Research on the Teaching Mode of Digital Innovation and Entrepreneurship Education Based on PBL

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ABSTRACT

Based on the theory of Problem-Based Learning (PBL), this study designed a hybrid PBL teaching framework of "online + offline" through literature research and empirical analysis. Taking "E-commerce B" course of Huaxin College of Hebei University of Geo sciences as the experimental carrier, the study uses questionnaire research combined with practical platforms such as "Internet+" Innovation and Entrepreneurship Competition to verify the teaching effect. The results show that the digital teaching mode based on PBL can significantly improve students' independent learning ability, teamwork ability and innovation and practice ability, and at the same time optimize the teacher-student interaction, so that the teacher changes from a knowledge transmitter to a learning guide. The innovation of this study is the deep integration of PBL with digital tools (e.g. Pair of points easy platform, virtual simulation system, etc.), constructing a closed-loop teaching process of "problem-driven-teamwork-practice verification-competition test", which provides a generalizable digital solution for innovation and entrepreneurship education in colleges and universities.

1.Introduction

With the rapid development of big data, cloud computing, AI (Artificial Intelligence), 3D printing, VR/AR and other digital technologies, "Internet+" has expanded to all walks of life, and people's lifestyles have begun to shift to digitalization, and education, as an important part of the social organization, is also integrating digital technologies to improve the quality of education and accelerate the sharing of educational resources. Education, as an important part of social organization, is also integrating digital technology to improve the quality of education and accelerate the sharing of educational resources, playing an important role in the construction of "Digital China". According to the model of individual development in the social-ecological system theory proposed by the famous psychologist Bronfenbrenner, it is emphasized that the development of the individual is nested in a series of environmental systems that interact with each other, the system interacts with the individual and influences the development of the individual, and the consistency of the school and the family in the second environmental level of the intermediary system for the education of the individual,and so on. Therefore, how to integrate digital technology and innovation and entrepreneurship education in colleges and universities and promote each other has become the focus and difficulty of constructing innovation and entrepreneurship education ecosystem in colleges and universities.

The rise of modern digital technology has pushed the teaching mode of colleges and universities to change from traditional teaching mode to digital teaching mode, deriving new teaching modes of precision, scenario, collaboration and hybridization. The digital business scene mode is necessary for the development of the times, which is also precisely what is lacking in the traditional entrepreneurship education mode in colleges and universities.The traditional entrepreneurshi-

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p education model lacks the content to solve the digital management problem, and it is urgent to build a professional practice teaching platform that integrates theory and industry with the existing digital technology and visual data analysis tools. The development of innovation and entrepreneurship education needs to be combined with the existing digital technology to make positive changes, so that it can "empower youth innovation and development with the power of digital technology". At this stage, innovation and entrepreneurship education in China's colleges and universities is a n important part of the educational work of colleges and universities, and innovation and entrepreneurship education ha s been put forward for more than 20 years, scholars have carried out research from different disciplinary perspectives, which has been very fruitful. Among them, the introduction of PBL teaching mode provides an effective guarantee for the teaching means of innovation and entrepreneurship education, and the PBL teaching mode, which aims to cultivate stud ents' ability to discover, analyze and solve problems, coincides with the educational objectives of innovation and entrepr eneurship education and professional courses. How to use PBL teaching mode to integrate the concept of innovation and entrepreneurship education into the teaching of professional courses is worthy of in-depth research and discussion.

PBL (Project based learning) project teaching mode was first proposed by Barrows, a professor of psychiatry in the United States, in the 1960s, and it was firstly a practical and richer teaching method in the field of medical education. Due to the problem of disconnection between theory and practice in the medical field, in order to better enable theory to guide practice and help more scholars to gain experience in project operation, the project-based teaching method of creating an effective context is proposed, which seeks to solve the problem of insufficient practical ability of many scholars. The traditional teaching mode emphasizes the independence and completeness of each discipline, and pays more attention to the theories established by the predecessors and their methods of teaching, but often ignores the relevance of each discipline and the curriculum system; while the PBL teaching mode is characterized by the promotion of the theory and knowledge of the relevant disciplines, and the problem-oriented drive of the students to actively think, the students in the real situation on the drive to explore the problem, and to play a cross-disciplinary, inter-disciplinary and inter-professional characteristics to develop problem-solving skills. In the field of education and teaching, scholars have focused on the integration of PBL and traditional teaching, and developed a series of PBL teaching models for a certain course or practical activities.

This study focuses on focusing on the digital teaching model based on PBL in innovation and entrepreneurship education project teaching by guiding students to select a meaningful project and complete the project plan in a teamwork way, the core of which is project-driven, and the design further embodies the constructivist "do-it-yourself le arning" and the idea of blended learning, and the implementation of the project is always through the "problem-driven-problem-solving-results communication" as a main line of thought. The design further embodies the constructivist idea of "learning by doing" and blended learning, and in the implementation of the project, the idea of "problem-driven-pro blem-solving-results exchange" is always running through the main line of thought. This paper applies the PBL teaching mode to the teaching of digital innovation and entrepreneurship education, and explores the feasibility and teaching val ue of PBL teaching in the teaching mode of digital innovation and entrepreneurship education through a questionnaire s urvey, so as to provide reference for the curriculum reform of innovation and entrepreneurship education.

2 Literature review

Project Based Learning (abbreviated as PBL) originated in the 16th century in Italian university teaching and gained attention in the 20th century from educational institutions in the United States and Europe [1]. This form of learning involves students completing one or more tasks in a project (or group) format, followed by reflection on their work. Internationally, PBL is also referred to as topic-based learning, program-based learning, or subject-based learning [2]. The model's earliest theoretical foundations can be traced back to Kilpatrick ' s The Project Method, which proposed that teaching activities should center on students' interests, integrating all subjects around their core curiosities [3]. Kilpatri ck emphasized that teachers should focus on stimulating students' curiosity and guiding them toward new areas of think ing [4]. Dewey (1933) further reinforced this approach, advocating for experiential and inquiry-based learning as essenti al components of education [5].

Orfiz-Medina pointed out in the article "Assessing an entrepreneurship education project in engineering studies by means of participatory techniques" that entrepreneurship is of great significance to students. He proposed that "the intensity and enthusiasm of entrepreneurship education can cultivate the professionalism and enthusiasm of students and faculty members to a certain extent, motivate them to meet new challenges, and recommend training based on real learning, alumni participation and teamwork to promote innovation and entrepreneurship education [6]". From this, it can be seen that the team entrepreneurship project learning method in a real situation has certain advantages for innovation and entrepreneurship education. In addition, Arpiainen, Riitta-Liisa et al. not only emphasized in the article " Introducing Team Learning in a Developing Economy:Students ' Experiences of Experiential Entrepreneurship Education in Namibia" that entrepreneurship is the driving force of economic development in various countries,but also

his research on entrepreneurship education is based on the starting point of teamwork and project exploration[7]. Based on the research purpose of investigating students' entrepreneurial education experiences in developing economies, especially their experiences of team learning and teamwork learning, it is not difficult to see that team culture and project learning are also closely related to entrepreneurial education.

In the field of education and teaching, many researchers have focused on the integration of PBL and traditional teaching. Many teachers define PBL as an "activity" that simply combines theory with practice—after teaching a knowled ge point, the instructor designs a small task to allow students to verify the theory through hands-on application[8].Howe ver, this approach remains fundamentally teacher-centered [9]. This article argues that true PBL teaching is student-cent ered, where learners acquire knowledge and skills through sustained exploration of complex problems over an extended period [10]. Its goal is to cultivate students ' mastery of core knowledge, critical thinking, problem-solving, teamwork, a nd self-management skills [11].

The PBL teaching model plays a vital role in the integration of innovation and entrepreneurship education and professional education in colleges and universities. Its main manifestation can be verified in the following two aspects [12,13]. First, it is reflected in innovation and entrepreneurship education. The educational concept of the PBL teaching model is to take students as the main body, teachers as the key, and problem-oriented. This educational concept can fully exert the subjective initiative of students in learning and significantly improve their learning interest. As an important part of the quality education system of colleges and universities, innovation and entrepreneurship education aims to cultivate students' innovation and entrepreneurship awareness and thinking, strengthen students' innovation and entrepreneurship capabilities and levels, and stimulate students' innovation and entrepreneurship passion. Secondly, it is reflected in professional education. In the process of professional course education and teaching practice in colleges and universities, the PBL teaching model is adopted, and students can cultivate innovative thinking and improve their innovation ability in the process of learning. At present, the teaching content of professional courses in colleges and universities is generally boring, and students generally lack passion in the process of learning. The PBL teaching model allows students to participate in professional course learning under the problem-oriented drive, gradually complete the learning tasks of raising questions, self-learning, collaborative discussion, and problem solving, and exercise innovative thinking methods to solve problems. At the same time, successfully solving the raised problems will give students a full sense of accomplishment, which can easily inspire students' enthusiasm for participating in learning practice and make students have a strong interest in the study and research of professional courses.

The advantages of digital PBL in innovation and entrepreneurship education are mainly reflected in three aspects. First, as Savery (2006) emphasizes in defining PBL's core characteristics, real problem situations can stimulate students' intrinsic interest in learning and improve their active participation by situating knowledge acquisition in authentic contexts [14]. Second, the model's emphasis on teamwork and autonomous learning aligns with Hmelo-Silver's (2004) findings on PBL's cognitive outcomes, demonstrating its effectiveness in cultivating students' multidimensional competencies including critical thinking, innovation ability, and business acumen through sustained problem exploration [15]. Finally, building on Bates' (2019) framework for technology-enhanced learning, the integration of digital tools creates flexible learning ecosystems where students can access just-in-time online resources and refine skills through iterative virtual simulations, significantly improving learning efficiency [16].

In formal education, when mentioning the overall design of the PBL teaching model, Gao Zhijun et al. innovatively summarized the seven typical learning strategies and methods of the PBL teaching model based on the original five learning characteristics as the teaching guidance of project-based learning activities in "The Application of Project-Based Learning (PBL) Model in Teaching" [17]. When designing teaching for a specific subject, Jiang Naijun proposed four guiding references in "Exploration of Project-Based Learning Methods in Information Technology Teaching": cultivating interests and discovering interests; unity and cooperation, democratic consultation: learning to use and serving the community; active exploration and independent innovation [18]. In addition, some researchers, such as Ma Hongliang, Zheng Xiaoli, Ren Yingjie, Wang Xinfa, etc., have put forward insights on the network environment and network team building of project-based learning [19-22]. Combined with the analysis of the literature, it can be seen that PBL has attracted much attention from researchers in recent years, from the guidance of the application model of project-based learning in teaching to the application of project-based learning theory to the research of specific subjects.

Unlike previous scholarly studies that applied PBL to teaching mode and talent cultivation, there are few studies that combine digital technology to integrate innovation and entrepreneurship education elements into professional courses and conduct them in the form of experiments to do data analysis, which can be said to be the key innovation point of this study. The teaching activities carried out in this study using the PBL model emphasize the cultivation of students' higher-order thinking skills such as independent learning, teamwork, integrated practice, and innovative thinking. Informatized teaching with the support of information technology tools can accelerate the establishment of a sound innovation and entrepreneurship education system in colleges and universities towards digitalization through technological means and tools, adapting to the multiple and complex needs of teachers and students.

3 Materials and Methods

3.1 Questionnaire design

The research object of the course "E-commerce B" taught in Huaxin College of Hebei University of Geosciences, 22 Business Administration 1-2 classes, 22 Logistics Management 1 class, 22 Information Management and Information Sys tem 1 class and 22 Administrative Management 1 class totaling 138 students, with the overall research object as the exp erimental sample, this chapter adopts the questionnaire survey method, using the questionnaire star survey tool for the higher education in the use of the PBL teaching mode to carry out the classroom teaching in higher education using PBL teaching mode, aiming to understand the student learning situation and provide a reference basis for subsequent resear ch.

The questionnaire was distributed in a combination of offline and online methods. Of the 138 questionnaires distributed with Likert scale, 116 were returned, with a recovery rate of 84%, totaling 116 valid questionnaires. Subsequently, SPSS statistical software was used to carry out basic data checking, and descriptive statistical analysis was done on the reliability, validity of the whole questionnaire and the content reflected by the survey.

3.2 Tables

According to the data in the Table 1, this study conducted a reliability analysis on the digital PBL innovation and entrepreneurship course scale, and the results showed that Cronbach's α coefficient was 0.731 (sample size N=116). This result shows that the measurement tool has acceptable internal consistency reliability. Specifically, the α coefficient is between 0.7-0.8, which meets the basic requirements for scale reliability in social science research (the minimum standard recommended by Nunnally is 0.7), indicating that the measurement items have good homogeneity and can stably measure the same latent concept.

Table 1: Reliability Analysis

Sample size	Cronbach. coefficient
116	0.731

The results of the Table 2 show that the measurement tool of the digital PBL innovation and entrepreneurship course has basically acceptable construct validity, but there is still room for improvement. From the perspective of factor loading, except for the "digital tool combination" item (0.44), the factor loadings of the other three items are between 0. 81 and 0.83, which are significantly higher than the standard threshold of 0.7, indicating that these items can measure the latent constructs well. The commonality analysis shows that the variance explanation rate of the last three items exceeds 65%, but the commonality of the digital tool combination item is only 0.194, which has weak explanatory power. The total variance explanation rate is 55.51%, which does not reach the ideal level of 60%, but is acceptable in social science research. The KMO value of 0.688 is close to the medium standard, and the Bartlett sphericity test result is significant, indicating that the data is suitable for factor analysis. It is worth noting that the current analysis forces the extraction of a single factor to mask the potential multidimensional structure, especially the use of digital tools and course effect evaluation belong to different dimensions.

Table 2: Validity Analysis

Item	Factor 1	Commonality
Does the PBL innovation and entrepreneurship course you are participating in combine digital tools (such as online collaboration platforms, AI analysis tools, etc.)?	0.44	0.194
How satisfied are you with the PBL Digital Innovation and Entrepreneurship course overall?	0.81	0.651
Do you think the PBL teaching model is helpful to improve your innovation and entrepreneurship ability?	0.83	0.688

Are you willing to continue to participate in or recommend others to participate in the PBL Digital Innovation and Entrepreneurship Course?	0.83	0.687
Eigenvalue (before rotation)	2.22	-
Variance explained% (before rotation)	55.51%	-
Cumulative variance explained% (before rotation)	55.51%	-
Eigenvalue (after rotation)	2.22	-
Variance explained% (after rotation)	55.51%	-
Cumulative variance explained% (after rotation)	55.51%	-
KMO value	0.688	-
Butt sphericity	114.899	-
df	6.000	-
P-value	-	-

4 Results

Based on the background of digital teaching, this study innovatively applies the PBL (Problem-Based Learning) teaching model to the innovation and entrepreneurship education system of colleges and universities, and explores new paths for teaching reform by combining theory with practice. Starting from the actual digital teaching situation of schools, the study integrates domestic and foreign research results to construct a new paradigm of innovation and entrepreneurship education that adapts to the digital age. The research team used the "E-commerce" course as an experimental carrier and adopted a questionnaire method to investigate the implementation of the PBL digital project teaching model, and finally formed a set of scalable digital innovation and entrepreneurship education solutions.The specific results are as follows.

Figure 1 shows yields significant differences in students' acceptance of different teaching modes. Blended teaching (combining online and offline) accounted for the highest percentage of 60.34%, indicating that students preferred flexible learning modes, which allowed them to schedule their time independently through online platforms, as well as to get interactive and practical guidance through offline classrooms. Online learning platforms (e.g. MOOCs) accounted for 46.55%, reflecting the popular demand for digital tools, but the purely online mode is less attractive than the blended one . Virtual simulation experiments (e.g., entrepreneurship simulation software) accounted for 52.59%, indicating that students are more interested in immersive and practical digital tools, which can effectively simulate real entrepreneurial scenarios and fit the concept of “learning by doing” in PBL. The offline classroom only accounted for 33.62%, highlightin g the limitations of the traditional single mode of instruction and the need to enhance the sense of participation through digital means.

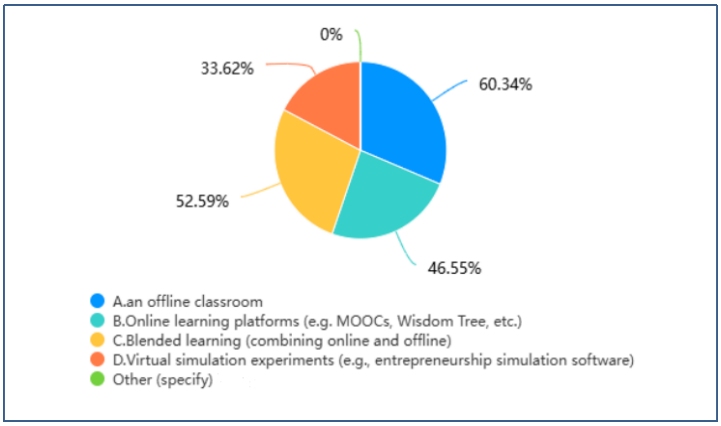

Figure 1: The main format of the PBL innovation and entrepreneurship program

According to Figure 2, 91.38% of the respondents chose "Yes" that digital tools are incorporated in PBL courses, while only 8.62% chose "No". This result clearly indicates that digital tools have been widely used in current Problem-Based Learning courses and have become an important part of teaching practice.

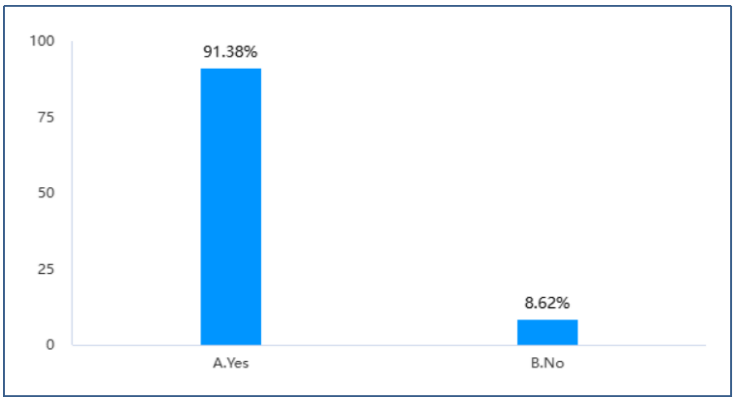

Figure 2: Does the PBL innovation and entrepreneurship course incorporate digital tools?

According to Figure 3, the commonly used digital tools in PBL innovation and entrepreneurship courses show diverse characteristics, with significant differences in the usage rates of different tools, reflecting the diversified needs of teaching scenarios and technological development trends. Among them, online meeting tools accounted for 66.88% such as Zoom and Tencent Meeting implies that these tools support cross-regional team exchanges, online guidance from experts, and on-line performances, which greatly expands the temporal and spatial flexibility of PBL teaching. Big data analysis tools accounted for 61.21%, and the highest usage rate was for data analysis tools such as Python and Tableau, which indicates that the PBL course attaches great importance to the cultivation of data-driven decision-making ability. Students analyze market data, user behavior and other information to verify entrepreneurial assumptions, reflecting the core requirement of "empirical thinking" in innovation and entrepreneurship education. These tools support cross-regional team communication, experts' online guidance, and online roadshows, greatly expa nding the temporal and spatial flexibility of PBL teaching.

The virtual simulation experiment platform accounts for 37.07% of the total, and the usage rate of simulation software such as BizCafe and SimVenture is more than one-third, which highlights the importance of practical tools. Through "trial and error learning" in the virtual environment, students can experience the whole process of entrepre neurship (e.g., financing, operation) at low cost and reduce the risk of real entrepreneurship.

AI assisted system accounts for 43.97%, intelligent tutors, automatic assessment and other AI tools are gradually penetrating into the teaching, especially in personalized feedback (such as business plan correction) and adaptive learning (recommending targeted cases), but there is still room for improvement. Team collaboration tools accounted for 28.45% of the total, and the usage rate of tools such as Slack and Trello is relatively low, as some courses rely more on localized platforms (e.g. Nail, Flybook), or group collaboration is not fully digitized.

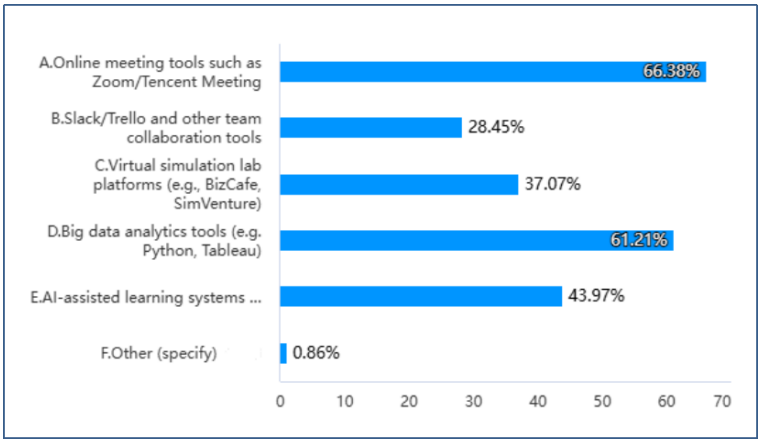

Figure 3:Classification of commonly used digitizing tools

According to Figure 4, the sources of problem design in the problem-oriented learning innovation and entrepreneurship course show diversified characteristics, with obvious differences in the adoption rate of different sources, reflecting the comprehensive consideration of authenticity, practicability and student subjectivity in teaching practice. The source of 85.34% provided by teachers or business mentors accounts for the highest percentage, indicatingthat most of the problems in the course are designed by teachers or industry experts. Its advantage is that it can combine professional knowledge and industry experience to ensure the practicality of the questions and the fit of the teaching objectives. The percentage of real entrepreneurship cases is 73.28%, and real cases are the second largest source, accounting for more than 70%. By analyzing successful or failed entrepreneurial cases (e.g., sharing economy models, the rise of new consumer brands), students are able to distill problems from actual business scenarios, enhancing the sense of immersion and relevance of learning.54.31%More than half of the courses will design problems from industry pain points, such as the dilemmas of digital transformation in traditional industries or regulatory gaps in emerging markets. These types of problems can help students develop a macro perspective and critical thinking, while stimulating innovative solutions.

The 46.55% proportion of students designing their own questions is relatively low, but is still used in nearly half of the courses. This approach emphasizes student agency and encourages them to identify problems from their own interests or observations, but more guidance is needed to ensure the feasibility and depth of the problems.

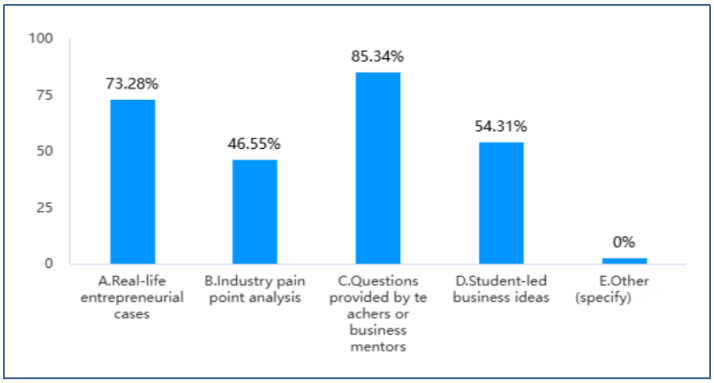

Figure 4:Primary sources of PBL problem design in the curriculum

According to Figure 5, 86.21% of the students believe that PBL mode can significantly increase students' interest and participation in learning, and stimulate learning motivation through real problem situations; secondly, 82.76% and 83.62% of the students believe that PBL effectively cultivates students' teamwork and problem solving abilities, which are the core qualities of innovative and entrepreneurial talents; thirdly, 75.86% of the students believe that the mode realizes the organic combination of theory and practice, and helps students transform knowledge into practical application ability; finally, 75% of the students believe that PBL significantly improves students' innovative thinking and entrepreneurial ability, and lays a foundation for their future innovative and entrepreneurial practice. Thirdly, 75.86% of the students believe that the model realizes the organic combination of theory and practice, helping students to transform knowledge into practical application ability; finally, 75% of the students believe that PBL significantly improves students' innovative thinking and entrepreneurial ability, and lays a solid foundation for their future innovation and entrepreneurship practice. These data show that PBL mode comprehensively improves the quality and effect of innovation and entrepreneurship education through its problem-oriented and practice-driven features, and is an effective way to cultivate innovative and practice-oriented talents.

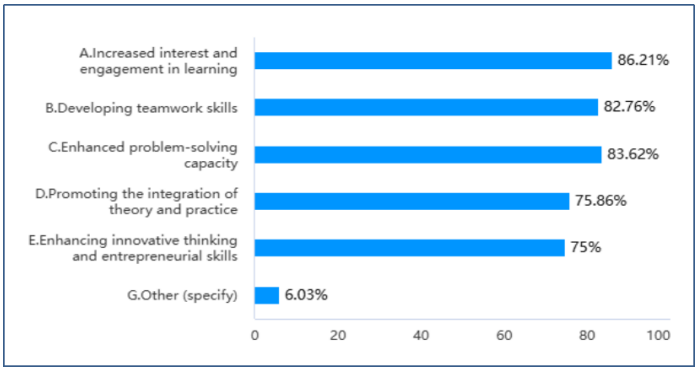

Figure 5:The main advantages of PBL teaching model in innovation and entrepreneurship education

Figure 6 shows that the challenges encountered in the PBL course 69.83% of the students, the unskilled use of digital tools greatly affects the learning efficiency, reflecting the lack of students' ability to apply technology; 60.34% of the students consider the complexity of the problem to be difficult to solve. In addition, the inefficiency of teamwork (52 .59%) and difficulties in time management (47.41%) also constrained learning effectiveness, indicating that students still need to improve in project management and team communication; comparatively speaking, the percentage of lack of faculty guidance was relatively low (27.59%), indicating that faculty support was relatively adequate. These data reveal that PBL courses need to focus on problem design rationality, digital skills training, and teamwork guidance to optimize teaching effectiveness.

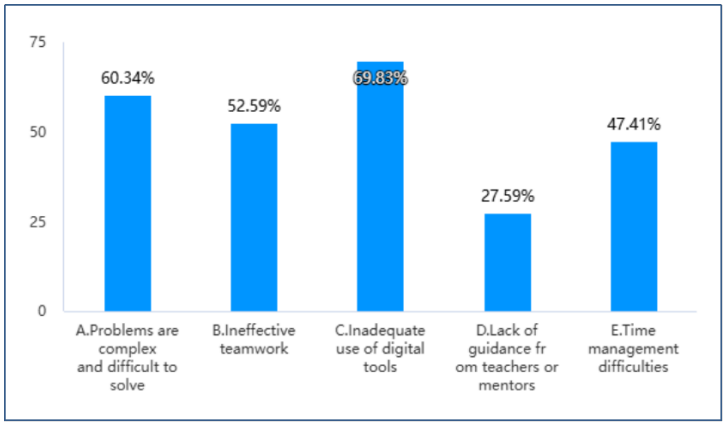

Figure 6: Main challenges encountered in PBL courses

According to Figure 7, the role of teachers in Problem-Based Learning courses is diversified, and their core functions are clearly reflected in the data: first, teachers dominate as learning guides (87.07%) and problem designers (75.86%), highlighting their key role in stimulating students' thinking and constructing learning frameworks; Secondly, the roles of resource provider (75%) and team coordinator (64.66%) were equally important, suggesting that teachers need to balance learning support with team dynamic management; furthermore, the share of assessment-feedback provider (56.03%) function showed the necessity of process evaluation, while the other roles (1.72%) were less influential. Overall, the PBL model requires teachers to transform from the traditional lecturer to a "guide-support-assessment" composite role in order to meet the needs of student-centered teaching and learning.

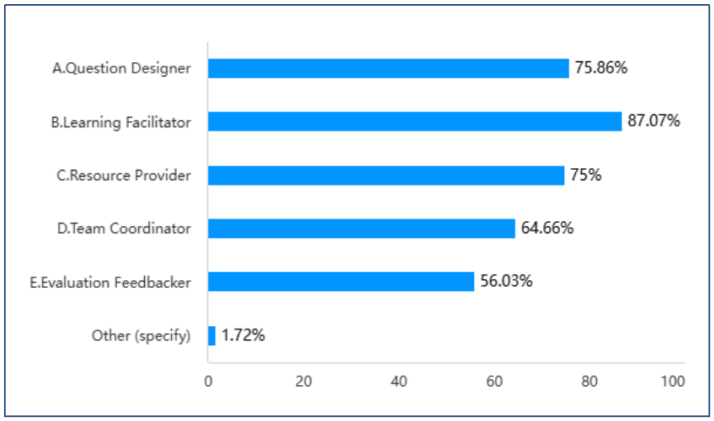

Figure7: Teachers' Roles in PBL Programs

According to Figure 8, it can be seen that the PBL digital innovation and entrepreneurship course needs to be focused on in terms of improvement. Firstly, optimizing the problem design (80.17%) has become the most urgent need , and students expect that the problems can be closer to real entrepreneurial scenarios and enhance the practicability of learning; secondly, the need for digital tool training (75.86%) follows, reflecting the obvious shortcomings of students' ability in technological application; furthermore, the need to Strengthening the guidance of teachers and enterprise mentors (62.93%) and improving the team collaboration mechanism (56.9%) also attracted much attention, indicating the need to enhance the effectiveness of faculty support and team management; comparatively speaking, the introduction of practice opportunities (44.83%) accounted for a slightly lower percentage of demand, but is still an imp-

ortant supplement. These data provide a clear path for curriculum optimization: focusing on real problems, strengthening the cultivation of digital competence, and at the same time improving the guidance and collaboration system, so as to comprehensively enhance the effectiveness of PBL curriculum in innovation and entrepreneurship education.

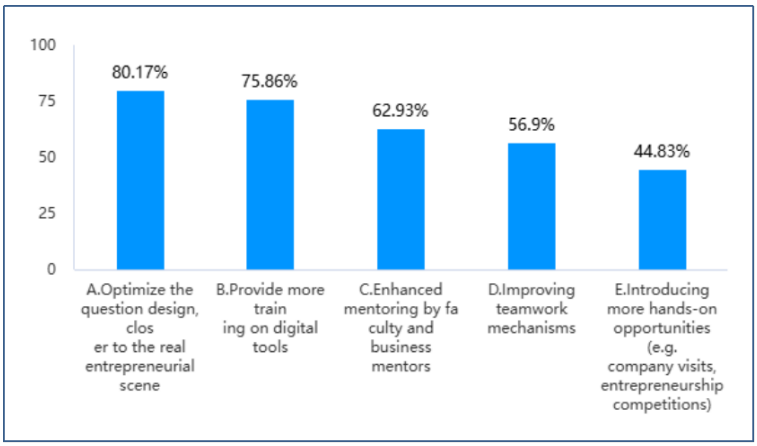

Figure 8:Improvement aspects of PBL digital innovation and entrepreneurship course

The research focuses on solving the three core problems existing in traditional innovation and entrepreneurship education: first, it changes the traditional teaching mode of "teacher-led and theory-based" and establishes a new teaching relationship of "student-centered and problem-oriented"; second, it breaks through the limitations of a single classroom and cultivates students' team awareness and practical ability through group collaborative learning; third, it reconstructs the role positioning of teachers and students, and teachers change from knowledge transmitters to learning partners, exploring innovation and entrepreneurship practices with students. The research innovatively integrates digital technology with the PBL teaching model, and builds a hybrid learning environment of "online + offline" and "in-class + out-of-class" with the help of online platforms such as Duifenyi, focusing on cultivating students' high-order thinking ability.

The project implementation first designs the core knowledge modules based on the digital platform; secondly, the entrepreneurial team is formed around the knowledge points and the business plan is completed; the third stage is to conduct public display and multi-party evaluation; the fourth stage is to optimize the project and participate in the competition; finally, the teaching effect is evaluated through data analysis. This teaching model gives students full autonomy to choose, and the project topic can be combined with professional background or derived from life practice, which effectively stimulates students' learning initiative and innovation potential.

5 Conclusions

This study developed a hybrid "online + offline" Problem-Based Learning (PBL) teaching framework by integrating theoretical research with empirical analysis. Using the "E-commerce B" course at Huaxin College of Hebei University of Geosciences as an experimental case, the research employed questionnaire surveys and practical platforms such as the " Internet+" Innovation and Entrepreneurship Competition to assess the framework's effectiveness. The findings demonstrate that the digital PBL teaching model significantly enhances students' independent learning, teamwork, and innovation abilities while optimizing teacher-student interaction by transforming instructors from knowledge transmitters into learning facilitators.

The key innovation of this study lies in the deep integration of PBL with digital tools (e.g., Pair of Points Easy platform, virtual simulation systems), establishing a closed-loop teaching process of "problem-driven teamwork–practice verification–competition assessment." This approach not only strengthens the practical application of PBL in innovation and entrepreneurship education but also provides a replicable digital solution for higher education institutions.

The results show that the PBL digital teaching model significantly improves students' innovation and entrepreneurship capabilities. Its advantages are mainly reflected in three aspects: the teaching method has achieved a change from passive acceptance to active exploration; the ability training has strengthened teamwork and practical application; and the technology application has built a digital learning support system. This model provides an operational implementation plan for innovation and entrepreneurship education in applied universities, and has important reference value for promoting education and teaching reform. Future research can further expand the scope of the experiment, explore the adaptability of different professional fields, and strengthen long-term follow-up evaluation.

CRediT authorship contribution statement

Li Xinhui: Writing – original draft, Supervision, Investigation. **Liu Hongya and Yan yue :** Writing – review & editing, Formal analysis, Data curation, Conceptualization. **Shi Yuxian and Wang Iikun:** Validation, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix

Questionnaire for the Study of Digital Innovation and Entrepreneurship Education and Teaching Model Based on PBL

Dear respondents:

Hello! This questionnaire aims to understand the implementation status and effect of the digital innovation and entrepreneurship education and teaching model based on PBL (Problem-Based Learning). Your valuable opinions will provide important reference for our research. This questionnaire is anonymous and the data is only used for academic research. Please fill in the form according to the actual situation. Thank you for your support!

Part I Basic Information

1. Your identity is:

A. Undergraduate student B. Master's student C. Doctoral student D. University teacher E. Other (please specify)_____

2. The main form of the PBL innovation and entrepreneurship course you participated in is: (multiple choices are allowed)

A. Offline classroom B. Online learning platform (such as MOOCs, Wisdom Tree, etc.) C. Hybrid teaching (online and offline combination) D. Virtual simulation experiment (such as entrepreneurship simulation software) E. Other (please specify)_____

Part II Application of PBL teaching model

3. Does the PBL innovation and entrepreneurship course you participated in combine digital tools (such as online collaboration platforms, AI analysis tools, etc.)?

A. Yes B. No

4. Commonly used digital tools in the course include: (multiple choices)

A. Online meeting tools such as Zoom/Tencent Conference B. Team collaboration tools such as Slack/Trello

C. Virtual simulation experiment platform (such as BizCafe, SimVenture) D. Big data analysis tools (such as Python, Tableau) E. AI-assisted learning system (such as intelligent tutor, automatic evaluation)

F. Others (please specify)_____

5. The PBL problem design in the course mainly comes from: (multiple choices)

A. Real entrepreneurial cases

B. Industry pain point analysis

C. Questions provided by teachers or corporate mentors

D. Entrepreneurial ideas proposed by students

E. Others (please specify)_____

6. What do you think is the main advantage of the PBL teaching model in innovation and entrepreneurship education: (multiple choices)

A. Improve learning interest and participation

B. Cultivate team collaboration ability

C. Enhance problem-solving ability

D. Promote the combination of theory and practice

E. Improve innovative thinking and entrepreneurial ability

F. Others (please specify)_____

Part III Learning Effect and Experience Evaluation

7. How satisfied are you with the PBL digital innovation and entrepreneurship course?

A. Very satisfied

B. Satisfied

C. Average

D. Dissatisfied

E. Very dissatisfied

8. Do you think the PBL teaching model is helpful to improve your innovation and entrepreneurship ability?

A. Very helpful

B. Somewhat helpful

C. Average

D. Less helpful

E. Not helpful

9. The main challenges you encountered in the PBL course are: (multiple choices)

A. High complexity of the problem, difficult to solve

B. Low efficiency of teamwork

C. Unskilled in the use of digital tools

D. Lack of guidance from teachers or mentors

E. Difficult time management

F. Others (please specify) _____

10. What role do you think the teacher should play in the PBL course: (multiple choices)
A. Question designer
B. Learning guide
C. Resource provider
D. Team coordinator
E. Evaluation feedback
F. Others (please specify) _____
Part IV Suggestions for Improvement
11. In what aspects do you think the PBL digital innovation and entrepreneurship course can be improved? (Multiple choices are allowed)
A. Optimize the design of questions to be closer to real entrepreneurial scenarios B. Provide more digital tool training C. Strengthen the guidance of teachers and corporate mentors D. Improve the team collaboration mechanism E. Introduce more practical opportunities (such as corporate visits, entrepreneurial competitions)F. Others (please specify)_____
12. Are you willing to continue to participate in or recommend others to participate in the PBL digital innovation and entrepreneurship course?
A. Very willing B. Willing C. General D. Unwilling E. Very Unwilling
13. Your other suggestions or opinions on the PBL digital innovation and entrepreneurship course:_____