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Bridging Knowledge and Practice: A Five-Year Assessment of an Innovative Entrepreneurship Education Program with a Focus on Medical Education Curriculum

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Abstract

Conventional, teacher-centered education has traditionally been employed to address students' educational needs by delivering essential knowledge. However, there has been a growing trend towards more innovative teaching methods, such as project-based and student-centered education. This study aimed to develop and assess a project-based, student-centered approach to teaching entrepreneurship and creativity.
This quasi-experimental study in education involved 450 medical students over a five-year period (2019-2023) who enrolled in a creativity course as an optional non-core component of the medical education curriculum. The course was structured into three segments: fundamentals of creativity and models, database searching, proposal writing, reference management, and the conversion of ideas into entrepreneurial plans and projects. The study continued with project-based learning in the creativity course and collected data through open-ended student feedback via WhatsApp regarding the educational method, its impact on student learning, related indicators, and any disadvantages associated with it. Students' scores were compiled in three stages, with a maximum final score of 20. The mean score for students in this course was 17.34 ± 1.54, indicating the achievement of learning objectives. Additionally, approximately 10 to 15 research projects were produced for every 100 students, resulting in team-authored scientific articles published in reputable journals. A content analysis of open-ended questions identified four dimensions of the educational intervention's impact: personal development, team learning potential, active research skills, and teaching characteristics. However, challenges included the need for additional time, high expectations, the requirement for a continuous process, and the availability of research resources. Project-based and student-centered teaching, along with a constructivist approach in medical sciences courses, are crucial strategies in education. Teachers in the field of medical sciences can utilize these methods to improve their teaching practices.

Keywords: Project-based teaching, Medical sciences, Teaching, Learning, Active learning, Creativity

Introduction

Traditional, teacher-centered education can effectively address students' educational needs by delivering essential knowledge. However, this approach often neglects the importance of students' active participation in their learning, the impact of teaching on learning outcomes, the practical application of acquired knowledge in professional settings, and its relevance to societal needs (1-3).

In today's world, where there is a vast amount of information available, education faces a significant challenge. As a result, the primary emphasis of many training courses tends to focus on knowledge acquisition (4).

Medical education is a complex process that integrates both theoretical and clinical elements. Enhancing educational productivity is crucial to achieve successful and effective education while keeping up with the dynamic advancements in both quantitative and qualitative aspects of medical sciences (5). Research findings have highlighted uncertainties regarding the roles of educators and instructors, as well as deficiencies in educational settings. Furthermore, there is a notable gap between clinical situations and theoretical principles, which can impact the quality and desirability of care services (6-8).

Project-based learning is an active learning approach that prioritizes learners' engagement and is viewed through a constructivist lens. This method promotes critical thinking, teamwork, creativity, and the development of problem-solving skills, making it a fundamental strategy in modern educational systems (9).

One potential issue with teacher-centered courses is the limited development of scientific skills among students. To keep up with the constantly evolving field of science and adapt to changing curricula, it is imperative to implement strategies that encourage student engagement in the learning process, offer opportunities for skills building, and foster meaningful learning experiences. This is particularly important for modern universities that are heavily influenced by technology, as it allows for the efficient utilization of existing knowledge and prepares students for its practical application.

Materials and Methods

Design and Setting

This study is a quasi-experimental study conducted in the field of education. As part of an educational reform in all medical courses, a course on creativity and entrepreneurship was offered as an optional subject in the new curriculum for general medicine courses from 2019-2023 (see Figures 1- 4).

Tools/Instruments

The curriculum for the course was divided into three parts, which were taught through team teaching. The first part covered creativity concepts, including models and decision-making. The second part focused on how to search databases, proposal writing, and reference management. The final part of the course involved transforming ideas into entrepreneurial plans and projects. During the first part of the course, students were required to turn a creative idea into a project by designing models, developing reasons, reviewing articles, and designing a business canvas. In the second part of the course, the review of the plan continued with the writing of the proposal. The students and professors then continued with implementation. Some of the best-developed proposals were submitted to journals or patented in the local Intellectual Property Registration Center. The projects that could be developed with the feedback and activities of the group were referred to the relevant professor for further continuation, promotion, and publication. The process was then followed up in the next semester (Figure 1-4).

Participants and Sampling

The study involved a total of 450 medical students who took the creativity course. The participants were sampled from all students who

took the course over five consecutive years. The proposed lesson plan focused on a theoretical curriculum to introduce students to the fundamentals of creativity and entrepreneurship.

Data Collection Methods

The study involved a change in the teaching approach for the creativity course. The change involved shifting from a theory-based course to a project-based, team-oriented, and performance-oriented course. Data was collected through open-ended questions about the educational method, its impact on student learning and related indicators, and any disadvantages associated with the method. Students who agreed to participate in the study were asked to send their responses via WhatsApp groups. The sampling method was purposeful, and 6-7 individuals from each group who had submitted the most complete response were included in the study. The responses were then analyzed after reaching data saturation in each group. The content analysis method was commonly used for data analysis. The information was validated by peer review, and codes, themes, and sub-themes were selected by agreement(member check, peer check). In presenting the data analysis, efforts were made to maintain objectivity, and every statement made was considered without personal interpretation. Furthermore, confidentiality was maintained during the data extraction process, and the participating students were thanked for their valuable contribution.

Stages of Content Analysis:

- Articulate Research Question: Define what to investigate.
- Select Relevant Material: Choose texts, images, or documents for analysis.
- Develop Coding Framework: Outline categories and themes (deductive or inductive).
- Apply Coding Scheme: Systematically identify and tag data segments.
- Analyze Data: Look for patterns and relationships using quantitative or qualitative methods.
- Interpret Findings: Draw conclusions related to the research question.

Data Analysis

The data was analyzed using content analysis of open questions. Meaning codes were identified through repetition and expression, then investigated for similarity in meaning. The codes were categorized into four dimensions. From this analysis, focus should be placed on the codes "Improved Skills" and "Engaging Experience" as they have the highest frequency and percentage, indicating they are key themes in participants' experiences. The steps are as follows:

- Select and analyze meaning codes from open-ended questions with high frequency and percentage.
-Data Collection: Gather responses to open-ended questions in each entry group.
- Coding: Review the responses and identify recurring themes or concepts. Assign meaning codes to these themes.
- Frequency Analysis: Count how often each code appears in the responses.
- Percentage Calculation: Calculate the percentage of each code relative to the total number of responses.
- Selection: Select the codes with the highest frequency and percentage for further analysis or reporting.
- Select all meaning codes with high frequency and percentage.

Results

During this training, various aspects of creativity and entrepreneurship were covered, which can be applied in different fields. The first part of the training aimed to enhance students' knowledge of creativity and provide them with current topics related to this subject. The content covered included the concept of creativity, search strategies in Google Patent, US Patent, and Lens website. All students were required to submit a group idea and upload their assignment in the LMS.

Dear students

In the initial phase of this study, participants were tasked with forming teams comprising two to three members and collectively reviewing their ideas. Drawing from the teaching materials on creativity models, participants were guided to assess the creativity of their ideas and officially register them in patent registration systems. Following a thorough examination of the viability of their proposed concepts, participants were mandated to craft a comprehensive business plan encompassing all essential components. Upon approval of the team's idea, it was then uploaded to the team's LMS (Learning Management System) account. Moreover, participants were directed to evaluate their ideas utilizing the Six Thinking Hats technique to facilitate creative decision making.

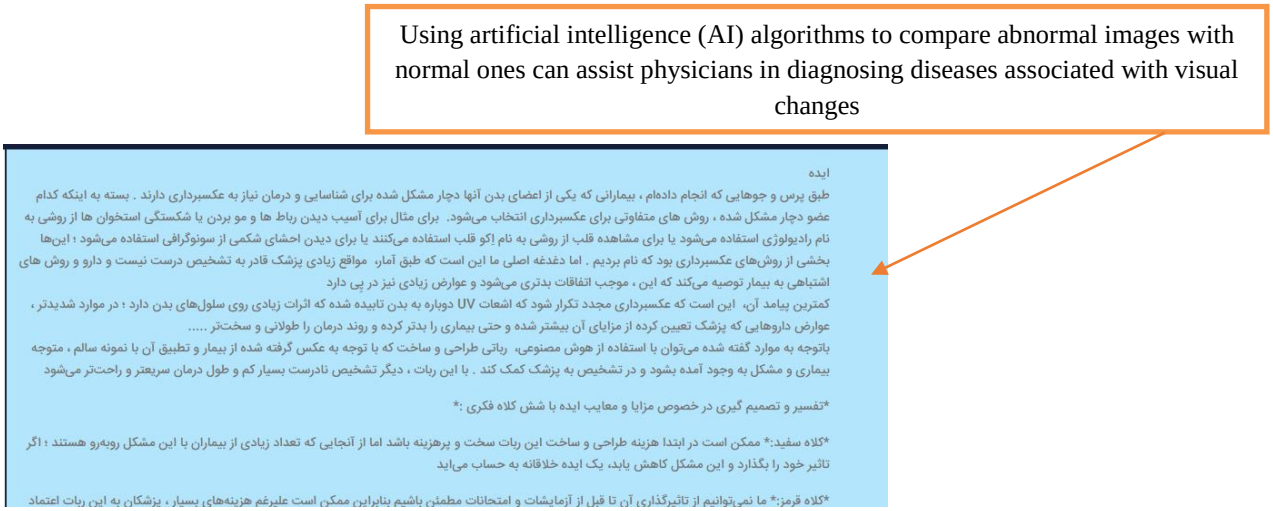

Figure 1. Sample of teamwork uploaded task in LMS

The creativity and novelty of the ideas presented were assessed, with a score of 6.6/20 allocated for this section. The ideas proposed were required to be unique, practical, and solve a problem or fulfill a need in the field of health and medicine. The mean score of students in this section was (4.49 ± 1.35), indicating the need for improvement in their learning objectives.

The second part focused on developing analytical and critical thinking skills in the context of team ideation. Brainstorming techniques were employed in the development of ideas, with the proposal written at this stage forming the basis of the group score. The mean score of students in the team activity was (5.14 ± 1.3)(scored from 6.8/20).

The third part aimed to strengthen project-oriented teamwork and creative thinking to achieve the desired results. Rethinking ideas and analysis resulted in action research work. Several creative projects were developed by students that were based on the needs of society and scientific thinking.

Some of these projects were promoted and registered in the University Patent Committee and Intellectual Property Registration Center, with a score of 6.6/20 allocated for this section. Final scores were calculated by adding scores from all three sections, with a maximum score of 20. The mean score of students in this course was 17.34 ± 1.54. Approximately 10-15 research projects were written for every 100 students, resulting in team scientific articles being published in reputable journals. The title of ideation and a sample list of ideas are presented in Tables 1 and 2, respectively. Data, idea, and production titles are finalized: The analysis of themes in students' open questions is presented in Table 3. The excluded themes and subthemes are categorized in Table 3. Finally, Table 4

displays the disadvantages of the educational program according to students' feedback.

ایده: استفاده از هوش مصنوعی برای تشخیص و گزارش اختلالات آناتومیک

استاد مربوطه:

نام اعضای (دانشجویان پزشکی ورودی بهمن ۹۹)

بخش های مشتری: مراکز درمانی سرمایه گذارها رادیولوژیست ها متخصصین ارتوپد و سایر رشته ها	ارتباط با مشتری: وبسایت، شبکه های اجتماعی، مراکز درمانی خاص کانال ها: سایت ها، شبکه های اجتماعی، فروشگاه های اینترنتی	ارزش پیشنهادی: بهتر کردن شرایط سلامت مردم، صرفه جویی در وقت پزشک و بیمار، تشخیص دقیق، راحت و کاربردی تر	فعالیت های کلیدی: طراحی و تولید محصول، برنامه نویسی پیشرفته، پشتیبانی و حمایت مالی منابع کلیدی: نمایندگی های توضیع، پزشکان و متخصصین، متخصصین نرم افزار و سخت افزار	شرکای کلیدی: حامیان مالی، مراکز درمانی، تیم پزشکان متخصص، تیم رادیولوژیست ها، تیم متخصصین کامپیوتر، داوطلبین
جریان های درآمدی: طراحی و فروش دستگاه هایی که قادر به تشخیص و گزارش اختلالات آناتومیک بدن هستند			ساختار هزینه: هزینه ساخت تجهیزات سخت افزاری، هزینه برنامه نویسی و ساخت پلتفورم های نرم افزاری، هزینه شرکت سازنده سخت افزار، هزینه تیم برنامه نویسی، هزینه تیم پزشکی	

Figure 2. Sample of business plan: Anatomical Disorder Detection Device in Radiology Department

Table 1. Students' ideas and production dimensions

Health problems (medical, rehabilitation, prevention)
Improving quality of life (tools, infrastructures, instruments)
Technology (education, website)
Translational medicine (Nanobiotechnology, Cancer and gene therapy, nano biosensor, nanomedicine)
Common issues (aging tools, etc.)

Discussion

Therefore, students must achieve their learning objectives and acquire the necessary knowledge in education. A content analysis of open questions extracted four dimensions of the effects of educational intervention, including personal development, team learning potential, active researchers' skills, and teaching characteristics. In a study conducted at Oman Health School, 62 students in the experimental group and 28 students in the control group were studied for two months. The results indicated that the project had a significant impact on the students' knowledge and attitude. The students' projects led to the creation of beautiful events, such as film production, student ambushes, and various exhibitions (10). A recent study showed

that the mean final score of students was acceptable in terms of knowledge level. In a systematic review study, project-based learning was investigated. The results showed that technology played a crucial role in carrying out projects, group processes, and striking a balance between traditional and general education with deep learning.

Figure 3. Sample of business plan: Production of Nano Arsenic for the Treatment of leukemia

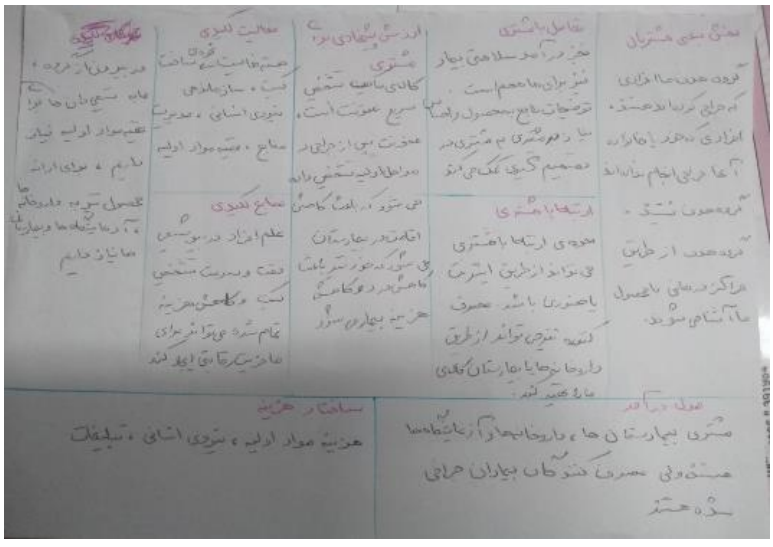

Figure 4. Sampling of Handwritten Designed Business Sample by One of the Teams

Table 2. Sample of innovative project ideas.

Ointment production for the treatment of deeper burns and wounds based on vitamins C and E
Production of probiotic bacteria for the treatment of colon cancer
Cancer detection using carbon-14-labeled glucose.
Design, production, and evaluation of a combined antibiotic cephalosporin and Flavophospholipol for the control of Salmonella typhi
Production of nanomedicine to inhibit atherosclerosis by the controlling monocytes
Production of a cell vaccine containing IL-7 and HER-2 carrier plasmid for the treatment of metastatic breast cancer patients
Production of hydrolytic blood coagulant gel based on plant polymers derived from seaweed for bleeding control
Production of folic acid and copper oxide nanoparticles for breast cancer treatment
Cell therapy for type 1 diabetes
Production and use of diagnostic kits impregnated with nanoparticles for early diagnosis of surgical wound infection
Arsenic nanoparticle production for leukemia treatment
Production of enriched juice to prevent stomach cancer
Using probiotic technology to increase the shelf life of cheese
Smart application for cleaning radiological photos
Smart application of psychological counseling
Smart table for the elderly
Smart teaching of embryology lessons with augmented reality technology
Smart box of daily medicines for high-risk patients
A tool for dividing tablets based on the drug label
Smartwatch for sensitive condition alarms
Neurosurgery smart knife
Automatic toothbrush and toothpaste for children
Smart sensor for tracking elderly people with Alzheimer's
Warning mask for acute diseases
Paper towels that destroy the virus

Table 3. Theme analysis of students' open questions with a high percentage of responses

Personal development characteristics	**team learning potentiality**	**Active researchers' skills**	**Teaching characteristics**
subthemes and meaning codes			
Creativity • Creative Thinking • Creativity in scientific writing • Creativity in scientific thinking • Creativity and innovation at work • Development of creative projects • Finding careers for the future	• teamwork • Trust in the team • Accepting the opinions of others • Team coordination in affairs • Individual analysis of the thinking process in the team • Team think tank • Scientific synergy • Instilling competence	• Thesis writing • A central goal in scientific work • Promotion of scientific information • Proposal writing skills • Scientific project • Update information • Facing the scientific learning environment • Using scientific projects	• Teaching efficiency • Applicability of education • Putting theory into practice • Promote teamwork • Use of learning in practice • Promote learning in the mind • Professional doctor • The hearty

• Promoting learning through comparison • Ability to make mental assumptions • Creative projects • Learning from threats • Creating opportunities to learn about problems • Project exercise • Creative thinking practice • Innovative and creative ideas • A new look at common topics • A clear view of affairs • A practical method of creative thinking • The ability to deal with the depth of topics • Creative ideas in existing theories **Problem-solving skills** • Deep learning • Promoting learning from medical science • Facing the educational-scientific environment • Promotion of physician learning • A broad view of affairs • Let's talk about topics • Create a context for the analysis of topics • Promotion of high-level thinking • You remember with learning • New window to solve problems • Desire to learn • Problem-solving methods • Scientific approach to the problems • Problem-solving methods • Ability to solve problems • Acquaintance with existing weaknesses	in the team • Team application of topics • Teaching the dynamics of teamwork • Familiarity with the team project • Strengthening the expression technique in the group	• Discovery in science • The cab of pure experiences • Non-normalization of problems • Clear and extensive learning • Learning practical skills • Information leap • Introduction of reliable research sites • Acquaintance with a knowledge-based ecosystem • Facing the logical project of need • Trying to meet needs scientifically • Attention to deficiencies • Acquaintance step-by-step • knowledge management • Sustainable scientific methodology • Improving visibility to affairs • Search for new content • Rent in the future • A non-commercial view of medicine • Development of basic knowledge • Pivotal production • Searching for effective treatment methods • Effective solutions and removing restrictions • Search for existing deficiencies • Thesis writing **Evidence-based skills** • How to get a profit- • The sites for selling drugs and related companies • Active search • Familiarity with search in a scientific search engine • Familiarity with the	understanding of his knowledge and central research • Promote enthusiasm for learning • A new attitude to science • Holistic education • Gaining new abilities • Turning ideas into action • Gaining self-esteem

• Existence of related assignments • Permanent scientific method • Entrepreneurial ideation **Critical thinking skills** • Critical understanding of scientific topics • A comprehensive view of topics • A broad view of needs and problems • Analysis of resources and problems • Promoting individual growth of the critic • Explore different topics • New window to topics • The art of right thinking		efficiency of sites • Preparation for great realizations • Awareness of up-to-date information • Familiarity with scientific software • Future research in medicine • Analysis of diseases • Discovering causes with evidence	

Table 4. Disadvantages of the educational program from the student's perspective

Failure to continue in the following years
The need to continue working: Some students found it challenging to balance their work commitments with the demands of the training program, which affected their ability to fully engage in the course.
Lack of time: Some students felt that there was not enough time to complete all the coursework and assignments, which created stress and anxiety.
The need for more practical work: Some students felt that the training program focused too much on theory and not enough on practical applications, which limited their ability to apply what they learned.
Not showing previous works: Some students felt that they were not given enough opportunities to showcase their previous work or experiences, which limited their ability to contribute fully to the program.
The need for more targeting: Some students felt that the training program was too broad and lacked focus, which made it challenging for them to identify specific areas of interest to pursue.
Lack of practical realizations: Some students felt that the training program did not provide enough opportunities for them to implement their ideas in real-life situations, limiting their ability to see the practical value of what they were learning.
Need more exposure: Some students felt that they needed more exposure to different fields and industries to fully appreciate the relevance of the training program.
Need time to develop: Some students felt that they needed more time to develop their ideas and projects, which limited their ability to fully realize their potential.
Being medically oriented: Some students felt that the training program was too focused on medical applications, limiting their ability to explore other areas of interest.
Need for more feedback: Some students felt that they needed more feedback and guidance from instructors to help them improve their work and achieve better outcomes.
Lack of research facilities: Some students felt that the lack of research facilities and resources limited their ability to fully explore their ideas and projects.
Volume and high level of assignments and work: Some students found the volume and level of coursework and assignments to be overwhelming, affecting their ability to fully engage and achieve their learning objectives.

Support and guidance, along with creating scaffolding for students, were also identified as important factors (11). This suggests that project-based learning can be an effective way to enhance students' learning outcomes.

A recent study confirmed the impact of educational intervention on team processes, innovation in teaching, and the promotion of personal skills. Another study examined the effect of educational projects on the self-regulation of engineering students in robotic systems control. The results indicated that the project had a positive effect on improving students' self-regulation skills (12). These findings indicate that educational interventions, like project-based learning, can assist students in developing crucial skills, such as self-regulation and teamwork, which can be beneficial for their future careers.

The promotion of innovative thinking, problem-solving skills, and critical thinking was identified as a significant subtheme within personal skills. Additionally, self-regulation skills were found to be related to these skills.

In a separate study, an interdisciplinary project was conducted for 40 Taiwanese girls in their final year of high school. The study indicated that the project had the potential to connect theoretical knowledge with practical applications. Additionally, the study emphasized the impact of the interdisciplinary project on the development of professors in integrating interprofessional learning effects of educational interventions on academic achievements (13).

In another report, a three-year project-based program was introduced for first-year students studying industrial engineering at a university in Portugal. The findings indicated that the program had a beneficial impact on meaningful learning and contributed to student motivation. The significance of the professor-student relationship was highlighted as a crucial element in the educational benefits of the program (14). These results imply that project-based learning can effectively enhance meaningful learning and student motivation, especially when there is a strong relationship between the professor and the student.

In another project-oriented study conducted in the engineering department, visual tasks were utilized to teach and comprehend course concepts. The students' understanding levels were assessed using this method. The study revealed that the project was more successful among girls than boys, with girls showing higher levels of motivation and interest during the project (15).

A recent study highlighted the importance of promoting personal skills, such as problem-solving and critical thinking, through project-based learning. Additionally, the study identified deep learning and innovative thinking as crucial factors.

Another study investigated the impact of project-based learning on English language learning. The study found that this approach had a significant effect on academic abilities, self-management, teamwork skills, and language skills. However, cognitive approaches were not found to be related to this approach (16). A study was conducted on second-year medical students as part of a 6-year project aimed at investigating the impact of project-based learning on students' communication skills. The results showed that while the overall level of empathy did not change, the students' average scores increased compared to before. The students believed that the project was effective in improving their skills (17).

The studies mentioned above confirm that project-based learning can be effective in promoting personal skills, language skills, and communication skills. The use of visual tasks, promoting deep learning, and innovative thinking can enhance the effectiveness of project-based learning. These findings are consistent with recent results and student perspectives on the effectiveness of educational programs.

A study was conducted to outline a 6-step creativity project for two groups of Chinese and international students. The project was delivered as a workshop program, and students were

examined through quantitative methods and focus groups. The study revealed that the project had a notable influence on both groups, enhancing their comprehension of idea generation and innovation,. One group excelled in mastering the content and forming a scientific group network (18).

Constructivist theories have been found to play an important role in promoting students' learning by increasing their participation in the learning process. This has been investigated and discussed in numerous studies. The use of constructivist teachings, along with the inclusion of a group project, is effective in promoting learning (19).

The effectiveness of team-based learning in improving students' knowledge, attitude, and skills has been demonstrated in numerous studies (20-24). These findings suggest that project-based learning and team-based learning can be effective approaches for enhancing students' learning outcomes.

These results confirmed the effect of team-based learning on knowledge and learning outcomes in a recent study.

Project-based learning has a significant impact on students, influencing not only their academic performance but also their emotional outlook, values, and various cognitive abilities. It helps develop key literacies and enhance advanced thinking skills. Students learn basic principles and tackle important issues through collaborating in small teams on practical problems. This approach boosts innovation, improves critical thinking skills, and hones practical abilities. Essentially, project-based learning is crucial for fostering students' abilities and preparing them for achievement in an ever-evolving world (25-28).

These studies and evidence confirm the impact of implementing educational projects in bridging the gap between theoretical concepts and practical applications, as well as promoting teamwork strategies in peer education. They also validate the four positive outcomes outlined in the qualitative section of the present study.

Conclusion

Based on the project-oriented nature of the studies mentioned above and the opportunities they provide to transform theory-based courses into project-based courses using a constructivist approach, it is recommended to utilize this approach in educational settings. The studies highlight the important role of student involvement in learning through practical experience and the significance of interdisciplinary teamwork in enhancing learning outcomes, especially in the field of medical sciences. Therefore, integrating project-based learning and interdisciplinary teamwork can create a dynamic learning environment and significantly influence students' learning outcomes.

Declarations

Acknowledgment

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Ethical consideration

All students consent to participate in the study and respond to open questions in groups.

Author Contribution

LM conceived, designed research, performed experiments, and analyzed data, also prepared the final draft of the paper; SEM and MA, and MK

interpreted results of the experiments; prepared figures and drafted the manuscript; all approved the final version of the manuscript.

Competing Interests

The authors declare no competing interests

Data Availability

The datasets generated for the current study are not publicly available, but are available from the corresponding author on reasonable request

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