeneration projects based on a model integrating the fuzzy Delphi method, the fuzzy AHP method, and the TOPSIS method. *Sustainability* **15** (4), 3769 (2023).
51. Berliner, D. C. Expert teachers: their characteristics, development and accomplishments. *Bull. Sci. Technol. Soc.* **24** (3), 200–212 (2004).
52. Somerville, P. Co-operative identity. *J. Co-Op. Stud.* **40** (1), 5–17 (2007).
53. Gambatese, J. A., Behm, M. & Rajendran, S. Design's role in construction accident causality and prevention: perspectives from an expert panel. *Saf. Sci.* **46** (4), 675–691 (2008).
54. Pill, J. The Delphi method: substance, context, a critique and an annotated bibliography. *Socio-economic Plann. Sci.* **5** (1), 57–71 (1971).
55. Oh, K. H. *Forecasting Through Hierarchical Delphi* (The Ohio State University, 1974).
56. Forza, C. Survey research in operations management: a process-based perspective. *Int. J. Oper. Prod. Manage.* **22** (2), 152–194 (2002).
57. Adler, M. & Ziglio, E. *Gazing into the Oracle: the Delphi Method and its Application To Social Policy and Public Health* (Jessica Kingsley, 1996).
58. Sekaran, U. & Bougie, R. *Research Methods for Business: A Skill Building Approach* (Wiley, 2016).
59. Cheng, C. H. & Lin, Y. Evaluating the best main battle tank using fuzzy decision theory with linguistic criteria evaluation. *Eur. J. Oper. Res.* **142** (1), 174–186 (2002).
60. Chu, H. C. & Hwang, G. J. A Delphi-based approach to developing expert systems with the Cooperation of multiple experts. *Expert Syst. Appl.* **34** (4), 2826–2840 (2008).
61. Murry, J. W. Jr & Hammons, J. O. Delphi: A versatile methodology for conducting qualitative research. *Rev. High. Educ.* **18** (4), 423–436 (1995).
62. Abdullah, M. R. T. L. *Development of activity-based Mlearning Implementation Model for Undergraduate English Language Learning* (University of Malaya (Malaysia), 2014).
63. Moore, S. *China's next act: How sustainability and technology are reshaping China's rise and the World's future* (Oxford University Press, 2022).
64. Kolb, D. A., Boyatzis, R. E. & Mainemelis, C. *Experiential Learning Theory: Previous Research and New directions, in Perspectives on thinking, Learning, and Cognitive Styles* p. 227–247 (Routledge, 2014).
65. Schenck, J. & Cruickshank, J. Evolving kolb: experiential education in the age of neuroscience. *J. Experiential Educ.* **38** (1), 73–95 (2015).
66. Wang, C. et al. Association between medical students' prior experiences and perceptions of formal online education developed in response to COVID-19: a cross-sectional study in China. *BMJ open.* **10** (10), e041886 (2020).
67. Wang, W. Medical education in china: progress in the past 70 years and a vision for the future. *BMC Med. Educ.* **21** (1), 453 (2021).
68. Brown, T. *Change by design: How design thinking creates new alternatives for business and society (Go seong yeon, Trans.).* KimYoungsa.(Original work published), 70–93. (2009).

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Declarations

Competing interests

The authors declare no competing interests.

Additional information

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