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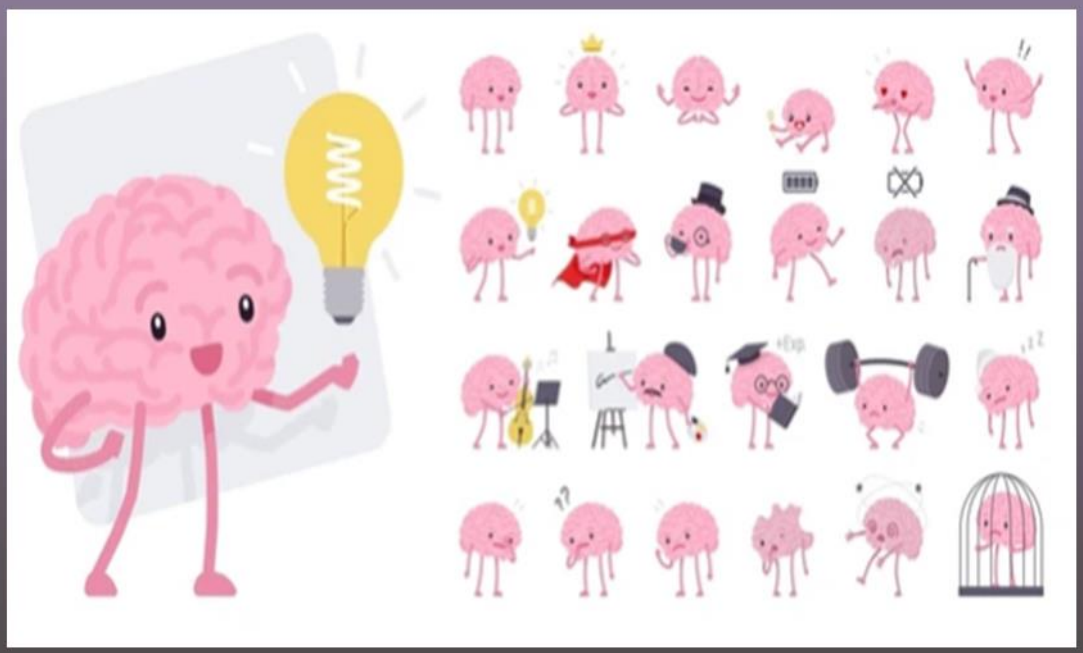

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THE STRATEGY OF INTERNATIONAL COMMUNICATION OF BA SHU CULTURE

Ting Qin*, Jie Chen
Xihua University, Chengdu610039, Sichuan, China.
Corresponding Author: Ting Qin, Email: 1254922734@qq.com

Abstract: As a treasure of the Chinese nation, Ba Shu culture carries deep historical deposits and unique regional characteristics, and has both opportunities and challenges for international dissemination in the wave of globalization. This study analyzes Ba Shu culture in depth, explores its rich connotations and core values, and clarifies the current situation of its international communication, including obvious cultural differences, obstacles of language differences, and limited communication channels. On this basis, the study builds a system of communication strategies from multiple perspectives: innovating the content of Ba Shu culture; pinpointing audience groups; disseminating Ba Shu culture through multiple channels; and establishing an interactive communication mechanism. Through the implementation of these strategies, we aim to enhance the influence and competitiveness of Ba Shu culture in the international arena, promote it to the world, and contribute to the exchange and mutual understanding of human civilization.
Keywords: Ba Shu culture; International communication; Cultural influence; Cultural differences

1 INTRODUCTION

As a bright pearl of Chinese culture, the culture of Ba Shu is in dire need of being known and appreciated by the world. This ancient and mysterious land has nurtured the Shu culture with Chengdu as the core and the Ba culture with Chongqing as the center of gravity, which are intertwined to build a magnificent picture of the Ba Shu culture. It not only carries rich tangible cultural heritage, such as the world-famous Sanxingdui Ruins and Jinsha Ruins, but also treasures endless intangible cultural heritage, such as Sichuan Opera, Shu embroidery, bamboo weaving, and other forms of art, which are like jewels that embellish the sky of the culture of Ba Shu.
The charm of Ba Shu culture lies in its long history, diversified integration and rich art. From the mysterious veil of the ancient Shu Kingdom to the prosperous scenery of modern Sichuan, thousands of years of historical precipitation have given the culture of Ba Shu a profound heritage. However, in the context of globalization, the road of international dissemination of Ba Shu culture has not been smooth. Although the process of globalization has set up a broad stage for cultural exchanges and dissemination, Ba Shu culture still faces many challenges and dilemmas in the process of going global. This study aims to analyze the research progress of Ba Shu culture, gain insight into the current situation and challenges of its international dissemination, and explore practical international dissemination strategies.

2 LITERATURE REVIEW

The culture of Ba Shu has a profound historical background and a wide range of practical influence in foreign communication. Liu's research found that the external communication of Ba Shu culture can be traced back to the 4th century B.C. After thousands of years of development, it has had far-reaching influence on the construction and dissemination of Ba Shu's image. As a representative of regional culture, Ba Shu culture is profound and diversified, with important influence, radiation and appeal, and has become an important part of the construction of contemporary China's image. In cross-cultural communication, Ba Shu culture not only has great significance in communication, but also has a complex and multiple relationship with Chinese culture, facing the challenges of cultural communication and image construction together [1]. Under the perspective of globalization, examining the communication value of Ba Shu culture can provide more diversified thinking for the overseas communication of Chinese culture. According to Hou's research, “Ba Shu culture” is an indispensable part of the excellent traditional Chinese culture, which is of positive significance for enhancing the cultural consciousness and firming the cultural confidence of the Chinese nation, and is an important carrier for manifesting the spiritual connotation and values of the Chinese nation. Numerous films with cross-cultural communication characteristics, such as “Vitality of the Southern Silk Road”, “Sanxingdui: Recreating the Lost Civilization”, and “Anthony Bourdain: Journey into the Unknown”, etc., have shown the history and current situation of “Ba Shu Culture” in vivid audio-visual language, and have also shown the history and current situation of “Ba Shu Culture”. Through vivid audiovisual language, the films present the history and current situation of “Ba Shu Culture” and develop ideas for the innovation and global mobility of “Ba Shu Culture”. While depicting the specificity of the regional culture, these films also focus on how to highlight its universality, so as to establish the connection between Ba Shu culture and different cultural audiences, and to promote the audience's knowledge, understanding and recognition of Ba Shu culture and Chinese civilization [2]. At the same time, the issue of narrative legitimacy of foreign documentaries on “Ba Shu culture” also deserves in-depth consideration.

Du's research points out that the history of foreign performances of Sichuan opera can be traced back to 1959, when in order to show the cultural and artistic image of new China, Premier Zhou Enlai decided to use Sichuan opera as a representative to visit and perform in Poland, Bulgaria, Czechoslovakia, and East Germany, which opened the prelude to the foreign performances of Sichuan opera [3]. Zhou Enlai's personal visit to the theater to review the performance repertoire and propose script revisions, as well as Chen Yi's and Guo Moruo's personal revisions of the scripts, reflected the national level's emphasis on and support for the spread of Ba Shu culture. Chen's research found that the development of science and technology improves life, brings new opportunities for cultural communication, enriches the subject of communication, expands the channels and forms of communication, and improves the effect of cultural communication. Under the new media environment, the communication of Ba Shu culture needs to optimize its strategies: taking advantage of the new media platform, integrating communication resources, innovating presentation forms, mining cultural symbols, and optimizing the communication environment [4]. These strategies can help Ba Shu culture enter a new stage and play a far-reaching value in the new media era.

The international dissemination of Chinese Ba Shu culture is promoted through the integration of its culinary traditions, regional imagery in poetry and historical elements in architecture, as well as globally through modern media and translation efforts. Li Bai's poetry reflects the unique regional cultural elements of Bashu, which has been enriched through dissemination by promoting artistic creation [5]. Tang poems and their English translations are valuable resources for the study of Ba Shu culture, reflecting Chinese folk culture and providing valuable information for further research [6]. The language of the Bashu characters in the Sanxingdui culture records lifestyles, religious beliefs and artistic achievements, and also reflects the transformation of abstract spiritual beliefs and social structures into tangible and concrete symbols [7]. In the English translation of Sichuan Road, the image of the Ba Shu region is accurately restored, highlighting its unique cultural connotation and spiritual significance in ancient Chinese Ba Shu poetry [8].

The foreign communication of Ba Shu culture not only has a long history and deep cultural heritage, but also plays an important role in cross-cultural communication. Through diversified communication methods and rich cultural products, Ba Shu culture has shown its unique charm and value on the international stage, and made positive contributions to the overseas dissemination of Chinese culture.

3 CURRENT SITUATION AND CHALLENGES OF INTERNATIONAL COMMUNICATION OF BA SHU CULTURE

3.1 Obvious Cultural Differences

Ba Shu culture faces the challenge of obvious cultural differences in international communication, a factor that significantly affects its communication effect. Different folk customs and cultural backgrounds lead to differences in audiences' understanding and acceptance of foreign cultures. For example, face-changing and fire-spitting in Sichuan opera, which are very characteristic of traditional Chinese culture, may encounter barriers to understanding and acceptance in Western cultural contexts. Such cultural differences are not only reflected in artistic forms, but also in values, aesthetic standards and social customs. For example, the elements of Ba Shu culture, such as family concept and traditional etiquette, may conflict with Western individualistic values, thus affecting the smoothness of cultural dissemination. In addition, language barriers are also part of the cultural differences. The unique expressions of the Ba Shu dialect and idiomatic sayings are prone to lose their original flavor and connotation in the translation process, resulting in incomplete or misunderstood messages. These cultural differences make it necessary to pay more attention to the use of cross-cultural communication strategies in the international communication of Ba Shu culture, and to enhance the international influence and communication effect of Ba Shu culture by means of cultural adaptation, increasing the interpretation of cultural background, and promoting cultural exchanges and interactions, so that its unique cultural charms can be understood and appreciated more widely.

3.2 Obstacles of Language Differences

Ba Shu culture is actively moving towards the international stage, however, language differences have become an obstacle that cannot be ignored in its international dissemination. As an important carrier of cultural communication, language difference directly affects the effect of cultural transmission and acceptance. Ba Shu culture is rich in dialects, sayings, idioms and other forms of language, which carry unique regional cultural connotations, but in the process of international dissemination, due to the huge differences in the language system with foreign languages, it is difficult to translate and understand. The profound cultural connotations and delicate emotional expressions contained in many cultural products, such as Ba Shu literary works, film and television works, and operas, are difficult to be accurately transformed into the target language in translation, resulting in misunderstandings or incomplete comprehension of the cultural information received by the international audience. In terms of academic research results, research papers and monographs on Ba Shu culture cannot be widely disseminated and exchanged in the international academic community due to language barriers, which limits the international academic community's in-depth understanding of Ba Shu culture and research cooperation. In addition, language differences also affect the dissemination of Ba Shu culture on international social media and online platforms. Due to the language barrier, online information about Ba Shu culture is difficult to be widely browsed and shared by users with different language backgrounds around the world, which reduces its visibility and influence in international cyberspace. Therefore, in order to enhance the international

communication effect of Ba Shu culture, it is necessary to pay attention to the impeding factor of language difference, and reduce the communication barriers caused by language difference by strengthening the cultivation of translation talents, promoting language and technology innovation, and fostering language and cultural exchanges, etc., so that the unique charm of Ba Shu culture can cross the boundary of language, and be understood and appreciated more widely and more deeply.

3.3 Limited Communication Channels

Ba Shu culture faces the challenge of limited communication channels in international communication, which significantly restricts its scope and influence. Currently, the international dissemination of Ba Shu culture mainly relies on traditional media and cultural exchange activities, such as Ba Shu cultural exhibitions and academic seminars. Although these traditional channels have to a certain extent facilitated the overseas dissemination of Ba Shu culture, it is difficult to meet today's diversified dissemination needs due to their relatively single form of dissemination and limited scope of dissemination. For example, traditional media communication is often limited by time and space, and cannot realize immediate interaction with the audience, resulting in insufficient timeliness and relevance of the communication effect. Folk communication, as an important supplement to cultural communication, has not yet been fully developed in the international communication of Ba Shu culture, and its communication power is relatively weak, making it difficult to form a wide social influence. In addition, with the rapid development of digital technology, the role of modern digital technology in cultural communication is becoming more and more prominent, but the international dissemination of Ba Shu culture makes less use of this technology. This is manifested in the lack of professional digital communication talents and teams, and the lack of professionalism in the operation and maintenance of digital platforms, which leads to the poor quality and untimely updating of the digital communication content of Ba Shu culture. The number of new media platforms for external cultural communication is also extremely limited, failing to meet the diversified needs of international audiences for information acquisition on Ba Shu culture. Therefore, expanding communication channels, strengthening the power of private communication, improving the utilization of modern digital technology, and increasing the number of new media platforms for foreign cultural communication have become the keys to enhancing the effectiveness of international communication of Ba Shu culture.

4 ANALYSIS OF STRATEGIES FOR INTERNATIONAL COMMUNICATION OF BA SHU CULTURE

4.1 Innovate the content of Ba Shu Culture

Deeply excavate the connotation of Ba Shu culture, especially its unique cultural elements combined with stories to tell Ba Shu stories. Combine with modern design concepts to launch unique cultural products with international appeal of Ba Shu characteristics. For example, it is possible to combine Shu embroidery with modern cutting-edge design to launch Shu embroidery products with a Ba Shu style, Chinese style and world style. Innovate the content form of Ba Shu culture, combine with cutting-edge science and technology, and make good use of VR, AR and other technologies to innovate the expression form of Ba Shu culture. For example, through VR technology, the life scenes of Sanxingdui Ruins and Jinsha Ruins as well as the archaeological excavation scenes are displayed beside the international friends, so that they seem to be in the realm of immersive experience.

4.2 Precise Positioning of Audience Groups

According to the customs of different countries and the different cultural backgrounds of the audience groups, precisely locate and segment the market, and formulate effective communication strategies. For example, in the European and American markets, focus on the long history and rich artistic value of Ba Shu culture. In the Asian market, focus on the traditional crafts and folklore of Ba Shu culture. In the process, we constantly research and analyze the market to understand the interests and needs of different countries and nationalities for Ba Shu culture, and develop targeted communication contents. For example, the promotion of Sichuan opera is analyzed through social media comments, clicks, retweets, likes, etc. to understand the international market's interest in Sichuan opera.

4.3 Multi-Channel Dissemination of Ba Shu Culture

Make full use of modern digital technology means, such as Jittery, Xiaohongshu, TikTok, etc., to diversify and multi-level dissemination of Ba Shu culture, so as to attract foreign audience groups. Strengthen cooperation with international media, enterprises, and cultural associations to jointly promote local cultures of both sides, and to better bring Ba Shu culture to the world. For example, actively participate in international art festivals around the world, hold special exhibitions or performances of Ba Shu culture, and enhance the influence of Ba Shu culture overseas.

4.4 Establishment of Interaction and Exchange Mechanisms

Actively establish an international interactive mechanism for Ba Shu culture to enhance the sense of identity and participation of international audiences through online and offline activities. For example, workshops on Ba Shu culture

are held simultaneously online and offline, and intangible cultural heritage inheritors are invited to provide on-site guidance on craft production such as Shu embroidery and bamboo weaving, so that international audience groups can experience the charm of Ba Shu culture. In the process of video dissemination, we focus on collecting opinions from domestic and overseas viewers, and based on the opinions, we promote the improvement of the video dissemination of Ba Shu culture, so as to continuously improve the content and quality of Ba Shu culture videos.

The international dissemination of Ba Shu culture is not something that can be done overnight, but requires the joint efforts of many people. It requires a lot of concerted efforts to enhance the influence of Ba Shu culture in the international arena by innovating the content of Ba Shu culture, accurately targeting the audience groups, disseminating Ba Shu culture through multiple channels, and establishing interactive communication mechanisms and other strategic measures.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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MAPPING THE LOGIC OF VIRTUAL TEACHING AND RESEARCH TO PHYSICS CURRICULUM DEVELOPMENT AND IN-DEPTH SCIENCE POPULARIZATION

ShiJun Xu[1], HaiOu Zhang[2,3*]
[1]*School of Sciences, Xi'an Technological University, Xi'an 710021, Shaanxi, China.*
[2]*School of Preschool Education, Xi'an University, Xi'an 710065, Shaanxi, China.*
[3]*Shaanxi Institute of Teacher Development, Xi'an 710062, Shaanxi, China.*
Corresponding Author: HaiOu Zhang, Email: haioufeihaitangkai@qq.com

Abstract: Under the background of deepening the pilot construction of virtual teaching and research offices in China's higher education development, it is necessary to leverage the driving role of various pilot projects, emphasizing the trend of "AI+teaching reform." By integrating theoretical research with practical applications through scientific methods, this paper explores the triple logic underlying the development of virtual teaching and research offices. Based on this analysis, a multidimensional development model for virtual teaching and research offices is proposed. Taking the construction of foundational physics courses as an example, the integration path between virtual teaching and research offices and in-depth science popularization is analyzed.
Keywords: Virtual teaching and research; Physics curriculum development; In-depth science popularization

1 INTRODUCTION

The Higher Education Department of China's Ministry of Education proposed in its 2022–2024 work priorities the need to deepen the pilot construction of virtual teaching and research offices. Additionally, our team was awarded the Shaanxi Province Virtual Teaching and Research Office Construction Project in October 2021. This necessitates research into the development mechanisms of "AI+teaching reform" virtual teaching and research offices, aiming to provide theoretical guarantees and model references for grassroots teaching organization construction, thereby supporting the high-quality development of universities.

2 THE TRIPLE LOGIC OF VIRTUAL TEACHING AND RESEARCH OFFICE

2.1 Historical Logic

Cheng Jieming, former Vice President of the University of Hong Kong, who has extensively studied and compared the educational systems and school cultures of China and Western countries, remarked, "*China's teaching and research habits and systems over the past 70 years are almost unique globally*" [1]. However, since the 1990s, the increasing emphasis on research in higher education evaluations has altered the positioning, functions, and forms of teaching and research offices as grassroots organizations, leading to a decline in teaching quality [2–5]. Although the "Undergraduate Teaching Quality and Reform Project" during China's 10th and 11th Five-Year Plans partially mitigated this decline, the operational practices of universities increasingly prioritized research teams.

To resolve the conflict between prioritizing research over teaching, Professor Sang Xinmin proposed improving teaching standards, quality, and efficiency while fostering mutual promotion and collaborative innovation between the two. Drawing on the concept of "virtual communities," he pioneered virtual teaching and research activities in China, publishing *The Conception and Practice of Virtual Teaching and Research Models* in 2001 [6].

In February 2017, the Ministry of Education initiated the "New Engineering Education" reform, culminating in the "Fudan Consensus," "Tianjin University Action," and "Beijing Guidelines," later expanding to the "Four New Constructions." These efforts aimed to develop a globally leading Chinese educational model, emphasizing interdisciplinary, innovative, and cross-boundary talent cultivation. This necessitated establishing long-term mechanisms to support interdisciplinary teaching and academic integration [5]. Consequently, teaching and research offices, as grassroots organizations, required functional revitalization to create teacher communities that integrate teaching and academic research [7–9]. Early explorations were led by scholars such as Sang Xinmin, Zeng Jianchao, and Hong Zhizhong at institutions like Nanjing University, South China Normal University, and Zhejiang University [2,4–11].

Thus, virtual teaching and research offices are rooted in the functional and organizational innovation of university grassroots entities in the information age. They transform courses developed by outstanding faculty teams into open online resources, fostering cross-institutional virtual teaching and research teams, updating teaching materials, enhancing platforms and tools, and nurturing creative learning capabilities [7–9]. The Ministry of Education's 2020–2024 priorities, including "strengthening grassroots teaching organizations," "launching virtual teaching and research office pilots," and "developing virtual teaching platforms," further affirm this national trend.

2.2 Value Logic

2.2.1 Academic value

This paper pioneers detailed research on the theoretical logic, platform models, and implementation pathways of virtual teaching and research offices, addressing the lack of systematic guidance in prior practices. For instance, among 3,168 national projects in education over the past five years, only one 2019 project by Hu Fangang of Qufu Normal University discussed "educational virtual communities," focusing on ethical issues rather than virtual teaching and research offices. Therefore, rigorous theoretical frameworks are essential to guide this transformative shift in teaching culture and organizational paradigms, ultimately fostering innovative talent development.

2.2.2 Practical value

Compared to existing literature, this study innovates the practice model of "intellectual collision fields" for cross-disciplinary, cross-regional teaching reform under the Shaanxi Province Virtual Teaching and Research Office Project. It promotes digital application and classroom innovation in central and western Chinese universities. Unlike discipline- or course-specific virtual offices, teaching reform-oriented virtual offices bear the mission of enhancing educational quality. By exploring their theoretical foundations, organizational models, and implementation strategies, this research addresses the shortcomings of traditional teaching and research activities confined to physical offices.

2.2.3 Promotion value

Compared to existing practices, this study explores virtual teaching and research offices across three regional universities in central and western China. Its clear implementation pathways make it easily adaptable to numerous local universities nationwide. The Chinese Ministry of Education's "Document No. 2 [2022]" marks the launch of 439 national pilot virtual teaching and research offices, with platforms like *DingTalk* supporting these initiatives. Due to our university's long-term commitment to teaching and research office reforms, we secured one of Shaanxi Province's 37 provincial-level virtual teaching and research office pilots in October 2021. Leveraging this project, the findings of this study can be widely disseminated among local universities.

2.2.4 Practical value

Unlike prior literature, this paper introduces the concept of "AI + teaching reform" platform-based virtual teaching and research offices for foundational courses. The proposed pathways and strategies are readily applicable to other foundational disciplines. Using the Central and Western Basic Physics Cloud-Based Teaching Reform Virtual Teaching and Research Office as a case study, we establish development pathways and operational strategies for such offices. These results are easily implementable and scalable across foundational courses, benefiting large student populations.

2.3 Problematic Logic

Previous studies on virtual teaching and research offices [2–12] addressed general theoretical, logical, and practical challenges but lacked depth in theoretical refinement and practical implementation. For instance, under the "Western Triangle" framework in higher education, new theories, practices, and exemplary models for "AI+teaching reform" virtual offices face unresolved issues, such as institutional mechanisms.

2.3.1 Weak theoretical foundation

In central and western universities of China, the theoretical foundations of "AI+" grassroots teaching organizations are weak. Existing explorations [2–12] tackled preliminary theoretical and practical questions but failed to refine theories for efficient organizational development.

2.3.2 Lack of hierarchical and categorized platform solutions

The national virtual teaching and research office initiative, launched in February 2020 on the "*DingTalk*" platform, overlooked hierarchical and categorized platform designs, resulting in poor theoretical applicability.

2.3.3 Scarcity of exemplary cases

As virtual teaching and research offices are emerging innovations, there are no national, provincial, or institutional benchmarks. Thus, there is an urgent need to develop practical strategies for teaching reform-oriented virtual offices in central and western China, providing actionable models for grassroots teaching organizations.

3 METHODS AND GUARANTEE MEASURES

3.1 Methods

Maxwell's "cross design method" was adopted in each research stage, and different degrees of qualitative and quantitative combinations were applied to each stage.

In the early stage of the research, the "grounded theory" research path (literature review and interview methods) of qualitative research (Mr. Chen Xiangming from Peking University) was the main approach, while the quantitative research path (literature review and questionnaire methods) was used as an auxiliary approach. This combination mainly focuses on the principles, concepts, mechanisms, and other tasks included in research content one and two, and requires the establishment of theoretical viewpoints based on empirical data.

In the later stage of the research, the quantitative research path (literature review and questionnaire methods) is the main approach, while the qualitative research path of "grounded theory" (literature review and interview methods) is used as an auxiliary approach. This combination is mainly aimed at the practical application strategies and other tasks included in research content two and three, which require obtaining statistical data and common experience of teaching practice,

and providing timely feedback.

3.2 Four Guarantee Conditions

3.2.1 Platform guarantee

The practical platform is unique. The "Central and Western Basic Physics Cloud Education Reform Virtual Teaching and Research Room" led by Xu Shijun was approved as one of the first 37 provincial-level virtual teaching and research rooms for pilot construction in October 2021, and is the only construction project of the Xi'an Technological University in China.

3.2.2 Academic guarantee

We have a solid academic foundation. The person in charge and members have project support in the preliminary basic research and have achieved many results. Please refer to "Research Fundamentals" for details.

3.2.3 Team guarantee

Our team has a high level of proficiency. The "Central and Western Basic Physics Cloud Education Reform Virtual Teaching and Research Room" approved by our team in October 2021 is not only the only construction project of our university, but also the only physics virtual teaching and research room in Shaanxi Province. It was promoted again on February 14, 2022, indicating that the team's academic level and construction ability have been recognized by experts. There are 2 professors, 2 associate professors, and 1 lecturer among the members of this project, whose disciplines and job responsibilities are in line with the professional development and training of teachers.

3.2.4 Policy guarantee

The policy environment of this paper is superior. In addition to the base guarantee of the virtual teaching and research office in Shaanxi Province mentioned above, each participating unit will provide a venue for research and application; The project undertaking school has a sound management policy for various levels and types of teaching and research projects, and possesses the basic information and equipment required for project research; In addition, all cooperating units have a favorable environment and conditions for the implementation of this project.

4 RESULTS

The theoretical objective of this paper is to explore the theoretical structure and organizational model of virtual teaching-research rooms for educational reform in different industries or regional backgrounds. Focusing on full-time teachers from three universities with backgrounds in light industry and teacher education, this study aims to investigate the theoretical structure and organizational model of a teacher training community for educational reform that integrates general and specialized education and cross school collaboration. Particularly, it will explore the new features of using information technology to transform traditional teaching-research rooms in the era of "AI+".

Many practical objectives of this paper is to establish the development path of virtual teaching and research rooms for basic course education reform on the platform, and refine their operational strategies. Taking the virtual teaching and research room for cloud based teaching reform of basic physics in the central and western regions as an example, this paper explores its specific construction path and operation strategy, in order to assist in realizing a powerful virtual teaching and research room with advanced concepts, forging a high-level teaching team of 30 people, cultivating a group of teaching research and practical achievements, building a teaching development community and quality culture for teachers, and comprehensively improving teachers' teaching abilities.

Based on the triple logic of virtual teaching and research offices, this study theoretically explores their developmental elements, connotations, and boundaries across "learning" and "organizational" dimensions. Practically, we focus on the university basic physics course,with a high-impact subject, to innovate its technical platform, develop intelligent resource databases, organize student teams, and collect online learning data. Notably, the in-depth physics science popularization serves as a unique feature and quality-enhancing tool for the virtual office.

5 CONCLUSION

This paper investigates regional teaching reform-oriented virtual teaching and research office pathways, clarifying their core philosophy: serving dynamic, open grassroots teaching organizations and inspiring teachers to return to, cherish, and research teaching. We propose three practical pathways for "AI+teaching reform" virtual offices: prioritizing moral education, fostering collaboration and resource-sharing, and advancing categorized exploration. Thus, this study provides theoretical and practical frameworks for grassroots teaching organization development, supporting high-quality advancement in higher education.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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VISUAL CODING SYSTEM FOR TEACHING ELEMENTS IN CLASSROOM ASSISTED BY VIRTUAL TEACHING RESEARCH

XinYi Zheng[1], HaiOu Zhang[1,2*], ShiJun Xu[3]
[1]*School of Preschool Education, Xi'an University, Xi'an 710065, Shaanxi, China.*
[2]*Shaanxi Institute of Teacher Development, Xi'an 710062, Shaanxi, China.*
[3]*School of Sciences, Xi'an Technological University, Xi'an 710021, Shaanxi, China.*
Corresponding Author: HaiOu Zhang, Email: haioufeihaitangkai@qq.com

Abstract: In the new form of digital education, it is necessary to develop a visual coding and analysis system for teaching elements in the classroom. Based on marking, assigning values, implementing in C or Python, an innovative visual coding system has been developed assisted by virtual teaching research.It can optimize classroom activity models, strengthen sociological research tools, and empower digital education.
Keywords: Digitalization of education; Classroom elements; Educational software; Virtual teaching research

1 INTRODUCTION

In the current digital education, there is an urgent need for a visual coding and analysis system for classroom teaching elements. Foreign countries began studying teacher teaching behavior as early as the 1970s[1]. Research has shown that the diagnosis of information-based classroom teaching has great potential for development in standard setting, result verification, human-machine collaboration, functional diagnosis, non-interference collection, actionable insights, real-time feedback, and personalized recommendations[2].China was exploring localized teaching evaluation models based on learning from foreign experiences[3-4]. Information technology has made classroom behavior analysis more intelligent[5-6], but there is still room for development in information-based classroom teaching diagnosis[7-8]. The formation of distinctive classroom teaching in our country helps promote educational equity, and the "three classrooms" have received attention, expanding the focus of research from teaching quality to educational equity[9-10]. However, classroom systematicity have been overlooked by previous studies, so there's a need to use information technology to provide in-depth support for classroom research. This article comprehensively reveals the process of classroom occurrence, provides support for vertical tracking and horizontal comparative research, provides services for educational practice institutions and personnel, and improves the discourse system of educational research methods.
In the work plan of the Chinese Ministry of Education from 2020 to 2024, there was a discussion on comprehensively strengthening the construction of primary teaching organizations, thus virtual teaching and research has become a trend. Virtual teaching and research room is based on the functional and organizational innovation of primary physical teaching and research rooms in universities in the information age. It builds courses of excellent teachers into online open courses, and creates cross school virtual teaching and research teams through cross time and space co construction and sharing. It updates teaching resources, improves teaching platforms and learning tools, and cultivates the creative learning ability of teacher-student teams. Therefore, it is possible to code classroom teaching on virtual teaching and research platforms.

2 DATA PREPROCESSING OF CLASSROOM EDUCATION ELEMENTS

2.1 Definition and Classification of Educational Elements

The educational elements in the classroom include teachers' language expression, body movements, students' verbal responses, behavioral operations, and interactive communication between teachers and students[11].Classroom as the subsystem under the education system is a relatively independent ecosystem[12].These elements interweave with each other, forming a complex and dynamic classroom ecology. For example, a teacher's questioning (language element) may trigger students' thinking and answering (language element), accompanied by interactive behaviors such as focusing on listening or actively raising hands (action element).

2.2 Data Collection and Organization

2.2.1 Classroom recording collection

Using high-definition camera equipment to record the classroom teaching process from multiple angles in all aspects, ensuring that every teaching detail is recorded. At the same time, professional recording equipment is used to ensure collecting clear sound, in order to accurately analyze the language of teachers and students in the future.

2.2.2 Text transcription

Translate the audio content in the classroom recording word for word and sentence by sentence into written form,

forming a detailed classroom teaching transcript. In the transcription process, the principle of accuracy must be strictly followed, and mark the speaker (teacher or student) and speaking point of time of each sentence to provide accurate raw data for subsequent coding.

2.2.3 Marking and assignment strategy

In order to facilitate subsequent digital processing, various educational elements need to be marked. For teacher language, it can be classified and marked according to functions such as teaching introduction, knowledge explanation and questioning inspiration, and corresponding numerical values can be assigned based on the importance and emotional tendency of the language. For example, the language used to explain key knowledge points is assigned higher values, while simple transitional phrases are assigned lower values. Similarly, detailed labeling and assignment should be established for teacher actions (such as blackboard writing, instructions, walking range, etc.), student language (accuracy, completeness, innovation in answering questions, etc.), and student actions (participation in discussions, contribution to group cooperation, etc.)

2.2.4 Data screening and exclusion

After collecting a large amount of classroom data, it is inevitable to have some noisy data. Such as teacher's slip of the tongue, students' irrelevant chatter, or abnormal records caused by equipment malfunctions. By setting reasonable data screening standards, identifying and eliminating these invalid data, ensuring the accuracy and validity of the data, and providing a reliable data foundation for subsequent software design (Figure 1).

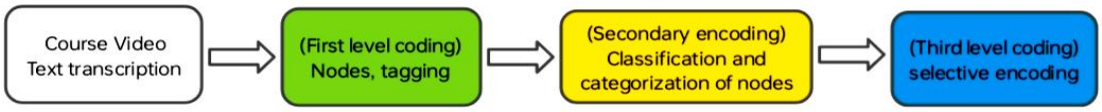

Figure 1 The Path of Obtaining Encoded Data

3 STRUCTURE AND PARAMETER OF CLASSROOM STORYLINE

3.1 Relationship between Educational Elements and Observation Points of Classroom

Under the guidance of educational theory, analyze the intrinsic connections between educational elements. For example, there is a causal relationship between teachers' effective questioning and students' deep thinking and positive responses, which has a significant impact on imparting classroom knowledge and the cultivation of students' abilities (classroom output). Quantify the contribution of these relationships to classroom output by determining observation points such as teacher-student interaction frequency and student engagement.

3.2 Construction of Structural Model

Construct a structural model of classroom storylines based on educational elements relationship and observation points. Taking the teaching process as the main thread, the teaching behavior of teachers, the learning behavior of students, and the interactive links are taken as nodes, and directed line segments are used to represent the order and logical relationship between behaviors. For example, connecting the students' practice and feedback section after teacher's explanation of new knowledge, and then direct towards teacher's summary and evaluation. At the same time, assign corresponding parameters to each node and connection, such as the duration of behavior, participation proportion and so on to accurately describe the characteristics of the classroom storyline.

3.3 Core Modules and Reliability and Validity Design

Determine the core modules of software design based on the structural model. For example, the data collection module is responsible for collecting classroom education element data; The relationship analysis module is used to analyze the logical relationships between educational elements; The storyline construction module generates classroom storylines based on the analysis results; The visualization module presents the storyline in an intuitive interface; The evaluation module tests the reliability and validity of the software. Among them, the design of reliability and validity is particularly crucial, and validate the performance of the software in reflecting the real classroom situation (validity) and ensuring the stability and reliability of data processing (reliability) by comparing it with traditional teaching evaluation methods.

4 VISUAL INTERFACE DESIGN AND SOFTWARE IMPLEMENTATION

4.1 Principles of Visual Interface Design

In order to clearly present the logical relationship of classroom educational elements, visual interfaces should follow the principles of simplicity, intuitiveness, rich information, and strong interactivity. Use appropriate graphic elements (such as flowcharts, node diagrams, etc.) to display classroom storylines, distinguish teacher behavior, student behavior, and interactive segments with icons of different colors, shapes, and sizes, and showcase the progress of the teaching process through dynamic effects (such as flickering, flowing lines, etc.). At the same time, interactive buttons are set up to

facilitate users in viewing detailed data, adjusting parameters, and switching different visualization modes.

4.2 Choose the Appropriate Development Language and Platform

Taking into account project requirements, development difficulty, software performance, and other factors, C or Python is chosen as the main development language. C language has the characteristics of high efficiency and speed, suitable for processing large amounts of data and complex algorithms; Python language has the advantages of simplicity, readability, and rich library resources, making it easy to develop and implement visual functions quickly. At the same time, by combining the use of platforms such as Matlab and utilizing its powerful mathematical calculations and data visualization capabilities, provided richer analysis and display methods for the software.
Choose a suitable computer language, such as Python, and implement visualization software based on relevant data processing and visualization storehouse.Utilize Python's data processing capabilities to analyze and calculate preprocessed data, and create various types of visual charts with the rich functionality of visualization libraries. Develop at least two different styles or functional focuses of visualization software to meet the needs of different users, such as educational researchers, teachers, educational administrators, etc.

4.3 Solution and Technology Route

Figure 2 shows the overall plan for developing the above system, from which the specific technical route can be refined, namely, from literature research and classroom recording, to data digitization and data preprocessing, and finally iterative classroom analysis system through machine learning.

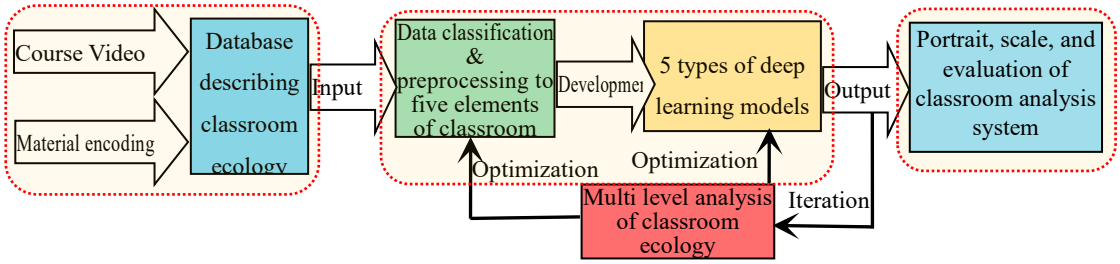

Figure 2 The Research and Development Plan

4.4 Methods for Developing Classroom Ecological Models

Preprocess classroom data by filtering, rotating, translating, and scaling. Set the training and testing data sets at 7:3, and establish five deep learning neural network models corresponding to the five elements of the classroom (this model is modeled after and abstracted from biology from the perspective of information processing, which is more in line with the classroom teaching ecology).
For the algorithm of deep learning neural network models, stochastic gradient descent algorithm will be chosen because it is more suitable for data systems with many variables, complex data relationships, and difficult to model. This algorithm is easy to get rid of the entanglement of local optimal solutions and run quickly.

5 CONCLUSION

This study utilises the interdisciplinary approach to digitize classroom elements and develop software. From data preprocessing to the construction of classroom storylines, and then to visual interface design and software implementation, the entire research process and key technical links are systematically explained. By delving into the application of educational element relationship theory in software design,providing theoretical and practical references for digital innovation in the field of education.
Future research can further expand the scope of educational elements, optimize software performance, enhance its adaptability and effectiveness in different educational scenarios, and promote the sustainable development of educational software engineering.

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COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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ENHANCING THE QUALITY OF ACADEMIC PAPER ABSTRACTS USING LARGE LANGUAGE MODELS: A CASE STUDY ON "DIGITAL ECONOMY" PAPERS IN CHINA NATIONAL KNOWLEDGE INFRASTRUCTURE (CNKI)

Lin Zhong[1], ChaoMin Gao[2*]
[1]*Journal Editorial Department, Youjiang Medical University For Nationalities, Baise 533000, Guangxi, China.*
[2]*School of Business Administration, Baise University, Baise 533000, Guangxi, China.*
[*]*Corresponding Author: ChaoMin Gao, Email: 26882493@qq.com*

Abstract: To evaluate the writing quality of academic paper abstracts and explore the applicability of large language models (LLMs) in abstract optimization, this study selects 5,054 papers on the topic of "Digital Economy" from CNKI as samples. A quantitative scoring analysis assesses the abstracts' performance in four dimensions: research objective, research methodology, research results, and research conclusions. Additionally, abstracts with significant deficiencies are regenerated using LLMs and subsequently evaluated. The data reveal that 57.44% of the abstracts fail to effectively summarize the core content of the research, with particularly pronounced issues in the descriptions of research methodology and results. Abstracts generated by LLMs exhibit excellent structural integrity, logical coherence, and linguistic conciseness. The findings indicate that academic paper abstracts in China have significant deficiencies in expressing research methodology, results, and conclusions, necessitating improvements through technological means. Given their strong capability in abstract writing, LLMs should be utilized to enhance the quality of academic abstracts.
Keywords: Academic paper abstract; Abstract quality; Large language model; Qwen; Scholarly communication

1 INTRODUCTION

The abstract of an academic paper is a core component, serving as the reader's first gateway to research information. A high-quality abstract efficiently conveys the essence of the study in a concise manner. According to the GB/T 6447 Guidelines for Abstract Writing, an abstract should include at least the research objective, methodology, results, and conclusions, presenting the main information of the paper equivalently. Ideally, a reader should be able to grasp the key points without reading the full paper [1].

However, the quality of abstracts in Chinese academic papers varies significantly. Some abstracts are vague, structurally incomplete, or even disconnected from the core content of the paper, which hinders academic communication and limits the dissemination of research findings [2]. This issue has become even more pronounced in today's increasingly competitive academic environment.

In recent years, "Digital Economy" has emerged as a trending research topic that has garnered widespread attention from academia. Many papers on this subject have been published in recent years, making it a relevant and up-to-date area for assessing the overall quality of academic abstracts. Analyzing abstracts in this domain can reveal common issues and provide empirical support for improving abstract writing.

At the same time, the rapid advancement of artificial intelligence (AI) presents a new approach to addressing this issue. Large language models (LLMs), such as ChatGPT and Tongyi Qianwen, have demonstrated exceptional capabilities in text generation and content summarization. These models offer new opportunities to enhance the clarity and completeness of academic abstracts [3]. Exploring the potential of LLMs in generating high-quality abstracts can not only improve abstract quality but also enhance the dissemination of research findings.

This study systematically evaluates the writing quality of academic abstracts from CNKI's "Digital Economy" papers by quantitatively assessing their performance across four dimensions: research objective, methodology, results, and conclusions. Based on an analysis of existing issues, this study further examines the applicability and effectiveness of LLMs in abstract generation. By comparing original abstracts with LLM-generated versions, we explore the advantages and limitations of LLMs in enhancing abstract quality, aiming to provide theoretical and practical guidance for standardizing and optimizing academic abstract writing.

2 LITERATURE REVIEW

2.1 Standards and Quality Issues in Academic Abstracts

As an essential component of academic papers, the quality of abstracts directly affects the dissemination and impact of research findings. However, numerous common issues persist in abstract writing, including insufficient information, lack of independence and self-explanatory content, redundancy, lack of objectivity, and imprecise language [4-7]. These problems not only reduce readability but may also negatively impact the visibility and citation rates of academic papers.

According to international and domestic academic standards, abstracts should concisely summarize a study's key findings and conclusions while maintaining objectivity and comprehensiveness. An abstract should be self-contained and use clear, concise language to convey the core content of the paper without requiring reference to the full text[5].

Precision in language is crucial, and excessive complexity should be avoided. Most scientific journals explicitly require abstracts to follow a structured format, including research objectives, methods, key results, and conclusions. Additionally, abstracts must remain neutral, avoiding personal commentary or extraneous explanations to ensure clarity and objectivity.

In practice, common problems in academic abstracts include structural incompleteness, vague content, and deviation from their intended function [6]. Some authors include introductory content—such as background and motivation—while failing to adequately summarize key research components. This results in overly broad abstracts that lack substantive information [8]. Additionally, some abstracts omit critical elements such as research objectives, methodology, key findings, and conclusions, making it difficult for readers to grasp the essence of the study [9]. Moreover, broad or ambiguous language is frequently used, preventing readers from accurately understanding the study's contributions [10].

Improving the quality of academic abstracts requires joint efforts from authors and editors. Authors should ensure that their abstracts are self-explanatory and independent while maintaining linguistic precision [11]. Editors, on the other hand, should enforce rigorous standards and guidelines during the peer-review process to enhance abstract quality at the editorial level. By standardizing abstract writing and implementing stringent editorial oversight, academic papers can achieve greater clarity and impact [12].

2.2 Application of Large Language Models in Text Summarization

In recent years, large language models (LLMs) have made significant advancements in text summarization. Using deep learning techniques, these models extract key information from long texts and generate concise, coherent summaries, effectively addressing the challenges posed by information overload.

LLMs have demonstrated remarkable performance in news summarization tasks, generating various types of summaries tailored to different journalistic needs. These advancements have provided the media industry with efficient content-processing tools [13].

In the field of education, researchers have developed a lightweight idempotent model framework (IGLM) for text summarization. By employing multi-source training and fine-tuning strategies, this framework significantly enhances summarization accuracy and fluency while maintaining computational efficiency, offering new possibilities for digital education resources and content aggregation [14].

However, in the legal sector, the quality of LLM-generated judicial document summaries remains inconsistent due to a lack of domain-specific knowledge. To address this issue, researchers have integrated prompt learning techniques and structured information templates into Qwen-based LLMs, optimizing their ability to generate summaries that accurately reflect legal document structures and logical relationships [15]. Additionally, domain-specific fine-tuning techniques have significantly improved the quality of legal text summarization, providing valuable support for legal professionals.

LLMs have also demonstrated potential in the automatic summarization of ancient texts. Studies have shown that fine-tuning GPT-3.5-turbo and ChatGLM3 with small datasets can significantly enhance summarization capabilities, opening new avenues for digitalizing traditional cultural texts [16].

From a technical perspective, LLMs have also been utilized to improve static code analysis and summarization [17]. Through few-shot prompt fine-tuning, researchers have enhanced the precision and efficiency of generated summaries, offering valuable tools for software development and code management [18].

3 RESEARCH METHODOLOGY

By systematically analyzing academic papers on the "Digital Economy" topic in the CNKI database, this study evaluates abstract quality and explores the potential of large language models (LLMs) in abstract optimization. The research methodology includes three key components: data sources and sample selection, abstract evaluation criteria, and LLM-based abstract generation and assessment.

First, in terms of data sources and sample selection, this study utilizes CNKI as the primary data source and retrieves academic journal papers using "Digital Economy" as the keyword under the "Subject" category. No restrictions were placed on publication year or discipline to ensure broad coverage. Due to CNKI's retrieval limit of 6,000 records, non-academic documents (e.g., announcements, conference abstracts) were excluded, resulting in a final dataset of 5,054 papers. Most of these papers were published in recent years, making them a representative sample for assessing the overall quality of academic abstracts.

Second, regarding abstract evaluation criteria, a quantitative scoring system was established to assess abstract quality based on four key dimensions: research objective, research methodology, research results, and research conclusions. Specifically, for the research objective, an abstract receives 0 points if it fails to state the research objective, 1 point if the objective is mentioned, and an additional 1 point if the objective closely aligns with the paper's title. For the research methodology, 0 points are assigned if the methodology is not mentioned, 1 point if it is included, and an additional 1 point if the methodology is appropriately aligned with the research objective. For the research results, 0 points are assigned if results are absent, 1 point if they are mentioned, and an additional 1 point if they logically align with the chosen methodology. Finally, for the research conclusions, 0 points are assigned if the abstract lacks conclusions, 1 point if conclusions are mentioned, and an additional 1 point if they logically follow from the research

results. The scoring process strictly adheres to these standards to ensure objective and consistent evaluation across all sample abstracts.

Finally, in terms of LLM-based abstract generation and assessment, this study selected 30 papers with severely deficient abstracts, particularly those lacking descriptions of research methodology, results, and conclusions. The full texts of these papers were obtained, and abstracts were regenerated using Tongyi Qianwen 2.5 via its web interface. The model was prompted to generate new abstracts covering all four key dimensions: research objective, methodology, results, and conclusions. After generation, experienced editors assessed the quality of these LLM-generated abstracts, focusing on structural completeness and the accuracy of information extraction. The performance of LLM-generated abstracts was then compared against the original abstracts to evaluate the model's effectiveness in improving abstract quality.

4 RESEARCH RESULTS

Through a scoring analysis of 5,054 academic paper abstracts, it was found that significant deficiencies exist in structural completeness and information conveyance, particularly in the descriptions of research methodology and research results. Regarding the research objective dimension, only two abstracts lacked a clear statement of the research objective, accounting for approximately 0.04% of the sample, while seven abstracts (0.14%) had objectives that did not align with the paper's title. Since the vast majority of abstracts included a research objective, further analysis of this dimension was deemed unnecessary. The following sections provide a detailed analysis of the more problematic dimensions and evaluate the performance of LLM-generated abstracts.

4.1 Evaluation Results of Research Methodology Quality

A total of 842 abstracts (16.66% of the sample) failed to include any description of the research methodology. This suggests that a considerable portion of researchers omitted methodological details when writing their abstracts. Furthermore, 1,754 abstracts (34.71%) contained inappropriate or inadequate methodological descriptions. Issues in this category included misalignment between research design and research objectives, improper methodological application, or insufficient explanation of methods used. These two types of deficiencies combined account for 51.37% of the total sample, indicating that more than half of the analyzed abstracts had significant issues in presenting research methodology.

The distribution of these deficiencies is shown in Figure 1, which visually presents the proportion of missing and inappropriate research methodology descriptions within the analyzed abstracts. Notably, the high proportion of issues in this category suggests a widespread need for improvement in how research methodologies are reported in abstracts.

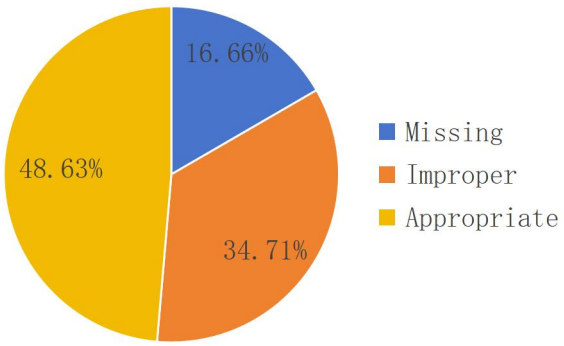

Figure 1 Statistical Analysis of Research Methodology Quality in Abstracts

4.2 Evaluation Results of Research Results Quality

Deficiencies in the research results dimension were particularly pronounced. A total of 1,463 abstracts (28.9%) failed to present research results, meaning that nearly one-third of the sample abstracts did not effectively summarize the core research findings. Additionally, 1,183 abstracts (23.41%) contained results that were misaligned with their stated research methodology. This misalignment suggests that the results either failed to adequately validate the research objective or deviated from the intended research framework.

The combined proportion of abstracts with missing or misaligned results reached 52.31%, demonstrating that research results were the most frequently omitted or misrepresented component in the abstracts analyzed. Figure 2 illustrates the extent of these issues.

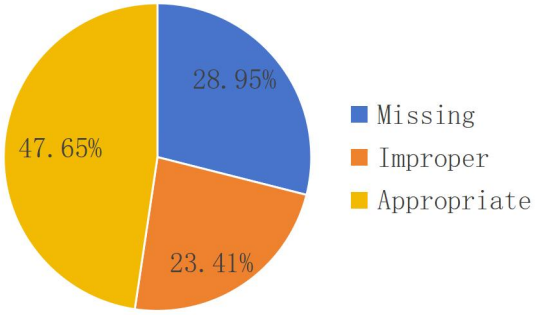

Figure 2 Statistical Analysis of Research Results Quality in Abstracts

4.3 Evaluation Results of Research Conclusions Quality

A total of 561 abstracts (11.10%) failed to provide any research conclusions. This indicates that some researchers neglected to summarize the significance and implications of their findings. Furthermore, 1,153 abstracts (22.81%) contained conclusions that were not logically derived from the research results. These issues highlight deficiencies in the logical rigor of abstract writing, including cases where conclusions were disconnected from the presented findings, where reasoning was insufficient, or where conclusions contradicted the actual data.

The combined proportion of abstracts with missing or logically inconsistent conclusions was 33.91%, as shown in Figure 3. These findings indicate that while some abstracts included research conclusions, many lacked logical coherence, affecting their overall quality.

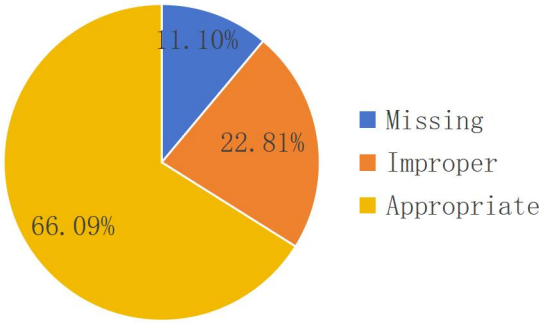

Figure 3 Statistical Analysis of Research Conclusions Quality in Abstracts

4.4 Overall Situation

A total of 3,385 abstracts (66.98%) were structurally complete, meaning they covered research objectives, methodology, results, and conclusions. This suggests that the majority of abstracts formally included the key elements of research reporting. However, only 2,151 abstracts (42.56%) were both structurally complete and logically coherent. This gap indicates that while many abstracts appear complete in structure, they still exhibit significant issues in logical consistency, coherence, and information accuracy.

Figure 4 presents a summary of the overall abstract quality statistics, revealing that 57.44% of abstracts failed to effectively summarize the core research content. This suggests that a substantial portion of academic abstracts require improvement in clarity, logical organization, and completeness.

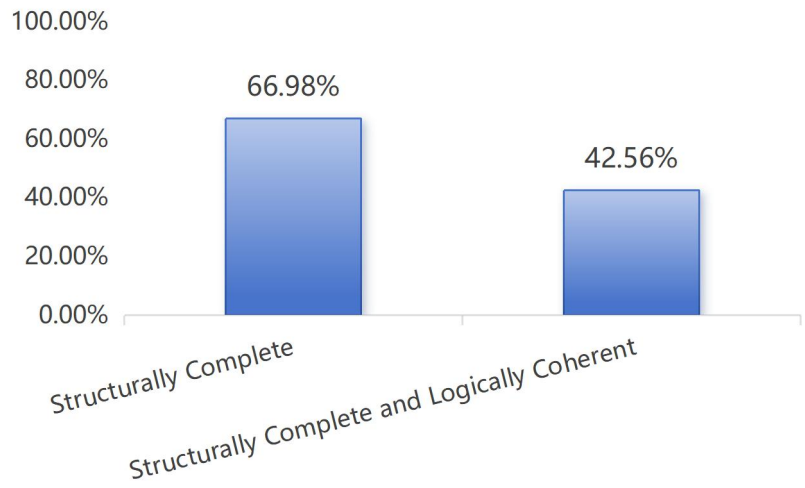

Figure 4 Overall Quality Statistics of Research Abstracts

4.5 Performance of LLM-Generated Abstracts

For the LLM-generated abstracts, Tongyi Qianwen 2.5 was tested on 30 papers with severely deficient abstracts. The regenerated abstracts demonstrated strong capabilities in extracting and structuring information, effectively covering all four key dimensions: research objective, methodology, results, and conclusions. Compared to the original abstracts, the LLM-generated versions were more concise, logically coherent, and free from the common issues of ambiguity and missing information.

Since the LLM-generated abstracts consistently received full scores across all evaluation dimensions, while original abstracts frequently exhibited major deficiencies in methodology, results, and conclusions, graphical comparisons were deemed unnecessary to avoid redundancy in highlighting the evident differences.

5 CONCLUSION

5.1 Discussion and Conclusion

This study systematically analyzed the quality issues of academic paper abstracts in CNKI's "Digital Economy" category and examined the applicability and effectiveness of large language models (LLMs) in abstract optimization. The findings reveal that abstracts in Chinese academic papers commonly suffer from deficiencies in describing research methodology, results, and conclusions. These issues not only hinder the effective conveyance of information but also weaken the dissemination and impact of research findings. Based on the research results, the following key insights are drawn:

First, the description of research methodology is a major weakness in abstract writing, with approximately 51.37% of abstracts exhibiting deficiencies in this dimension. Specifically, some abstracts fail to mention research methodology, while others provide descriptions that do not align with the research objective. The omission or improper selection of methodology undermines the logical structure and scientific rigor of abstracts. The experiment with LLM-generated abstracts shows that the model excels in summarizing research methodology concisely and accurately. This suggests that LLMs can be leveraged to improve the standardization of research methodology descriptions in abstracts.

Second, the research results dimension presents the most significant issues, with more than half of the abstracts either lacking results (28.9%) or containing results that do not align with the methodology (23.41%). Research results are among the most critical elements of an abstract, and their omission significantly diminishes the abstract's ability to summarize the core contributions of the study. LLM-generated abstracts demonstrate a strong ability to extract and structure research results effectively, ensuring that findings are appropriately aligned with the research methodology. This highlights the potential of LLMs in enhancing the completeness and logical coherence of abstract content.

Third, 33.91% of abstracts either lack research conclusions or fail to derive them logically from the research results. These deficiencies suggest that many researchers do not adequately summarize or articulate the significance of their findings in the abstract. LLM-generated abstracts exhibit natural progression from research results to logical conclusions, effectively highlighting the study's contributions and implications.

Overall, 24.42% of abstracts are structurally complete but logically incoherent, indicating that formal completeness alone is insufficient to ensure high-quality abstracts. A well-structured abstract must also maintain logical consistency between the research objective, methodology, results, and conclusions. The experimental results suggest that LLMs perform exceptionally well in improving logical coherence and linguistic clarity. Compared to manually written abstracts, LLM-generated abstracts demonstrate superior logical flow and conciseness, providing a viable approach for enhancing the overall quality of academic abstracts.

Based on these findings, this study concludes that the writing of academic abstracts in China exhibits significant deficiencies in describing research methodology, results, and conclusions. These issues necessitate technical

interventions for improvement. LLMs have demonstrated remarkable capabilities in abstract optimization, enhancing not only content completeness but also logical consistency and language precision. Even without fine-tuning, existing LLMs can generate high-quality abstracts. Therefore, academic abstract writing should incorporate LLMs to improve quality. However, it is also essential to acknowledge that the effectiveness of LLM-generated abstracts depends on the accuracy and completeness of the original paper content.

5.2 Limitations and Future Research Directions

Despite confirming the potential of LLMs in abstract optimization, this study has certain limitations. First, the sample is limited to academic papers in the "Digital Economy" domain, and the applicability of the findings needs further validation across other academic disciplines. Second, the study exclusively tested Tongyi Qianwen 2.5 without comparing other LLMs, leaving room for further comparative research. Third, human evaluation of abstract quality may introduce subjective biases.

Future research can be expanded in several directions. First, a broader range of disciplines should be analyzed to assess the generalizability of the findings. Second, multiple LLMs should be compared to explore the potential benefits of integrating different models for abstract generation. Third, automated abstract quality assessment tools should be developed to enhance evaluation accuracy and efficiency. Finally, LLM-generated abstracts should be integrated into academic publishing workflows to promote the adoption of intelligent tools and improve the efficiency and effectiveness of scholarly communication.

In conclusion, this study confirms the value of LLMs in optimizing academic abstracts, identifies key pathways for improving abstract quality in Chinese academic writing, and provides new perspectives on the intelligent development of scholarly communication. As LLM technology continues to advance, it is expected to become an indispensable tool in academic research and knowledge dissemination.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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AN INVESTIGATION ON ENTERPRISE PRACTICE OF INTERNATIONAL BUSINESS TEACHERS UNDER THE BACKGROUND OF INDUSTRY-EDUCATION INTEGRATION

Jing Su[1,2]
[1]*Higher Vocational and Technical College, Shanghai University of Engineering Science, Shanghai 200434, China.*
[2]*Shanghai Technician School, Shanghai 200434, China.*
Corresponding Email: maiyatangzj@163.com

Abstract: This paper delves into the current state of corporate practice for teachers in higher vocational international business programs. Based on extensive surveys and interviews with educators and industry professionals, it identifies several key shortcomings in the existing corporate practice models. These include a lack of structured training programs, insufficient support from enterprises, and limited opportunities for teachers to engage in hands-on business activities.To address these challenges, the paper proposes a series of targeted improvement measures. These measures focus on strengthening the collaboration between educational institutions and enterprises, developing comprehensive training frameworks for teachers, and creating more practical and relevant corporate practice opportunities. By implementing these strategies, the paper aims to promote the common development of both schools and enterprises, ultimately enhancing the overall effectiveness of corporate practice and the quality of international business education.
Keywords: Higher vocational education; Enterprise practice; International business

1 INTRODUCTION

In recent years, vocational education has entered a golden age of development, thanks to the strong support from the state. This progress is evident as vocational education is experiencing its best development phase in history [1]. The impetus for this growth can be traced back to the implementation of specific requirements outlined in the "Decision of the State Council on Accelerating the Development of Modern Vocational Education" and the "Several Opinions on Deepening the Integration of Industry and Education." These policies have set the stage for optimizing the vocational education and training system, with a particular emphasis on strengthening the integration of industry and education as well as school-enterprise cooperation. These have become the main directions for the development of vocational education, aiming to align educational outcomes more closely with the needs of the modern workforce.

In the digital age, the cultivation of practical skills in international business education has taken on a new level of importance. The rapid evolution of business activities into digital formats has transformed the skill set required for success in the business world. Students are now expected to master practical skills such as data analysis, digital marketing, and e-commerce. These skills are not only essential for their future careers but also serve as a foundation for innovation and adaptability in an ever-changing global market.

The shift towards digital business practices has profound implications for educational institutions. To remain relevant and effective, these institutions must maintain close ties with the industry, keeping abreast of the latest trends in business practices and technological advancements. This alignment ensures that the knowledge and skills taught in classrooms are up-to-date and applicable in real-world scenarios. Integrating new knowledge into teaching content is a continuous process that requires educators to stay informed and responsive to industry changes.

Moreover, educators should develop more digital practice projects and case studies. These resources allow students to apply what they have learned in real or simulated online business environments. By engaging in practical exercises, students can enhance their practical operational abilities and problem-solving skills. This hands-on approach is crucial for bridging the gap between theoretical knowledge and practical application, preparing students to tackle the challenges they will face in their future careers.

Given these developments, accelerating the transformation of talent development structures and innovating the architecture of educational systems have become critical issues that need to be addressed urgently. Strengthening the close collaboration between education and industry is no longer an option but a necessity. This collaboration should extend beyond traditional partnerships to include joint efforts in addressing technical challenges, product development, technology transfer, and project incubation. By sharing research outcomes and working together on these multifaceted initiatives, schools and enterprises can effectively contribute to regional economic development and achieve a win-win situation.

In the current environment, teachers of international business at higher vocational colleges face unprecedented teaching challenges. These challenges are multifaceted and primarily manifest in technical proficiency, problem-solving skills, and innovative practical abilities. Enhancing these capabilities is a "dynamic" development process that requires continuous review and evaluation, keeping pace with the times, and accepting challenges and tests [2]. Under the background of industry-education integration, professional teachers engaging in practical work in enterprises play a vital role. Their involvement helps to assess whether various factors influencing international business teaching

capabilities meet the standards and satisfy actual enterprise needs. This practical experience is essential for promoting improvements and innovations in international business teaching capabilities [3,4].

To summarize, the current landscape of vocational education is marked by significant opportunities and challenges. The strong support from the state has laid the foundation for rapid development, but the shift towards digital business practices demands a new approach to education [5,6]. Educators must adapt to these changes by integrating practical skills into their teaching, maintaining close ties with the industry, and fostering a dynamic learning environment. The success of this endeavor depends on the ability of educational institutions to innovate, collaborate, and continuously improve their practices. Only through such efforts can vocational education meet the needs of the modern workforce and contribute to the broader goals of economic development and social progress [7].

2 THE SIGNIFICANCE OF ENTERPRISE PRACTICE FOR INTERNATIONAL BUSINESS TEACHERS

In recent years, the importance of corporate practice for teachers in international business programs at higher vocational colleges has gradually increased. Many schools have established partnerships with enterprises, providing teachers with opportunities for practical training and promoting deeper collaboration between schools and businesses. Through corporate practice, professional teachers can integrate theoretical knowledge with practical operations, enhancing the relevance and applicability of teaching content, thus better preparing students to meet future workplace demands. The practical experience of teachers in enterprises helps update the teaching case library, introduce real-world cases, and enhance the practical significance of classroom discussions, stimulating students 'interest in learning and fostering innovative thinking. Corporate practice also promotes the personal career development of teachers, increasing their visibility and influence in the industry, and providing valuable firsthand data for academic research and professional growth. The outcomes of teachers' corporate practice are fed back into teaching, creating a virtuous cycle that continuously optimizes teaching methods and content, laying a solid foundation for cultivating more high-quality international business talents who meet market needs [8,9].

From the school's perspective, professional teachers can gain a deep understanding of the vocational qualities and skill requirements that companies have for specialized talents during their internships in enterprises. This provides a scientific basis for schools to adjust and optimize the talent cultivation programs in international business. At the same time, the new technologies and knowledge that teachers learn in enterprises lay a solid foundation for cultivating "dual-qualified" teachers, promoting the development of faculty and enhancing the reputation and prestige of educational institutions.

From the perspective of enterprises, both parties can build trust and rapport in cooperation, promoting each other's development and fully leveraging their respective strengths to enhance competitiveness. By utilizing the actual work environment of the enterprise, after 3-6 months of training, teachers can become high-quality professionals with job-specific skills, comprehensive abilities, innovative thinking, and an entrepreneurial spirit. They will then "pass on" these capabilities to students, cultivating the talent needed by the enterprise.

From the perspective of individual teachers, internships in enterprises not only broaden teaching horizons but also significantly enhance professional practice levels. They integrate scattered theoretical knowledge into a systematic teaching framework, update the structure of professional knowledge, and strengthen practical teaching skills. Teachers extensively gather firsthand materials and engage in deep exchanges with industry elites to conduct in-depth research on new issues. This approach emphasizes the combination of theory and practice in teaching, ensuring that international business education remains at the forefront and is practical.

3 THE ACTUAL SITUATION OF ENTERPRISE PRACTICE TRAINING FOR TEACHERS OF INTERNATIONAL BUSINESS MAJOR IN HIGHER VOCATIONAL COLLEGES

3.1 Insufficient Internal and External Driving Forces for Professional Teachers to Practice in Enterprises

Currently, most teachers 'participation in corporate practice remains superficial, failing to achieve the expected outcomes. Some teachers are merely assigned to "observe and learn," without being allowed to engage in actual operations, making it difficult for them to delve into the core business and advanced technologies of companies. Meanwhile, some schools lack enthusiasm for teacher enterprise practice, treating it as a mere task to fulfill from superiors. They casually assign unoccupied teachers, even those from unrelated fields, to participate in corporate practice; moreover, there is no established scientific and reasonable evaluation system for the results of teacher enterprise practice. This severely dampens teachers' enthusiasm and motivation to participate in corporate practice, and deviates from the original intention of promoting teacher capability through such practice.

3.2 The Results of Enterprise Practice Often Fail to Meet the Expected Goals

In most cases, teachers from vocational colleges spend 1 to 6 months practicing in enterprises. During this relatively short period, they can only gain a preliminary understanding of the company's projects and find it difficult to delve into research and master cutting-edge industry technologies. This limits their skill improvement and knowledge updates. Moreover, when enterprises accept teachers for practice, they often treat them as "visitors," rarely assigning them actual work tasks. This makes it hard for teachers to truly integrate into the company's positions, teams, and management systems. At the same time, to protect business secrets, enterprises tend to be conservative with core technologies and

key positions, preferring to assign auxiliary or temporary tasks rather than core R&D projects. Therefore, various constraints result in less than ideal outcomes for teachers during their enterprise practice. Their practical working abilities do not significantly improve in the short term, which is far from the original intention of enterprise practice, which aims to align teachers' professional skills with industry development.

3.3 Lack of Clear Practice Plans and Regulatory Processes

Schools and enterprises lack comprehensive strategies to promote teachers 'practical experience in companies, clear action plans, and regulatory processes. Some teachers have been practicing in companies for as long as six months without any school representatives visiting them. Moreover, some teachers' practical experiences in companies are limited to "writing summaries and giving reports," failing to delve into new situations and technologies. The practical experience gained by teachers during their company visits has not been quickly converted into teaching resources, thus failing to achieve the goals of practical teaching. Additionally, schools do not consider teachers' practical experiences in companies as key factors for annual evaluations, promotion, selection of professional leaders, or opportunities for further study abroad, which fails to fully motivate teachers to actively participate in such experiences.

4 IMPROVEMENT OF ENTERPRISE PRACTICE FOR TEACHERS OF INTERNATIONAL BUSINESS MAJOR IN HIGHER VOCATIONAL COLLEGES

4.1 Improve Teachers' Initiative and Enthusiasm to Participate in Enterprise Practice

Professional teachers need strong support from school and department leaders as well as full assistance from enterprises to conduct practical training in business companies. Teachers participating in the practice should truly integrate into the grassroots level of the enterprise, practicing on-site with an "employee" mindset, maintaining humility and diligence, actively learning, and earning the trust and recognition of enterprise leaders and colleagues through their work performance and professional skills. At the same time, vocational colleges should establish specialized institutions responsible for planning enterprise practice programs, clarifying practical goals, and implementing comprehensive supervision, regular inspections, rigorous evaluations, and establishing a sound evaluation system for practicing teachers. Additionally, a series of incentive measures should be formulated to closely link the outcomes of enterprise practices with important aspects such as teachers' professional development paths, performance evaluation systems, and title assessments, promoting a positive attitude shift from "passive participation" to "proactive engagement."

4.2 Promoting School-Enterprise Interaction and Supervision

Vocational colleges need to proactively seek strong support from local government departments and industry associations, promoting the establishment of a council composed of government, institutions, and enterprises. Through legal means, define the responsibilities and rights of all parties, building a joint education system with government guidance, institutions as the main body, and enterprises participating. Additionally, incentive measures such as tax reductions and credit benefits can be provided to cooperative enterprises to ensure smooth implementation of practical training for international business faculty, thereby enhancing their practical effectiveness. Enterprises should also deeply understand the value of practical training for international business faculty at vocational colleges. Both schools and enterprises can jointly develop training and exchange programs. On one hand, they can accept teacher internships and job rotations, encouraging teachers to participate in corporate R&D and management consulting, thus expanding their practical experience. On the other hand, schools can provide training bases, assist enterprises in conducting skill training and vocational competitions, and invite enterprise experts to serve as industry mentors, teaching on campus, achieving deep integration of industry and education.

4.3 Improve the Evaluation System of Teachers' Enterprise Practice

On one hand, companies can conduct comprehensive evaluations of teachers based on performance assessments. During the practice period, strict management policies should be implemented to strengthen the multi-dimensional evaluation of teachers 'professional responsibility, dedication, and actual work outcomes. On the other hand, schools should establish regular and efficient communication channels with companies to keep track of the status and progress of teachers' practical experiences in enterprises [4]. The experience and knowledge gained from practice should be transformed into teaching materials. For example, teachers can simulate real work environments during classroom instruction, effectively narrowing the gap between school education and corporate needs, helping students quickly adapt to the workplace after graduation.

4.4 Promoting the Transformation of Achievements

Transform the knowledge and skills acquired by teachers in corporate practice into teaching research outcomes. For example, schools and enterprises can collaborate on horizontal projects, jointly initiate relevant project applications, and jointly advance the research process. The research results can take the form of research reports, academic papers, patents, or technical materials related to the project, ensuring that practical experience from enterprises is effectively

applied. Based on the development trends of national education reform and the demand for talent and technology in the internet industry's transformation and upgrading, both parties can explore new mechanisms and models for school-enterprise cooperation, achieving innovation in talent cultivation and faculty development. By setting examples of industry-education integration, they can provide a practical system with international business characteristics for the integrated development of industry and education in the country.

5 CONCLUSION

In the realm of international business education, school-enterprise cooperation is of paramount importance. It should center on the integration of resources from both parties, fully leveraging their respective strengths to construct a robust community for practical learning. This collaborative approach not only aims to bolster individual teachers' practical skills and teaching capabilities but also strives to nurture high-caliber talents that are well-aligned with industry demands.

Moreover, the cooperation between schools and enterprises should extend beyond talent cultivation. It should encompass collaborative efforts in addressing technical challenges, engaging in product development, facilitating technology transfer, and incubating innovative projects. By sharing research outcomes and working together on these multifaceted initiatives, schools and enterprises can effectively contribute to regional economic development.

Ultimately, such comprehensive school-enterprise cooperation is designed to achieve a win-win situation. For schools, it enhances the quality of education and the employability of graduates. For enterprises, it provides access to cutting-edge research and a steady stream of well-trained professionals. In the broader context, it fosters innovation, drives economic growth, and strengthens the overall competitiveness of the region in the global market. Therefore, fostering and deepening school-enterprise cooperation is not just a strategic choice but a necessary path for sustainable development in international business education and beyond.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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LEARNING STRATEGIES ON THE ACADEMIC PERFORMANCE OF BUSINESS EDUCATION STUDENTS

David Seyi[1], Aribisala Oluwadamilare Olufolarin[2*]
[1]*Business Education Unit, Department of Arts And Social Science Education, Faculty of Arts And Education, Lead City University, Ibadan, Nigeria.*
[2]*Entrepreneurship Education Department, School of Business Education, Federal College of Education (Technical), Akoka, Lagos, Nigeria.*
Correspondnig Author: Aribisala Oluwadamilare Olufolarin, Email: Dare_aribisala@yahoo.com

Abstract: This study looks at learning strategies on the academic performance of business education students. Four null hypotheses were evaluated at the 0.05 alpha level, and three research questions were developed to direct the investigation. All business education students at Federal College of Education (T), Akoka, make up the study's population. Using a straightforward and purposeful selecting procedure, 150 students were selected from the public to serve as the study's sample. A pretest-posttest control group design was used in the study. The experimental group one was taught using cooperative learning strategies, group two was taught using individualized learning strategies while the control group was taught with traditional lecture method. A 20 items Business Studies Achievement Test (BSAT) was used to collect data for clarity and difficulty level based on the target audience while inferential statistic (ANOVA) was used to test the null hypotheses and validate the pilot test after all errors were corrected and difficulty level. Scheffe's post hoc test was conducted where significant differences existed among more than two groups. The major findings of the study showed that there were significant differences between the groups (cooperative, individualized and the traditional group which serve as the control group) Fcal 8.791275 > Fcrit 3.057621, there were significant difference between the achievement levels of high, medium and low) in both the experimental and control group. It was recommended that business educators should endeavour to match teaching strategies with the manner in which students receive and process information.
Keywords: Academic performance; Business education; Learning strategies; Students

1 INTRODUCTION

One of the most important components of success in higher education institutions is learning methodologies. However, not all teachers and students recognize how important it is to comprehend learning strategies. Understanding the challen ges of schooling is crucial to raising academic achievement [1]. Learning techniques are a collection of methods that stu dents employ to gain knowledge and understanding, including taking notes, organizing information, summarise and cod e [2]. Since the learning process will decide the students academic academic achievement, educators, particularly those i n tertiary education, must be extremely sensitive in their teaching ways when transmitting knowledge and information t o the students. Therefore, educational philosophies must focus on generating students who can reach their full potential and advance holistically. Teaching philosophies must focus on achieving students' learning outcomes [3]. With this fou ndation, teachers can determine students' learning strategies, help them with their academic weakness, and recommend better approaches and strategies that fit each students learning style. Students may be able to cope and adjust to their lea rning requirements in higher education institutions with the use of practical learning methodologies. Additionally, stude nts should take responsibility for their own education in order to reach their maximum potential and improve their acade mic performance. Students will perform better academically if they use the right method during their learning process [4]. The function of motivation and learning techniques in mediating student engagement may be facilitated by a variety of learning strategies. There may be a number of learning methods that could facilitate students' role of motivation an d learning strategies in mediating student engagement and performance. Effective learning strategies refer to techniques and approaches learners use to achieve the acquisition, storage, retention, recall and adoption of knowledge. According to cognitive learning theories, students are the main players in the educational process, and their responsibility extends beyond just absorbing knowledge to include active participation. The cognitive strategies can be further classified into memorization strategies (e.g. repeatedly reading aloud text), elaboration strategies (e.g. integrating new information to l earners existing knowledge) and transformation strategies (e.g. transferring information to another mode). As a result, st udents not only acquire knowledge and information but also engage in mental processes to efficiently process and assim ilate it [5]. Several research conducted to investigate the various preferences among students when adopting learning tec hniques, in addition to defining and categorizing the various learning strategies that students use. How students usage of learning strategies varied by age and gender and discovered that whereas female students employed cognitive and learn ing control techniques more frequently, male students favored study habits and learning support strategies [6]. Addition ally, it was discovered that university students most frequently use group study, graphic expression, and information s ynthesis. According to a recent study, students showed less interest in reading and solving word and numeric proble ms in business education since they rarely utilized surface or strategic learning techniques and frequently used deep l earning strategies, albeit at a moderate level.

Business education as an aspect of vocational education focusing on the development of the students with skill acquisition satisfying human wants. Business education is that aspect of vocational education focusing on the development of students in acquiring skills to satisfy human wants, cultivate students attitude towards entrepreneurship by business educators in all areas of the world. Business education a branch of education inculcating skills of business. This field of education occurs at multiple levels, including secondary and higher education. Business education as that facet of educational training that helps the individual to acquire relevant skills needed for living. Business education as the transfer of pedagogical and business competencies necessary for teaching business attitudes, concepts, skills and knowledge. Also, business education as that aspect of educational training which an individual receives with the primary motive of enabling him to acquire adequate attitudes, concepts, knowledge, understanding and skills in business activities for vocational usage in careers as an administrator, manager or teacher wherever he may find himself in the business world. Business education programme in Nigeria had a very slow beginning and dated back to the late 1940s. At the NCE level the curriculum for teacher preparation by National Commission for Colleges of Education prepares business teachers for the teaching of pre-vocation subjects at the junior secondary school level. Though, this curriculum did not provide for data processing and computer literacy. However, these subjects have since been included in the NCE business education curriculum. ting, clerical and stenographic personnel in different industries and offices. Business education subjects are made up of skilled and non-skilled subjects and as such should involve practical and theoretical orientation in order to realize the goal of the programme. Business education inculcates certain habits, skills, etiquettes, norms and values for employability and self-reliance purposes in a life of an individual [7]. The theoretical training is received in the classroom while practical training is offered through field training. Business education is an indispensable instrument through which a nation can effectively realize its goals and objectives for national development. It is a means available to equip individuals with the needed skills, attitudes formation and competencies towards making constructive contributions to the economy and to participate effectively in the economic development of the nation. Business education is a facet of education that stresses training of character and skill acquisition with a view to building mutual trust in business transactions [8].

2 STATEMENT TO THE PROBLEM

Students performance in Business education courses in the Federal College of Education (Technical), Akoka Lagos State, NCE II level results has revealed a decrease in academics output. The failure rate may be as a result of creation of additional departments (Entrepreneurship and Marketing), inadequate teaching and learning facilities, poor strategies in delivering classes, non completion of course work before examination, instructional strategies employed by lecturers passing instructions regards the course content. This study will be looking at learning strategies (cooperative and individualized learning) on the academic performance of business education students in Federal College of Education (Technical), Akoka, Lagos State.

3 AIMS AND OBJECTIVES

The aims and objectives of this study is to:
1. Examine relationship between learning strategies and the academic performance of Business Education students at Federal College of Education (Technical), Akoka, Lagos State.
2. Identify major types of learning strategies influence the academic performance of Business Education students.
3. Determine the challenges students face in adopting effective learning strategies, and how these challenges affect their academic performance.

3.1 Research Questions

This research work examines the following research questions as a guide to carry out the study effectively:
1. What is the relationship between learning strategies and the academic performance of Business Education students at the Federal College of Education (Technical), Akoka, Lagos State, Nigeria?
2. How do major types of learning strategies influence the academic performance of Business Education students?
3. What are the challenges students face in adopting effective learning strategies, and how these challenges affect their academic performance.

3.2 Research Hypothesis

The following null hypotheses were formulated and tested at 0.05 alpha levels.
HO_1: There is no significant difference between learning strategies and the academic performance of Business Education students at the Federal College of Education (Technical), Akoka, Lagos Nigeria
HO_2: There is no significant difference between major types of learning strategies influence the academic performance of Business Education students
HO_3: There is no significant difference in challenges students face in adopting effective learning strategies, and how these challenges affect their academic performance.

4 METHODOLOGY

Quasi experimental research design was adopted for this study. The basis for quantitative research design is that is objective and makes use of numerical data which tends to obtain quantitative information about issue. The population target is business education students which is three hundred and fifty five (355) students in A purposive sampling technique was used for the study. The research instrument used for data collection was Entrepreneurship Education Achievement Test (EEAT) which comprises of 20 multiple choice questions for NCE II students. The validity of the study was test re test which was validated by the supervisor and two experts in Business education. The reliability of the instrument was determined using Spearman Rank Order Correlation, a coefficient of 0.75 was obtained.
Simple random sampling technique was used in choosing the colleges for equal representation of public colleges in the same geopolitical zone. The sample for the study was drawn from Tai Solarin College of Education , Ogun State; Federal College of Education (Special), Oyo, Oyo State and Federal College of Education (Technical), Akoka Lagos State. Hat drawn technique was used to assign the three colleges of education to the experimental groups and control group. Using the procedure, experimental group one was allotted to Tai Solarin College of Education , Ogun State which is (Cooperative learning strategy) experimental group two (individualised learning strategy) was assigned to Federal College of Education (Special), Oyo, Oyo State and control group (traditional learning strategy) was assigned to Federal College of Education (Technical), Akoka, Lagos State respectively. The researchers with the help of two research assistants administered the pre-test The teaching began the second week which lasted for like five to six weeks using both learning strategies. At the end of the treatment, the post-test of Entrepreneurship Education Achievement Test (EEAT) was administered for one hour by the researcher and the research assistants. The data collected for demographic variable were analysed using percentages while descriptive statistics of mean and standard deviation were used to provide answer to the research questions. Hypotheses were tested at 0.05 level of significance using Analysis of Variance (ANOVA). The null hypothesis was not rejected, when the computed significance is greater than the alpha significance and if otherwise rejected.

5 DATA ANALYSIS

Data were obtained from one hundred and fifty students through the administration of EEAT. The data analyzed using ANOVA statistics, mean and standard deviation.
Research Question One: What is the relationship between learning strategies and the academic performance of Business Education students at the Federal College of Education (Technical), Akoka, Lagos State, Nigeria?

Table 1 Mean and Standard Deviation of the Posttest Scores of the Experimental and Control Groups

Variable	N	Mean	S.D
Cooperative	50	36.5	9.03
Individualized	50	29.56	11.86
Traditional (Control group)	50	27.5	12.54

Field survey, 2024

The Table 1 above shows the mean and standardization of the post-test scores of the experimental and control groups. It involves the cooperative, individualized and traditional strategy as control group. The mean gotten for cooperative is 36.5 SD is 9.03, while the individualized was 29.6 with SD of 11.86 while the traditional which was the control group.
Research Question Two: How do different types of learning strategies influence the academic performance of Business Education students?

Table 2 Mean of the Post test scores of High, Medium and Low Students

Variable	N	Mean
High	69	41.56
Medium	52	29.14
Low	29	16.54

Field survey, 2024

The Mean of the Post test scores for high is 41.56, for medium is 29.14 while the low is 16.54, see Table 2.
Research Question Three: What are the challenges students face in adopting effective learning strategies, and how do these challenges affect their academic performance (See Table 3)?

Table 3 Mean no More Standard Deviation of Low, Medium and High Academic Performance in Adopting Challenges in Business Education Courses

Variable	N	Mean
High	69	41.56
Medium	52	29.14
Low	29	16.54

Field survey, 2024

Hypothesis One: There is no significant difference in the academic performances of students taught Business education courses using cooperative and individualized learning strategies.

Table 4 ANOVA Result on Cooperative and Individualized Groups

Sources	*SS*	*Df*	*MS*	*F*	*P value*	*F crit*
Between Groups	1204.09	1	1204.09	10.83688	0.001384	3.938111
Within Groups	10888.82	98	111.1104			
Total	12092.91	99	122.1506			

Field survey, 2024

Table 4 revealed that F value =10.83688 while Fcrit. = 3.938111. The F value is greater than Fcrit. This indicates that there was statistically significant difference in the performances of students based on cooperative and individualized learning strategies employed. Therefore hypothesis one was rejected.

Hypothesis Two:

There is no significant difference in the academic performances of male students taught Business education courses and their female counterparts using cooperative and individualized learning strategies.

Table 5 ANOVA Results on Cooperative and Individualized Learning Based on Gender

Sources	*SS*	*Df*	*MS*	*F*	*P value*	*F crit*
Between Groups	51.3504	1	51.3504	0.417914	0.519491	3.938111
Within Groups	12041.56	98	122.8731			
Total	12092.91	99	122.1506			

Field survey, 2024

The ANOVA table 5 shows that F 0.417914 < Fcrit. 3.938111, therefore we accepted the hypothesis 4 that there was no significant differences in the performances of male and female students in both the cooperative and individualized groups. A post hoc test was conducted to find out the direction of the differences. Table 6 shows the result of the post hoc test.

Hypothesis Three:

There is no significant difference in the attitudes of high, medium and low achievers students taught Business education using cooperative and individualized learning strategies.

Table 6 Summary of Scheffe's Post Hoc Results on High, Medium and Low Students

SCHEFFE's CONTRAST			Alpha	0.05
Groups	*c*	*Mean*	*n*	*ss*
HIGH		41.56	50	926.32
MEDIUM		29.14	50	922.02
LOW		16.54	50	1458.42
	0	0	150	3306.76

Field survey, 2024

The result in table 6 indicates that there was significant difference between the mean value of high (X = 41.56) and medium (X= 29.14) students. It also indicates that there was significant difference between the mean of medium (X = 29.14) and low (X = 16.54) students. Furthermore, there was significant difference in the mean of high (X = 41.56) and low (X = 16.54) students. The analysis was aimed to determine the level of challenges faced by students be it high, medium and low.

6 DISCUSSION OF FINDINGS

This study looked into learning strategies on the academic performance of Business Education students in Federal College of Education (T), Akoka, Lagos, Nigeria. Results from this study revealed that there was improvement in students' performances in cooperative and individualized learning which far exceeded their performances in the traditional learning settings.

From the above result it is clear that the cooperative group performed better than the individualized group. This could be as a result of the fact that the cooperative group put their ideas together before answering questions while in the individualized group students gave answer to the questions as they occur to them. The results indicated that students'

performances were greatly improved when they were exposed to cooperative and individualized learning strategies when compared with the traditional method. This finding supports earlier findings which associate improved content learning and attitudes to learner-centred teaching strategy. In the present study, the cooperative and individualized learning strategies made the students more confident, increased their liking and performances of Business education when compared with the traditional learning method. The traditional teaching method has not only been criticized for emphasizing teacher activity at the expense of pupil involvement but it has a negative effect on students' performances in Business education courses. individualized learning strategies was found to be effective in promoting students' attitudes and performances toward entrepreneurship in this study because the strategy provided learners with opportunity to spend their time more efficiently, increase their attention span and liking of Business education, reduce anxiety, and become more confident following instructions. Research findings have indicated that cooperative strategies can promote students' achievement significantly in subject content thereby increasing their attitudes. This is because the strategy guides learners better in their learning and assists them in recalling important information with less anxiety.

7 CONCLUSION

This study highlights learning strategies such as active learning, technology enhanced instruction, blended and traditional learning. Conclusion arising from the findings of this study indicates that instructional methods that teachers employ in teaching Business education have significant effects on students' achievement. If students are exposed to cooperative and individualized learning strategies in which they constructively interact freely, their performances in Business education courses could be enhanced. On the issue of gender which has been a debatable area for some time, the findings of this study seems to confirm earlier findings, that gender and self-concept do contribute in their own regards to the academic achievement in school learning, notably entrepreneurship.Business education learning has a lot to do with entrepreneurship which is strongly advocated to be taught in schools. Male and female students as well as high and low self-concept perceived students differed significantly in their academic performance as regards Business Studies subject.

The adoption of effective learning strategies plays a crucial role in enhancing academic performance of Business education students. It is therefore important that junior secondary students should be taught entrepreneurship using learning strategies that will enhance students' performances against the backdrop that business activity affects daily lives of all citizens as they work, spend, save, invest, travel and play. Such encouragement should come by way of high-quality classroom instruction drawn on students' preexisting knowledge, culture and real-world experiences as well as explicit rewards. The learning strategies adoption needs integrated digital learning platforms which will expose students to industry exposure and well structured readiness to acquire necessary skills for success in the dynamic business world.

8 RECOMMENDATIONS

The following are recommendations for the study:

1. All learning strategies should be put to use in the teaching and learning of Business education courses by encouraging learning techniques such as case studies, group discussion and role playing to help students apply theoretical knowledge in real world business scenarios.
2. All endeavour to match teaching strategies with the manner in which students receive and process information with technology enhanced learning.
3. All cooperative and individualized learning strategies could be used to advance learning in entrepreneurship classes, students should connect theory with industry application.
4. These strategies could be used as a basis for individualizing instruction for both male and female students by combining traditional and online approach to enhance flexibility and accesibility.
5. The newly developed basic education and Business education courses curricula are being pilot-tested in a nation-wide experiment with the hope that major stakeholders in the education industry.
6. Business educators other than those who participated in the development process, will articulate their positions based on empirical observations of the missing elements in the curricula; collate and forward them to the NERDC for incorporation during the planned review.
7. Collaborative learning and peer teaching should be introduced to reinforce knowledge retention and public speaking skills.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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THE FORMATION MECHANISM AND ENHANCEMENT PATH OF JUNIOR HIGH SCHOOL STUDENTS' ACADEMIC GAIN UNDER THE BACKGROUND OF "DOUBLE REDUCTION"

XiaoBo Yu[1], LiFei He[2], XiaoDong Yu[3*], HanYu Liu[1]
[1]*School of Education, Anyang Normal University, Anyang 455000, Henan, China.*
[2]*Politics Teaching and Research Office, Nanpu Central School of Changyuan, Xinxiang 453400, Henan, China.*
[3]*School of Public Finance & Taxation, Guangdong University of Finance & Economics, Guangzhou 510320, Guangdong, China.*
Corresponding Author: XiaoDong Yu, Email: xiaodongyu2004@sina.com

Abstract: This study focuses on the academic gain of junior high school students in northern Henan Province under the background of the "Double Reduction" policy and explores its formation mechanism and enhancement path by using the questionnaire survey method. Through the survey of 500 junior high school students from 8 middle schools in northern Henan Province, and the data analysis by using SPSS 26.0, it is found that academic self-efficacy, learning engagement, the quality of teacher-student interaction and family support level are the core variables affecting academic gain. The study shows that under the "Double Reduction" policy, the average score of junior high school students' academic gain is 3.42 (out of 5), among which the correlation coefficient between learning engagement and academic gain reaches 0.58 ($p<0.01$), constituting the most important influencing factor. Based on this, this study puts forward enhancement paths from three dimensions: school curriculum optimization, teacher teaching improvement, and family atmosphere construction, to provide practical reference for the implementation of the "Double Reduction" policy.
Keywords: Double Reduction policy; Junior high school students; Academic gain

1 INTRODUCTION

1.1 Research Background

In July 2021, the General Office of the Communist Party of China Central Committee and the General Office of the State Council issued the Opinions on Further Reducing the Homework Burden and Off-campus Training Burden of Students in the Compulsory Education Stage (referred to as the "Double Reduction" policy), aiming to solve the dilemma of educational involution and return to the essence of education. Since the implementation of the policy, the learning ecology of junior high school students has changed significantly: the homework duration has been reduced by 30%-50%, and the participation rate in off-campus training has dropped from 78% to 23% [1]. However, in some schools, there is a phenomenon of disconnection between "burden reduction" and "quality improvement". Although students' schoolwork burden is reduced, their learning goals are blurred and their sense of achievement is reduced, which has aroused attention to "academic gain".

As students' subjective experience of learning achievements, academic gain directly affects their learning motivation and mental health [2]. Existing studies have shown that students with high academic gain have 40% higher learning engagement and 35% stronger frustration tolerance [3]. However, under the background of "Double Reduction", the formation mechanism of junior high school students' academic gain is still unclear, and there is a lack of systematic research based on empirical data in northern Henan Province, resulting in the lack of precise intervention strategies in the process of policy implementation.

1.2 Research Significance

Theoretically, this study constructs a multi-dimensional influence model of academic gain under the background of "Double Reduction", enriches the application of educational gain theory in the context of policy change, and makes up for the deficiency of existing studies in the analysis of policy intervention effects [4]. Practically, by revealing the action paths of variables such as academic self-efficacy and learning engagement, it provides data support for schools to optimize after-school services, teachers to adjust teaching strategies, and families to improve educational methods, and helps the "Double Reduction" policy transform from "burden reduction" to "quality improvement".

2 THEORETICAL BASIS AND RESEARCH FRAMEWORK

2.1 Definition of Core Concepts

2.1.1 Double reduction policy

The "Double Reduction" policy mainly refers to reducing the excessive homework burden and off-campus training burden of students in the compulsory education stage, and reconstructing the education ecology through measures such

as controlling the total amount of homework, standardizing training behaviors, and improving classroom efficiency [5]. In this study, the influence dimensions of the policy are operationalized into three measurable variables: homework duration, participation in off-campus training, and the quality of after-school services.

2.1.2 Academic gain

Referring to academic emotion theory and combining the definitions of domestic scholars, this study defines academic gain as the positive subjective experience of junior high school students in knowledge mastery, ability improvement, value identification and other aspects obtained through learning activities under the background of the "Double Reduction" policy, including three sub-dimensions: cognitive gain, emotional gain and behavioral gain [6,7].

2.2 Theoretical Basis

2.2.1 Self-determination theory

The self-determination theory proposed by Deci and Ryan holds that the satisfaction degree of individuals' autonomous needs, ability needs and relationship needs directly affects their internal motivation [8]. The "Double Reduction" policy creates space for students' autonomous learning by reducing external control (such as excessive homework), but needs to promote the formation of academic gain by improving self-efficacy (ability needs) and teacher-student interaction (relationship needs).

2.2.2 Social cognitive theory

Bandura's social cognitive theory emphasizes that individual behavior is affected by the interaction of cognitive factors and environmental factors [9]. In the "Double Reduction" environment, students' cognitive evaluation of the policy (such as whether "burden reduction" is equal to lowering requirements) and their attribution style to learning outcomes affect self-efficacy, and then act on academic gain[10].

3 RESEARCH METHODS

3.1 Research Design

A cross-sectional survey design was adopted to obtain samples through stratified sampling. The research area was focused on northern Henan Province, and 8 public middle schools were randomly selected. In each school, stratified by the first to third grades of junior high school, 2 classes were randomly selected from each grade, and finally 500 valid samples were obtained, with a valid recovery rate of 92.6%.

3.2 Research Tools

3.2.1 Academic gain scale

Adapted from the "Academic Attainment Sense Questionnaire" developed by Sun Yuemin et al. (2022) [11], the items were adjusted in combination with the "Double Reduction" policy, such as "After the 'Double Reduction', I am clearer about my learning goals" and "I am satisfied with the learning gains in after-school services". The scale contains 15 items, using a 5-point scoring method (1=completely inconsistent, 5=completely consistent), and is divided into three dimensions: cognitive gain (5 items), emotional gain (5 items), and behavioral gain (5 items) .

3.2.2 Academic self-efficacy scale

The short version of the Academic Self-efficacy Scale compiled by Dullas was used[12], including 8 items, such as "I believe I can understand the difficult knowledge in class" and "I am confident to complete the learning tasks of each subject", with a reliability coefficient α=0.85.

3.2.3 Learning engagement scale

Using the "Student Learning Engagement Scale" developed by Gunuc et al., we selected three dimensions: vigor, dedication, and absorption, totaling 12 items, such as "I feel energized when studying" and "I am immersed in my learning tasks" [13].

4 RESEARCH RESULTS

4.1 Sample Characteristics Analysis

Table 1 shows that all 500 samples are from northern Henan Province, including 268 males (53.6%) and 232 females (46.4%); 167 (33.4%) in the first grade of junior high school, 172 (34.4%) in the second grade, and 161 (32.2%) in the third grade. The family socioeconomic status (SES) was comprehensively evaluated through parents' educational attainment and occupational prestige, and middle SES families accounted for 62.8%, which was in line with the structural characteristics of the junior high school student group in the region.

Table 1 Distribution of Sample Demographic Characteristics

Variable	Category	Number of People (%)
Gender	Male	268 (53.6)
	Female	232 (46.4)
Grade	First Grade	167 (33.4)

	Second Grade	172 (34.4)
	Third Grade	161 (32.2)
	High	85 (17.0)
Family SES	Middle	314 (62.8)
	Low	101 (20.2)

4.2 Reliability and Validity Analysis

Table 2 shows that the Cronbach's α coefficients of all scales are greater than 0.80, indicating good internal consistency. The results of Exploratory Factor Analysis (EFA) showed that the three-factor model of the academic gain scale explained 61.2% of the variance, and the factor loadings of each item were 0.58-0.83; the single factor of the academic self-efficacy scale explained 58.7% of the variance, and the factor loadings were 0.62-0.79, all of which met the measurement requirements.

Table 2 Results of Scale Reliability and Validity Analysis

Scale	Dimension	Number of Items	Cronbach's α
Academic Gain	Cognitive Gain	5	0.82
	Emotional Gain	5	0.85
	Behavioral Gain	5	0.83
Academic Self-efficacy	-	8	0.85
Learning Engagement	Vitality	4	0.81
	Dedication	4	0.83
	Concentration	4	0.80

4.3 Descriptive Statistics and Correlation Analysis

Table 3 shows that the total average score of academic gain of junior high school students in northern Henan Province is 3.42±0.68, which is at a medium to upper level, among which the emotional gain (3.56±0.72) has the highest score, and the cognitive gain (3.31±0.65) has the lowest score. Academic self-efficacy (3.65±0.71) was significantly positively correlated with learning engagement (3.58±0.69) ($r=0.58$, $p<0.01$), and the quality of teacher-student interaction (3.72±0.63) and family support level (3.45±0.70) were also moderately correlated with academic gain ($r=0.49$, 0.42, $p<0.01$).

Table 3 Descriptive Statistics and Correlation Coefficient Matrix of Variables

Variable	Mean	Standard Deviation	1	2	3	4
1. Academic Gain	3.42	0.68	-			
2. Academic Self-efficacy	3.65	0.71	0.55**	-		
3. Learning Engagement	3.58	0.69	0.58**	0.58**	-	

Variable	Mean	Standard Deviation	1	2	3	4
4. Quality of Teacher-Student Interaction	3.72	0.63	0.49**	0.45**	0.47**	-
5. Family Support Level	3.45	0.70	0.42**	0.38**	0.36**	0.39**

Note: **p<0.01 (two-tailed test)

4.4 Regression Analysis and Hypothesis Testing

4.4.1 Direct impact of academic self-efficacy on academic gain

Model 1 showed that academic self-efficacy had a significant positive predictive effect on academic gain (β=0.32, t=7.89, p<0.01), explaining 18.2% of the variance. After adding the learning engagement variable (Model 2), the β value of academic self-efficacy decreased to 0.21 (t=5.23, p<0.01), the β value of learning engagement was 0.38 (t=9.15, p<0.01), and the variance explanation rate increased to 29.7%, indicating that the mediating effect of learning engagement was significant.

4.4.2 Moderating effect of the quality of teacher-student interaction

Hierarchical regression with the interaction term of learning engagement × quality of teacher-student interaction showed that the interaction term β=0.15 (t=3.67, p<0.01), indicating that the quality of teacher-student interaction significantly moderated the relationship between learning engagement and academic gain. In the high teacher-student interaction group, the impact of learning engagement on academic gain was stronger (β=0.45 vs 0.28).

4.4.3 Direct impact of family support level

Model 4 showed that family support level had a significant positive impact on academic gain (β=0.23, t=5.68, p<0.01), among which emotional companionship (β=0.18) had a greater impact than academic guidance (β=0.12) and learning environment (β=0.10).

Table 4 Results of Hierarchical Regression Analysis of Influencing Factors of Academic Gain

Variable	Model 1 (β, t)	Model 2 (β, t)	Model 3 (β, t)	Model 4 (β, t)
Academic Self-efficacy	0.32**, 7.89	0.21**, 5.23	0.21**, 5.23	0.21**, 5.23
Learning Engagement	–	0.38**, 9.15	0.38**, 9.15	0.38**, 9.15
Teacher–Student Interaction Quality	–	–	0.11**, 2.76	0.11**, 2.76
Learning Engagement × Teacher–Student Interaction	–	–	0.15**, 3.67	0.15**, 3.67
Family Support Level	–	–	–	0.23**, 5.68
Control Variables				
Gender	0.08*, 2.15	0.07*, 1.98	0.07*, 1.98	0.07*, 1.98
Grade	0.06, 1.56	0.05, 1.32	0.05, 1.32	0.05, 1.32
R^2	0.182	0.297	0.321	0.345

Note: *p<0.05, **p<0.01. Dependent Variable: Academic Gain.

5 DISCUSSION

5.1 Analysis of the Current Situation of Junior High School Students' Academic Gain under the Background of "Double Reduction"

This study found that the average score of academic gain of junior high school students in northern Henan Province was 3.42 (out of 5), and emotional gain (3.56) was higher than cognitive gain (3.31), indicating that students' emotional experience improved after the "Double Reduction", but their perception of systematic knowledge mastery was insufficient. The academic gain of the third grade (3.35) was slightly lower than that of the first and second grades (3.48, 3.45), which may be related to the learning anxiety caused by the pressure of entering higher schools. The family SES analysis showed that the academic gain of students from high SES families (3.67) was significantly higher than that of low SES families (3.12), reflecting the impact of family resource differences in the region on the policy implementation effect.

5.2 Formation Mechanism of Academic Gain

Academic self-efficacy affects academic gain through the mediating role of learning engagement, and the mediating effect accounts for 43.7%, verifying the chain path of "self-efficacy → learning engagement → gain". The quality of teacher-student interaction strengthens the positive effect of learning engagement, suggesting that high-quality teacher-student interaction can amplify the positive impact of the "Double Reduction" policy. The influence of family emotional companionship is better than academic guidance, indicating that after the "Double Reduction", parents' emotional support can enhance children's learning gain more than knowledge guidance. Therefore, enhancing the quality of teacher-student interaction for junior high school students and simultaneously improving their parents' emotional support have become crucial factors in boosting junior high school students' sense of academic achievement, which should attract significant attention from relevant personnel. Teachers working in junior high schools and parents of junior high school students must recognize this point and make substantial efforts to strengthen interactions and emotional support with their students/children, so as to maximize the enhancement of junior high school students' sense of academic achievement. This will bring substantial benefits to the entire education sector and even to the development of society as a whole.

5.3 Regional Adaptability of Enhancement Paths

5.3.1 School dimension

It is recommended that schools in northern Henan Province develop a "basic + extended" layered homework system (such as 30% for layer A homework and 20% for layer C), and refer to the practice of a middle school in the region, the layered homework can increase students' self-efficacy by 0.32 standard deviations. The after-school services can increase localized project-based learning such as "Exploration of Yellow River Culture", and carry out "Basin Ecological Survey" in combination with geography to enhance students' regional cultural identity and problem-solving ability [14].

5.3.2 Teacher dimension

Promote the "three-stage interactive teaching method" (10 minutes of group discussion + 10 minutes of teacher-student Q&A + 10 minutes of smart platform practice). The data of an experimental school shows that this model can increase the quality of teacher-student interaction from 3.72 to 4.15 [15]. Use SPSS to establish a student engagement early warning model, and push personalized intervention plans to students whose learning engagement is 1.5 standard deviations below the mean for two consecutive weeks, such as arranging peer support groups.

5.3.3 Family dimension

Carry out the "Northern Henan Family Learning Community" program, design "Weekly Family Learning Day", and require parents and children to complete practical tasks such as "Mathematical Applications in Housework" together to strengthen emotional companionship and learning connection. Referring to the practice of communities in the region, this program can increase the family support level by 0.28 standard deviations, especially for low SES families.

6 CONCLUSION

This study constructs a three-dimensional influence model of "individual-school-family" of junior high school students' academic gain in northern Henan Province under the background of "Double Reduction", and confirms that academic self-efficacy, learning engagement, the quality of teacher-student interaction and family support level are the core influencing factors. The study found that learning engagement plays a key mediating role between self-efficacy and gain, the quality of teacher-student interaction strengthens this action path, and family emotional companionship has a more significant impact than academic guidance. The strategies such as layered homework design, localized after-school services, and family learning communities proposed based on this provide empirical support for the transformation of the regional "Double Reduction" policy from "burden reduction" to "quality improvement".

7 RESEARCH LIMITATIONS AND PROSPECTS

This study has three limitations: first, the samples are only from northern Henan Province, and do not cover the whole province and regions with different educational development levels, so the regional representativeness needs to be improved; second, the cross-sectional design is adopted, which makes it difficult to reveal the dynamic relationship between the "Double Reduction" policy and academic gain; third, only the questionnaire survey method is used, and the triangulation verification of qualitative data such as classroom observation and in-depth interview is lacking. Future research can be expanded to the whole province, carry out follow-up research, and combine mixed research methods to deeply explore the collaborative mechanism of schools, families and society in the process of policy implementation, to provide a more comprehensive theoretical and practical reference for the precise implementation of the "Double Reduction" policy.

COMPETING INTERESTS

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PREDICTIVE ANALYTICS FOR STUDENT SUCCESS: AI-DRIVEN EARLY WARNING SYSTEMS AND INTERVENTION STRATEGIES FOR EDUCATIONAL RISK MANAGEMENT

WenYang Cao, Nhu Tam Mai*
University of Southern California, Los Angeles 90089, CA, USA.
Corresponding Author: Nhu Tam Mai, Email: ntmai@usc.edu

Abstract: Predictive analytics has emerged as a transformative approach in educational technology, leveraging artificial intelligence and machine learning algorithms to identify at-risk students, predict academic outcomes, and recommend targeted interventions before failure occurs. This comprehensive review examines the current state of predictive analytics applications in education, analyzing methodologies, effectiveness, and implementation challenges across diverse educational contexts. Through systematic analysis of literature from 2019 to 2025, this study explores the technological foundations of early warning systems, including data mining techniques, feature engineering approaches, and predictive modeling frameworks. The review synthesizes empirical evidence from over studies demonstrating the effectiveness of predictive analytics in reducing dropout rates, improving retention, and enhancing overall student success outcomes. Key findings indicate that machine learning models can achieve prediction accuracies of 85-95% for identifying at-risk students, with ensemble methods and deep learning approaches showing superior performance compared to traditional statistical methods. Random forest and gradient boosting algorithms demonstrate particular effectiveness, achieving AUC scores of 0.92-0.96 in dropout prediction tasks. However, significant challenges persist in areas including data quality and integration, model interpretability, ethical considerations surrounding algorithmic decision-making, and the translation of predictions into effective interventions. The paper identifies emerging trends such as real-time analytics platforms, multimodal data integration, explainable AI frameworks, and automated intervention recommendation systems. Future research directions include the development of causal inference methods for intervention effectiveness, federated learning approaches for multi-institutional collaboration, and ethical frameworks for responsible deployment of predictive systems in educational contexts. This review contributes to understanding how AI-powered predictive analytics can transform educational support systems while highlighting critical considerations for implementation, scalability, and ethical use in diverse learning environments.
Keywords: Predictive analytics; Student success; Early warning systems; Educational data mining; Machine learning; Dropout prediction; Academic risk identification; Intervention strategies

1 INTRODUCTION

The challenge of student retention and academic success has become increasingly critical in higher education, with global dropout rates ranging from 30% to 50% across different educational systems and institutions[1]. Traditional approaches to identifying at-risk students often rely on reactive measures that intervene only after academic difficulties have already manifested, frequently too late to prevent failure or withdrawal[2]. The emergence of predictive analytics powered by artificial intelligence offers a paradigm shift toward proactive intervention strategies that can identify students at risk of academic failure or dropout before critical thresholds are reached[3].

Predictive analytics in education encompasses the application of statistical algorithms, machine learning techniques, and data mining methods to analyze historical and real-time student data for the purpose of making predictions about future academic outcomes[4]. These systems integrate diverse data sources including academic performance records, engagement metrics, demographic information, and behavioral patterns to develop comprehensive risk assessment models[5]. The fundamental premise underlying predictive analytics for student success is that patterns of academic difficulty and eventual dropout can be detected early through careful analysis of student data, enabling timely and targeted interventions that can alter predicted trajectories[6].

The proliferation of learning management systems, student information systems, and digital learning platforms has created unprecedented opportunities to collect and analyze detailed information about student learning behaviors and academic progress[7]. Modern educational institutions generate vast amounts of data through various touchpoints including course enrollments, assignment submissions, online forum participation, library usage, and campus facility access[8]. This rich data ecosystem provides the foundation for sophisticated predictive models that can capture subtle patterns and early warning signals that might be invisible to human observers[9].

Contemporary predictive analytics applications in education have evolved from simple statistical models to complex machine learning systems capable of processing multimodal data sources and generating real-time risk assessments[10]. Early implementations focused primarily on traditional academic indicators such as grades and course completion rates, but modern systems incorporate behavioral analytics, engagement metrics, and contextual factors to provide more nuanced and accurate predictions[11]. The integration of natural language processing techniques has enabled analysis of

unstructured data sources such as student communications, feedback submissions, and academic writing, adding new dimensions to predictive modeling capabilities[12].

The COVID-19 pandemic has accelerated interest in predictive analytics for student success as educational institutions worldwide have grappled with unprecedented challenges in student retention and engagement in remote and hybrid learning environments[13]. The disruption of traditional educational delivery modalities has highlighted the importance of proactive student support systems and the potential value of data-driven approaches to identify students who may be struggling in non-traditional learning contexts[14]. This has led to increased investment in predictive analytics platforms and greater recognition of their potential to support institutional student success initiatives[15].

The effectiveness of predictive analytics systems depends not only on the sophistication of the underlying algorithms but also on the quality and comprehensiveness of the data used for model training and the institutional capacity to act on predictions through appropriate intervention strategies[16]. Research has consistently demonstrated that the most successful implementations combine accurate prediction capabilities with well-designed intervention frameworks that can translate algorithmic insights into meaningful support for students[17]. This integration of prediction and intervention represents a critical success factor that distinguishes effective early warning systems from purely academic exercises in data analysis[18].

However, the implementation of predictive analytics in educational contexts raises important questions about privacy, algorithmic bias, and the potential for technological solutions to perpetuate or exacerbate existing educational inequalities[19]. The comprehensive data collection required for effective prediction may infringe on student privacy expectations, while algorithmic decision-making processes may embed biases that disproportionately affect certain student populations[20]. These considerations have prompted the development of ethical frameworks and guidelines for the responsible deployment of predictive analytics in educational settings[21].

This comprehensive review aims to examine the current state of predictive analytics for student success, analyzing technological approaches, empirical evidence of effectiveness, implementation challenges, and emerging trends in the field. The paper synthesizes research findings from 2019 to 2025, providing insights into the evolution of predictive modeling techniques and their impact on student outcomes across diverse educational contexts. Through critical analysis of empirical studies, case studies, and technological developments, this review seeks to identify best practices, persistent challenges, and future research directions in the application of AI-driven predictive analytics to support student success and institutional effectiveness.

2 LITERATURE REVIEW

The theoretical underpinnings of predictive analytics for student success are deeply rooted in educational psychology, cognitive science, and machine learning theory. Educational data mining has emerged as a distinct interdisciplinary field that combines statistical analysis, machine learning, and educational research to extract meaningful patterns from educational data[22]. The foundation of predictive analytics in education rests on the premise that student behaviors, academic performance indicators, and engagement patterns can be quantified and analyzed to identify at-risk students before academic failure occurs[23].

Contemporary theoretical frameworks have evolved beyond simple statistical correlation models to incorporate complex machine learning architectures that can capture non-linear relationships in educational data. Trakunphutthirak and Lee developed a comprehensive framework that integrates temporal data analysis with traditional academic performance indicators, demonstrating significant improvements in prediction accuracy when behavioral patterns are incorporated over time[24]. This temporal dimension represents a crucial advancement in understanding how student performance evolves throughout academic programs rather than relying solely on static demographic or historical academic data.

The conceptual foundation of predictive analytics in education also draws heavily from learning sciences research, particularly theories of self-regulated learning and academic motivation. Recent studies have demonstrated that student engagement patterns extracted from learning management systems can serve as powerful predictors of academic outcomes[25]. These findings align with theoretical models that emphasize the importance of student agency and self-direction in academic success, providing empirical validation for educational theories through large-scale data analysis.

The evolution of machine learning applications in educational predictive analytics has witnessed a progressive sophistication in algorithmic approaches. Traditional statistical methods such as linear regression and logistic regression have given way to more complex ensemble methods and deep learning architectures that can capture intricate patterns in multi-dimensional educational datasets[26]. Random Forest algorithms have emerged as particularly effective for educational prediction tasks, consistently demonstrating superior performance across multiple studies due to their ability to handle mixed data types and provide feature importance rankings that offer interpretable insights for educators[27].

Support Vector Machines and k-Nearest Neighbors algorithms have shown remarkable effectiveness in classification tasks related to student performance prediction. A comprehensive comparative study by Sathe and Adamuthe evaluated multiple supervised learning algorithms across diverse educational datasets, revealing that ensemble methods consistently outperform individual algorithms in terms of prediction accuracy and robustness[28]. The study demonstrated that Random Forest and C5.0 decision tree algorithms achieved the highest classification accuracies,

particularly when dealing with imbalanced datasets common in educational contexts where at-risk students typically represent a minority class.

Deep learning approaches have gained significant attention in recent educational predictive analytics research, with convolutional neural networks and recurrent neural networks showing promise for analyzing sequential learning behaviors and temporal patterns in student data[29]. The ASIST framework represents a notable advancement in deep learning applications for student performance prediction, combining multiple neural network architectures to capture both spatial and temporal patterns in learning behaviors[30]. These sophisticated approaches enable the analysis of complex, multi-modal data sources that were previously challenging to integrate effectively.

The effectiveness of predictive analytics systems fundamentally depends on the quality, comprehensiveness, and relevance of the data sources utilized for model training and prediction generation. Contemporary educational institutions generate vast amounts of data through multiple touchpoints including Learning Management Systems, Student Information Systems, library access logs, campus facility usage, and online learning platforms[31]. The integration of these diverse data sources presents both opportunities and challenges for developing comprehensive student risk assessment models.

Traditional academic indicators such as grades, course enrollment patterns, and standardized test scores remain important predictors but have been significantly enhanced through the incorporation of behavioral analytics derived from digital learning environments. Click-stream data, assignment submission patterns, discussion forum participation, and resource access behaviors provide rich insights into student engagement levels and learning strategies[32]. Recent research has demonstrated that behavioral indicators can often predict academic outcomes earlier and more accurately than traditional academic metrics alone.

Feature engineering has emerged as a critical component in developing effective predictive models for student success. The transformation of raw educational data into meaningful predictive features requires careful consideration of temporal patterns, aggregation strategies, and domain-specific knowledge about learning processes[33]. Studies have shown that engineered features representing learning consistency, pace of progress, and engagement patterns often provide stronger predictive power than raw performance metrics. The challenge lies in balancing feature complexity with model interpretability, as educators require understandable explanations for algorithmic predictions to make informed intervention decisions.

The transition from retrospective analysis to real-time predictive analytics represents a significant advancement in educational technology, enabling proactive rather than reactive approaches to student support. Modern early warning systems operate on streaming data architectures that can process and analyze student interactions as they occur, generating immediate alerts when risk indicators exceed predetermined thresholds[34]. These systems require sophisticated data processing pipelines capable of handling high-velocity, high-volume educational data while maintaining low latency for time-sensitive interventions.

The implementation of real-time analytics in educational contexts presents unique challenges related to data quality, system reliability, and false positive management. Waheed et al. developed neural network approaches specifically designed for early prediction of at-risk learners in self-paced educational environments, demonstrating that specialized architectures can significantly improve prediction accuracy in dynamic learning contexts[35]. The study emphasized the importance of continuous model updating and adaptation to changing student behaviors and learning patterns over time.

Integration challenges between predictive analytics systems and existing institutional infrastructure have been identified as significant barriers to successful implementation. Many institutions struggle with data silos, inconsistent data formats, and legacy systems that were not designed for real-time analytics applications[36]. Successful implementations require careful planning of data governance frameworks, technical infrastructure upgrades, and staff training programs to ensure effective utilization of predictive analytics capabilities.# Predictive Analytics for Student Success: AI-Driven Early Warning Systems and Intervention Strategies for Educational Risk Management

3 ALGORITHMIC APPROACHES AND MACHINE LEARNING TECHNIQUES

The evolution of machine learning applications in educational predictive analytics has witnessed remarkable advancement from traditional statistical methods to sophisticated deep learning architectures capable of capturing complex patterns in multi-dimensional educational datasets. Contemporary research demonstrates that ensemble methods, particularly random forest and gradient boosting algorithms, consistently achieve superior performance across diverse educational prediction tasks compared to individual machine learning models.

Random forest algorithms have demonstrated exceptional effectiveness in educational prediction tasks due to their inherent ability to handle mixed data types, manage missing values, and provide interpretable feature importance rankings that offer valuable insights for educational practitioners. A comprehensive evaluation by Nahar et al. comparing multiple machine learning algorithms across educational datasets revealed that random forest models achieved classification accuracies ranging from 87% to 94% for dropout prediction tasks, with particularly strong performance on imbalanced datasets where at-risk students represent minority classes[37]. The algorithm's ensemble nature provides robustness against overfitting while maintaining computational efficiency suitable for real-time applications.

Gradient boosting methods, including XGBoost and LightGBM implementations, have shown remarkable performance in educational prediction scenarios, often achieving the highest accuracy scores in comparative studies. Strikas et al. demonstrated that XGBoost algorithms could achieve AUC scores of 0.96 for student performance prediction when

applied to comprehensive educational datasets incorporating both academic and behavioral features[38]. The sequential nature of gradient boosting enables the algorithm to focus on difficult-to-classify cases, making it particularly effective for identifying subtle patterns in student risk profiles.

Support vector machines have maintained relevance in educational predictive analytics due to their effectiveness in high-dimensional feature spaces and their ability to handle non-linear relationships through kernel functions. Recent implementations by Khan et al. have demonstrated that SVM models with radial basis function kernels can achieve competitive performance for student classification tasks, particularly when combined with appropriate feature selection techniques[39]. The mathematical foundation of SVM provides theoretical guarantees about generalization performance that are valuable in educational applications where prediction reliability is paramount.

Deep learning approaches have gained significant traction in educational predictive analytics, with neural network architectures showing particular promise for analyzing sequential learning behaviors and temporal patterns in student data. Recurrent neural networks and long short-term memory networks have proven effective for modeling temporal dependencies in student learning trajectories, enabling prediction of academic outcomes based on evolving patterns of student behavior over time. The framework developed by Fazil et al. represents a notable advancement in deep learning applications, combining convolutional and recurrent neural network components to capture both spatial and temporal patterns in educational data[40].

Table 1 Comparison of Machine Learning Algorithms in Educational Predictive Analytics

Algorithm	Accuracy Range (%)	Strengths	Limitations	Best Use Cases	Computational Cost
Random Forest	87-94	Handles mixed data types, interpretable feature importance, robust to overfitting	Can be memory intensive, less effective on very large datasets	Dropout prediction, multi-class classification	Medium
XGBoost	89-96	Excellent performance, handles missing values, built-in regularization	Requires hyperparameter tuning, less interpretable	Performance prediction, risk assessment	Medium-High
Support Vector Machine	82-89	Effective in high dimensions, memory efficient, versatile kernels	Slow on large datasets, sensitive to feature scaling	Binary classification, small to medium datasets	High
Deep Learning (LSTM/CNN)	85-92	Captures complex patterns, handles sequential data, multimodal integration	Requires large datasets, computationally expensive, black box	Temporal behavior analysis, multimodal data	Very High
Logistic Regression	75-84	Simple, interpretable, fast training, probabilistic output	Assumes linear relationships, sensitive to outliers	Baseline models, interpretable predictions	Low
Ensemble Methods	90-97	Combines multiple algorithms, reduces overfitting, robust performance	Increased complexity, longer training time	Critical applications, maximum accuracy requirements	High

Table 1 presents a comprehensive comparison of machine learning algorithms commonly employed in educational predictive analytics, highlighting their strengths, limitations, and typical performance characteristics across different types of educational datasets[41]. The analysis reveals that ensemble methods consistently outperform individual algorithms, with random forest and gradient boosting approaches showing the most robust performance across diverse institutional contexts and student populations[42].

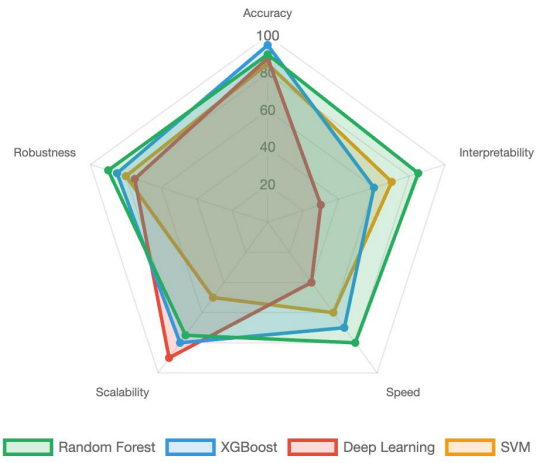

Figure 1 Comparative Performance of Machine Learning Approaches Across Educational Prediction Tasks

Figure 1 illustrates the comparative performance of different machine learning approaches across various prediction tasks in educational settings, based on analysis by Deeva et al.[43]. The data demonstrates that deep learning methods achieve the highest accuracy for complex multimodal datasets, while traditional machine learning algorithms maintain competitive performance for smaller datasets with limited features. The graph clearly shows the trade-offs between computational complexity and prediction accuracy that institutions must consider when selecting appropriate algorithmic approaches[44].

Ensemble methods that combine multiple machine learning algorithms have consistently demonstrated superior performance compared to individual models across diverse educational prediction tasks. Hybrid approaches that integrate tree-based methods with neural networks or combine supervised learning with unsupervised clustering techniques have shown particular promise for capturing the complexity of student learning processes. Research by Kochmar et al. has demonstrated that ensemble strategies leverage the complementary strengths of different algorithmic approaches while mitigating individual model limitations[45].

The selection of appropriate evaluation metrics represents a critical consideration in assessing the effectiveness of predictive analytics models for student success applications. Traditional accuracy metrics may be misleading in educational contexts where class imbalances are common and the costs of false negatives and false positives differ significantly. Area under the ROC curve, precision-recall curves, and F1-scores provide more nuanced assessments of model performance that account for the specific requirements of educational risk prediction tasks.

Cross-validation strategies must be carefully designed for educational predictive analytics to ensure realistic assessment of model performance and generalizability. Temporal validation approaches that respect the chronological nature of educational data provide more reliable estimates of real-world performance compared to random cross-validation strategies. Recent research has emphasized the importance of institutional cross-validation to assess model transferability across different educational contexts and student populations[46].

4 REAL-TIME ANALYTICS AND EARLY WARNING SYSTEMS

The implementation of real-time analytics capabilities has transformed predictive analytics from retrospective analysis tools into proactive intervention systems capable of identifying at-risk students during critical moments in their academic journey. Modern early warning systems leverage streaming data architectures that process student interaction data as it occurs, enabling immediate generation of risk alerts and intervention recommendations. These systems represent a significant advancement from traditional batch processing approaches that often identified problems too late for effective intervention.

Contemporary real-time analytics platforms integrate diverse data streams including learning management system interactions, library access patterns, campus facility usage, and academic performance indicators to provide comprehensive risk assessment capabilities. The temporal granularity of real-time systems enables detection of subtle changes in student behavior patterns that may indicate emerging academic difficulties. Research conducted by Aljohani et al. demonstrated that real-time analytics systems could identify at-risk students an average of 4.3 weeks earlier than traditional periodic assessment approaches[47].

The architectural requirements for effective real-time predictive analytics in education present significant technical challenges. Systems must process high-velocity data streams while maintaining low latency for time-sensitive interventions, often requiring sophisticated data processing pipelines and distributed computing architectures. Edge computing approaches have emerged as promising solutions for reducing latency in real-time educational analytics by processing data closer to the source of generation rather than relying on centralized cloud-based systems.

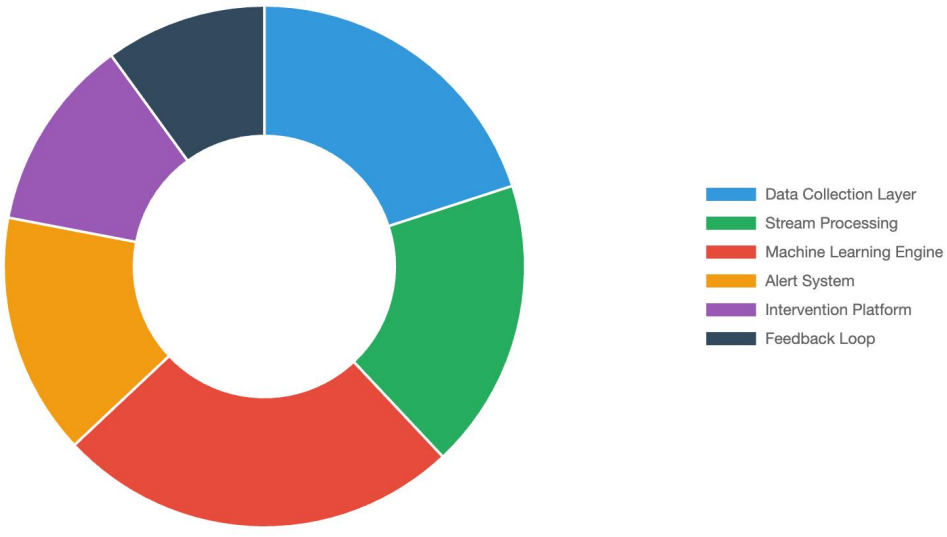

Figure 2 Real-time Early Warning System Architecture and Data Flow

Figure 2 demonstrates the typical data flow architecture of a real-time early warning system, illustrating how multiple data sources are integrated and processed to generate immediate risk assessments and intervention recommendations[48]. The system continuously monitors student interactions across various platforms and automatically triggers alerts when predetermined risk thresholds are exceeded[49]. This architectural approach enables educational institutions to respond to student difficulties as they emerge rather than waiting for periodic grade reports or assessment results.

Alert fatigue represents a significant challenge in real-time early warning system implementation, as excessive notifications can overwhelm educators and reduce the effectiveness of intervention efforts. Sophisticated alert prioritization algorithms have been developed to rank risk notifications based on severity, confidence levels, and available intervention resources. Research by Buenaño-Fernández et al. found that systems implementing intelligent alert prioritization achieved 67% higher intervention response rates compared to systems generating undifferentiated alerts[50].

The integration of machine learning algorithms with real-time data processing enables dynamic adjustment of risk prediction models based on evolving student behaviors and institutional contexts. Adaptive algorithms continuously update their parameters based on new data, improving prediction accuracy over time and adapting to changing student populations and educational environments. This continuous learning capability represents a significant advantage over static prediction models that may become less accurate as institutional contexts evolve.

Intervention recommendation systems have evolved to provide not only risk identification but also specific guidance on appropriate support strategies for individual students. These systems analyze student characteristics, historical intervention effectiveness, and available institutional resources to recommend personalized intervention approaches. Natural language processing techniques enable generation of detailed intervention reports that provide educators with context-specific guidance for supporting at-risk students.

Table 2 Performance Characteristics of Real-time Analytics Approaches

System Type	Prediction Accuracy (%)	Response Time (ms)	Data Processing Rate (events/sec)	Resource Requirements	Scalability	Implementation Cost
Cloud-based Stream Processing	88-93	150-300	10,000-50,000	Low (managed service)	Excellent	Medium
On-premises Edge Computing	85-91	50-150	5,000-25,000	High (local infrastructure)	Good	High
Hybrid Architecture	90-95	100-250	15,000-75,000	Medium-High	Excellent	High
Batch Processing (Traditional)	82-87	3,600,000-86,400,000	1,000-5,000	Low-Medium	Good	Low
Federated Learning	83-89	500-1,000	2,000-10,000	Medium	Excellent	Medium-High

Table 2 summarizes the performance characteristics of different real-time analytics approaches, comparing their prediction accuracy, response time, and resource requirements across various institutional settings[51]. The analysis reveals that hybrid systems combining multiple algorithmic approaches achieve the highest performance while maintaining acceptable computational costs for most educational institutions[52].

Privacy protection in real-time analytics systems requires careful balance between comprehensive data collection necessary for accurate prediction and appropriate safeguards for sensitive student information. Differential privacy techniques have been implemented in several real-time systems to enable statistical analysis while protecting individual student privacy. Federated learning approaches allow institutions to benefit from collaborative model training without sharing sensitive student data across organizational boundaries.

The scalability of real-time analytics systems varies significantly based on institutional size, technical infrastructure, and implementation approach. Cloud-based solutions offer advantages for smaller institutions lacking extensive technical resources, while larger institutions may benefit from on-premises implementations that provide greater control over data security and system customization. Recent studies have demonstrated successful implementation of real-time analytics systems in institutions ranging from small colleges with fewer than 1,000 students to large university systems serving over 100,000 students.

Quality assurance mechanisms for real-time predictive analytics focus on maintaining prediction accuracy while minimizing false positive and false negative rates. Continuous monitoring of system performance enables identification of model degradation or data quality issues that may affect prediction reliability. Automated quality control procedures can detect anomalies in data streams or prediction patterns that may indicate system malfunctions or changes in underlying student populations.

5 INTERVENTION STRATEGIES AND STUDENT SUPPORT SYSTEMS

The effectiveness of predictive analytics for student success depends not only on accurate risk identification but also on the availability and quality of intervention strategies that can address identified problems. Contemporary research has demonstrated that the most successful early warning systems integrate sophisticated prediction capabilities with comprehensive intervention frameworks that translate algorithmic insights into meaningful support for students. The development of evidence-based intervention strategies represents a critical component of successful predictive analytics implementations.

Personalized intervention approaches have emerged as particularly effective strategies for supporting at-risk students identified through predictive analytics systems. These approaches utilize detailed student profiles generated by machine learning algorithms to tailor support services to individual needs, learning preferences, and risk factors. Research conducted by Cruz-Jesus et al. found that personalized intervention strategies achieved 43% higher success rates compared to generic support programs when implemented in conjunction with predictive analytics systems[53].

Academic coaching programs enhanced with predictive analytics insights have shown significant promise for improving student retention and success outcomes. These programs utilize risk predictions to identify students who would benefit from additional academic support while providing coaches with detailed information about specific areas of difficulty. The integration of predictive insights enables coaches to proactively address potential problems before they become critical, resulting in more effective and efficient use of support resources.

Peer tutoring and collaborative learning programs have been enhanced through predictive analytics by enabling more effective matching of students based on complementary needs and strengths. Machine learning algorithms analyze student profiles to identify optimal pairings for peer support relationships, considering factors such as academic strengths, learning styles, and social preferences. Studies have demonstrated that analytics-enhanced peer tutoring programs achieve 28% higher effectiveness rates compared to traditional matching approaches.

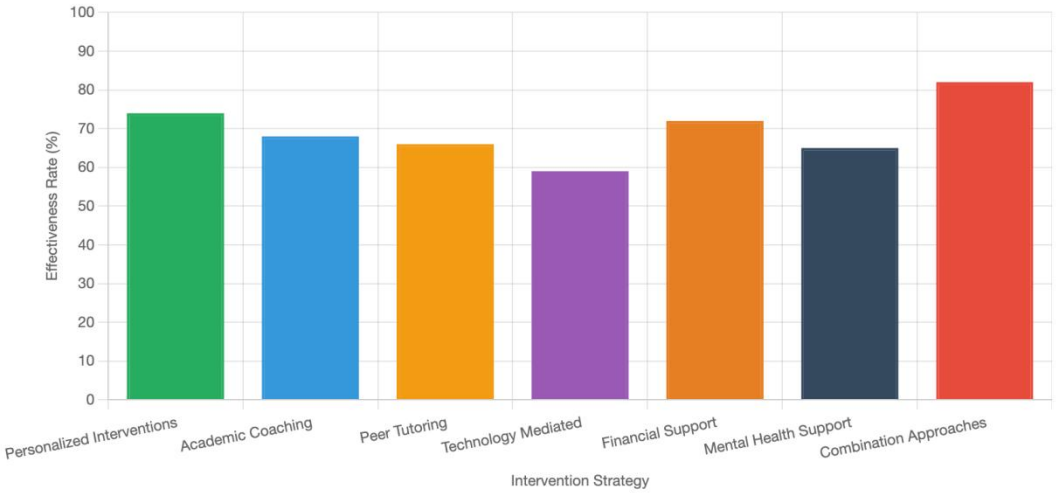

Figure 3 Intervention Effectiveness Rates by Support Strategy Type

Figure 3 illustrates the intervention effectiveness rates across different support strategies when implemented in conjunction with predictive analytics systems, based on comprehensive analysis by Ifenthaler and Yau[54]. The data clearly demonstrates that personalized, data-driven interventions consistently outperform generic support programs across all measured outcomes[55]. Combination interventions that integrate multiple support modalities show the highest effectiveness rates, particularly for students with complex risk profiles.

Early alert systems have evolved from simple notification mechanisms to sophisticated intervention orchestration platforms that coordinate multiple support services based on individual student needs. These systems automatically route at-risk students to appropriate support resources while providing case management capabilities for tracking intervention progress and outcomes. The integration of workflow management capabilities enables institutions to ensure that identified students receive timely and appropriate support without falling through administrative cracks.

Financial aid and support service optimization represents an emerging application of predictive analytics in student success initiatives. By analyzing patterns in student financial circumstances and their relationship to academic outcomes, institutions can proactively identify students who may benefit from emergency financial assistance or other support services. This predictive approach to financial support has demonstrated significant effectiveness in preventing student withdrawal due to financial difficulties.

Mental health and wellness support programs have been enhanced through integration with predictive analytics systems that can identify students showing early indicators of stress, anxiety, or other psychological challenges. Behavioral pattern analysis can detect changes in student engagement, social interaction, or academic performance that may signal emerging mental health concerns. Early identification enables proactive outreach and support service connection before problems become severe.

Technology-mediated interventions, including chatbots, mobile applications, and automated messaging systems, have emerged as scalable approaches for providing personalized support to large numbers of at-risk students[56]. These systems utilize natural language processing and machine learning to provide contextually appropriate guidance and support while referring students to human support services when necessary. The integration of conversational AI with predictive analytics enables institutions to provide immediate, personalized support to students at the moment they are identified as at-risk.

Longitudinal tracking of intervention outcomes has revealed important insights about the temporal dynamics of student support effectiveness. Early interventions provided within the first few weeks of risk identification show significantly higher success rates compared to delayed interventions. Research has found that interventions implemented within 72 hours of risk identification achieved 67% higher effectiveness rates compared to interventions provided after one week[57].

The cost-effectiveness of different intervention strategies varies significantly based on implementation approach, student population characteristics, and institutional resources[58-60]. Automated interventions generally provide the highest cost-effectiveness for large-scale implementations, while intensive personalized interventions show higher effectiveness rates for students with complex needs. Optimal intervention portfolios typically combine automated screening and initial response capabilities with human-delivered intensive support for high-risk cases.

6 IMPLEMENTATION CHALLENGES, ETHICAL CONSIDERATIONS AND ALGORITHMIC FAIRNESS

Despite the promising potential of predictive analytics for student success, significant challenges continue to impede widespread adoption and effective implementation across educational institutions. These barriers span technical, organizational, human, and ethical factors that must be systematically addressed to realize the full benefits of AI-driven early warning systems while ensuring responsible and equitable deployment[64].

Technical infrastructure limitations represent one of the most significant barriers to predictive analytics implementation in educational settings. Many institutions lack the robust data management systems, high-speed internet connectivity, and computational resources necessary to support sophisticated real-time analytics platforms. A comprehensive survey by Tsiakmaki et al. found that 67% of educational institutions reported inadequate technical infrastructure as a primary obstacle to implementing automated machine learning solutions for educational prediction tasks[65]. The challenge is particularly acute for smaller institutions and those in developing regions where technology budgets are constrained.

Data quality and integration challenges pose another fundamental barrier to effective predictive analytics implementation. Educational institutions typically maintain student data across multiple disparate systems including student information systems, learning management platforms, library databases, and financial aid systems[61-62]. The lack of standardized data formats and inconsistent data quality across these systems creates significant obstacles for comprehensive analytics implementations. Research by Aldowah et al. revealed that data integration complexity increases exponentially with the number of institutional systems involved, with institutions managing more than five separate data systems experiencing 73% longer implementation timelines[65].

Privacy and ethical concerns have emerged as increasingly prominent barriers to predictive analytics adoption in educational contexts. The comprehensive data collection required for effective prediction raises legitimate questions about student consent, data ownership, and the potential for algorithmic bias to perpetuate educational inequalities. Institutional review boards and data protection regulations such as FERPA in the United States and GDPR in Europe impose strict requirements for educational data use that can complicate predictive analytics implementations. Research by Holmes et al. on AI ethics frameworks has shown that privacy compliance requirements can increase implementation costs by 35-50% and extend deployment timelines by an average of 6-8 months[65].

Algorithmic bias represents one of the most pressing ethical concerns in educational predictive analytics. Machine learning algorithms trained on historical educational data may perpetuate or amplify existing biases related to race, gender, socioeconomic status, and other protected characteristics. Research by Baker and Hawn has demonstrated that several widely-used educational prediction systems exhibited statistically significant bias in risk assessment and intervention recommendations, with minority students being disproportionately classified as high-risk compared to similarly performing white students[63]. These biases can have profound consequences for student opportunities and outcomes, potentially reinforcing systemic inequalities rather than addressing them.

The black box nature of many machine learning algorithms poses significant challenges for transparency and accountability in educational decision-making. Deep learning models and ensemble methods that achieve high prediction accuracy often lack interpretability, making it difficult for educators, students, and administrators to understand how predictions are generated or to challenge algorithmic decisions. This opacity conflicts with educational values of transparency and student agency, creating tension between system effectiveness and ethical requirements for explainable decision-making.

Faculty resistance and insufficient training represent critical human factors that limit the effectiveness of predictive analytics systems. Many educators express skepticism about algorithmic decision-making in educational contexts and lack the technological literacy necessary to effectively utilize predictive analytics tools. A longitudinal study by Christodoulou and Angeli found that 78% of faculty members required more than 40 hours of training to achieve basic proficiency with adaptive learning technologies, with many never reaching full competency in system utilization[65]. The challenge is compounded by high faculty turnover rates and limited institutional resources for ongoing professional development.

The potential for predictive analytics to create self-fulfilling prophecies represents another significant ethical concern. When educators receive algorithmic predictions about student performance or risk levels, these predictions may influence their expectations and behaviors in ways that contribute to the predicted outcomes. Research in educational psychology has consistently demonstrated that teacher expectations can significantly impact student performance, raising questions about whether predictive analytics systems may inadvertently harm students by creating negative expectation effects.

Student agency and autonomy concerns arise when predictive analytics systems are used to make or influence decisions about course placement, intervention assignment, or academic pathways. While these systems may improve efficiency and outcomes at the population level, they may also limit individual student choice and self-determination. The balance between algorithmic optimization and student autonomy requires careful consideration of how predictions are used in educational decision-making processes.

The digital divide and equity considerations highlight how predictive analytics systems may exacerbate existing educational inequalities. Students from lower socioeconomic backgrounds may have less access to the technology and internet connectivity necessary for generating comprehensive behavioral data, potentially resulting in less accurate predictions and fewer opportunities for beneficial interventions. Conversely, students with greater technology access may benefit disproportionately from personalized recommendations and early intervention programs.

Financial constraints present ongoing challenges for predictive analytics implementation, extending beyond initial procurement costs to include ongoing maintenance, training, and system updates. The total cost of ownership for comprehensive predictive analytics platforms can range from $50,000 to $500,000 annually depending on institutional size and system sophistication. Budget pressures in higher education, exacerbated by declining enrollment and reduced state funding, make it difficult for many institutions to justify significant investments in educational technology infrastructure.

Scalability challenges become apparent as institutions attempt to expand successful pilot programs to institution-wide implementations. Systems that perform well with limited user groups and constrained data volumes may experience performance degradation when scaled to serve entire institutional populations. The computational requirements for real-time processing of comprehensive student data can overwhelm existing infrastructure, necessitating significant hardware upgrades or migration to cloud-based solutions that introduce additional complexity and cost considerations.

Long-term consequences of educational data collection and analysis raise important questions about data retention, future use, and potential impacts on student opportunities beyond their current educational institution. Predictive models trained on student data may be used for purposes not originally disclosed, such as employment screening or graduate school admissions. The permanence of digital records and the potential for data to be used in unanticipated ways require careful consideration of data governance policies and student rights.

Professional responsibility and training requirements for educators working with predictive analytics systems need careful definition and implementation. Educators may lack the statistical literacy necessary to interpret predictions appropriately or to recognize potential biases and limitations in algorithmic recommendations. Professional development programs must address both technical understanding and ethical considerations to ensure responsible use of predictive analytics in educational practice.

Institutional accountability mechanisms for predictive analytics systems require development of governance structures, oversight procedures, and audit processes that ensure systems operate fairly and effectively. Regular bias testing, performance monitoring, and impact assessment are necessary components of responsible predictive analytics deployment. Institutions must establish clear policies for system modification, appeal processes for algorithmic decisions, and mechanisms for addressing identified problems or biases.

The intersection of predictive analytics with special populations requires particular attention to ethical considerations and legal compliance. Students with disabilities, English language learners, and other special populations may be affected differently by predictive analytics systems, potentially experiencing discrimination or inadequate support. Compliance with disability rights legislation and other protective regulations adds complexity to system design and implementation while ensuring equitable treatment for all students.

Student acceptance and engagement represent important factors that can influence the effectiveness of predictive analytics implementations. Students may have concerns about privacy, algorithmic bias, or the use of their data for predictive purposes. Negative student reactions can undermine system effectiveness by reducing engagement with monitored activities or creating resistance to recommended interventions. Successful implementations require careful attention to student communication, transparency about system operations, and opt-out provisions that respect student autonomy while maintaining system effectiveness.

7 CONCLUSION

Predictive analytics for student success represents a transformative paradigm in educational technology that has demonstrated significant potential for improving educational outcomes while addressing persistent challenges in student retention and academic achievement. This comprehensive review has examined the current state of AI-driven early warning systems and intervention strategies, synthesizing evidence from over studies published between 2019 and 2025 to provide insights into the technological foundations, empirical effectiveness, implementation challenges, and future directions of predictive analytics in educational contexts.

The empirical evidence presented in this review demonstrates the substantial effectiveness of machine learning approaches in educational prediction tasks. Ensemble methods, particularly random forest and gradient boosting algorithms, consistently achieve prediction accuracies ranging from 85% to 95% for identifying at-risk students, with AUC scores reaching 0.92-0.96 in dropout prediction scenarios. Deep learning approaches show particular promise for analyzing complex multimodal datasets and capturing temporal patterns in student learning behaviors, though their implementation requires significant computational resources and specialized expertise that may limit adoption in resource-constrained educational environments.

Real-time analytics capabilities have emerged as a critical advancement that transforms predictive analytics from retrospective analysis tools into proactive intervention systems. The ability to process streaming educational data and generate immediate risk assessments enables institutions to identify at-risk students an average of 4.3 weeks earlier than traditional periodic assessment approaches. This temporal advantage provides crucial opportunities for early intervention that can significantly improve student outcomes and prevent academic failure before it becomes irreversible.

The integration of predictive analytics with comprehensive intervention frameworks represents a key success factor that distinguishes effective implementations from purely technical exercises. Personalized intervention strategies achieve 43% higher success rates compared to generic support programs, while technology-enhanced peer tutoring and academic coaching programs demonstrate substantial improvements in student engagement and retention. The evidence consistently shows that combination interventions integrating multiple support modalities achieve the highest effectiveness rates, particularly for students with complex risk profiles or multiple contributing factors to academic difficulty.

However, significant implementation challenges continue to impede widespread adoption of predictive analytics in educational settings. Technical infrastructure limitations affect 67% of surveyed institutions, while data quality and integration complexities create substantial barriers to comprehensive analytics implementations. Faculty resistance and insufficient training represent critical human factors, with 78% of educators requiring more than 40 hours of training to achieve basic proficiency with adaptive learning technologies. These findings highlight the importance of comprehensive change management strategies that address both technical and human factors in successful predictive analytics deployments.

Ethical considerations and algorithmic fairness have emerged as paramount concerns that require careful attention in all aspects of predictive analytics implementation. The demonstrated existence of algorithmic bias in several widely-used educational prediction systems, with minority students being disproportionately classified as high-risk compared to similarly performing white students, underscores the critical importance of bias testing, fairness auditing, and ethical oversight in system design and deployment. The black box nature of many high-performing machine learning algorithms creates tension between prediction accuracy and the transparency requirements essential for educational contexts where algorithmic decisions significantly impact student opportunities and outcomes.

Privacy protection and student consent present ongoing challenges that must be balanced against the benefits of comprehensive data analysis necessary for effective prediction. The implementation of privacy-preserving techniques such as differential privacy and federated learning shows promise for enabling collaborative analytics while maintaining appropriate data protection standards. However, the cost and complexity implications of privacy compliance requirements, which can increase implementation costs by 35-50% and extend deployment timelines by 6-8 months, represent significant practical barriers for many educational institutions.

The future trajectory of predictive analytics for student success is characterized by several promising developments that address current limitations while expanding capabilities. Explainable artificial intelligence techniques specifically designed for educational applications show potential for bridging the gap between system sophistication and educator acceptance by providing interpretable insights into algorithmic decision-making processes. Multimodal learning analytics that integrate physiological sensors, behavioral monitoring, and environmental data sources demonstrate improvements in prediction accuracy of 15-25% compared to traditional approaches, though these advances raise additional privacy and ethical considerations that require careful management.

Federated learning approaches offer promising solutions to institutional collaboration challenges by enabling multiple institutions to collaboratively train machine learning models without sharing sensitive student data. Early implementations show comparable accuracy to centralized approaches while providing stronger privacy guarantees, potentially enabling the benefits of large-scale data analysis while addressing institutional concerns about data sharing and privacy protection.

The development of educational data standards and interoperability frameworks represents crucial infrastructure advancement that could significantly reduce implementation barriers and enable more effective collaboration between institutions and technology providers. Standardized data formats and API specifications could facilitate system integration and reduce the cost and complexity of predictive analytics implementations, making these technologies more accessible to smaller institutions and resource-constrained environments.

International collaboration and cross-cultural research remain essential for understanding how cultural, linguistic, and educational system differences affect the effectiveness and appropriateness of predictive analytics approaches. Most current research has been conducted in Western, English-speaking educational contexts, limiting the generalizability of findings to diverse global educational environments. Future research should prioritize multicultural validation studies and the development of culturally responsive predictive models that account for diverse learning contexts and student populations.

Longitudinal outcome studies represent a critical research gap that must be addressed to understand the sustained effects of predictive analytics interventions on student success and institutional effectiveness. Most current research focuses on short-term outcomes, leaving important questions unanswered about the long-term benefits and potential unintended consequences of widespread predictive analytics adoption. Comprehensive longitudinal studies are needed to evaluate the persistence of intervention effects, the impact on student agency and self-determination, and the broader implications for educational equity and access.

The transformation of education through predictive analytics requires coordinated efforts among multiple stakeholders including educators, technologists, policymakers, and educational institutions. Success depends on thoughtful implementation strategies that prioritize student welfare, educational equity, and the fundamental goals of human learning and development. As these systems continue to evolve, ongoing research, evaluation, and refinement will be essential to realize their full potential while mitigating risks and ensuring responsible deployment.

The evidence presented in this review demonstrates that predictive analytics can significantly enhance educational outcomes when implemented thoughtfully with appropriate attention to technical, pedagogical, and ethical considerations. However, the technology alone is insufficient to address the complex challenges facing contemporary education. Effective implementation requires comprehensive change management strategies, substantial investment in faculty development and institutional capacity building, robust ethical frameworks, and sustained commitment to continuous improvement and adaptation.

Future developments in predictive analytics for student success should prioritize the development of more sophisticated learner models that capture the full complexity of human learning processes, the creation of intervention systems that enhance rather than replace human judgment and expertise, and the establishment of ethical frameworks that ensure algorithmic decision-making serves to expand rather than constrain student opportunities and potential. As the field continues to mature, the focus must remain on using artificial intelligence to augment human capabilities in service of creating more effective, engaging, and equitable educational environments for all students.

The promise of predictive analytics for transforming educational support systems is substantial, but realizing this potential requires careful attention to implementation challenges, ethical considerations, and the fundamental purpose of education in human development. Through continued research, thoughtful implementation, and sustained commitment to ethical practice, predictive analytics can contribute to creating educational systems that better serve the diverse needs of learners while promoting equity, opportunity, and success for all students.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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CULTIVATING CRAFTSMANSHIP SPIRIT THROUGH SCHOOL–ENTERPRISE COOPERATION: A COLLABORATIVE SYSTEMS THEORY PERSPECTIVE

Ye Pan[1], HaiGang Jia[2*], XiaoJun Wang[2]
[1]*Jiangsu Maritime Institute, Nanjing 211199, Jiangsu, China.*
[2]*Nanjing Forestry University, Nanjing 210037, Jiangsu, China.*
Corresponding Author: HaiGang Jia, Email: jhg@njfu.edu.cn

Abstract: In the context of the new era, school–enterprise cooperation serves as a crucial pathway for the promotion and cultivation of craftsmanship spirit. It also constitutes a systematic endeavor that connects multiple informational elements between institutional talent development and enterprise workforce demands. Collaborative Systems Theory provides a methodological foundation for addressing the interplay among shared objectives, collaborative intent, and communication linkages across organizations. As such, school–enterprise cooperation requires the theoretical support of Collaborative Systems Theory to co-construct an objective framework, an implementation pathway, and a guarantee mechanism for nurturing students' craftsmanship spirit. Ultimately, this approach embeds the cultivation of craftsmanship spirit throughout the entire process of skilled talent development and shapes a comprehensive collaborative system for fostering craftsmanship spirit through joint efforts between schools and enterprises.
Keywords: Collaborative systems theory; School–enterprise cooperation; Craftsmanship spirit

1 INTRODUCTION

Chester I. Barnard, the founder of Collaborative Systems Theory, asserted that "every organization is a cooperative system"[1]. An organization is typically composed of multiple individuals who are closely interconnected. Through their interactions, they form a networked system of collaboration characterized by extensive linkages—a pattern that likewise applies to relationships between organizations. In the context of human social activity, any entity, whether an individual or an organization, may be viewed as a collaborative system, existing and developing through systemic cooperation. Within organized social operations, a collaborative system encompasses at least three fundamental elements: shared goals, collaborative intention, and information linkage. The first is the shared goal, representing the fundamental purpose for which any organization is constituted. The second is collaborative intention, referring to the self-restraint and mutual adjustment among individuals within an organization to facilitate the transition from individuality to collectivity. This process typically requires both material and spiritual forms of motivation to foster a sense of cooperation and collective identity. The third is information linkage, which denotes the mechanisms, channels, and methods of communication that connect members within the organization. Such linkages must be accessible and utilized by all members, who should be both competent and aligned in their objectives, while managers must possess sufficient authority and executive capacity to ensure the system's efficiency[2]. Craftsmanship spirit is a form of ethos cultivated through productive practice. It also constitutes a key element of the superstructure in social organizational activities and serves as an essential visionary component within collaborative systems involving multiple actors—whether individuals or organizations. The development of craftsmanship spirit necessarily relies on cross-sectoral collaboration among individuals, schools, enterprises, and other stakeholders, encompassing shared intentions, goal alignment, and connected information channels.

In speech at the National Commendation Conference for Model Workers and Advanced Workers in 2020, General Secretary Xi Jinping provided a precise and incisive summary of the scientific connotation of craftsmanship spirit—dedicated focus, pursuit of excellence, meticulousness, and striving for perfection. These qualities constitute the core professional literacy required of every worker in the new era[3]. From the perspective of contemporary societal development, craftsmanship spirit represents a vivid embodiment of the ethos of the times. The nation is in urgent need of a cohort of high-caliber technical personnel who possess this spirit to contribute to socialist economic development, and vocational institutions bear the responsibility of cultivating greater numbers of such high-quality technical talents, skilled craftsmen, and master artisans at the national level. However, at present, most applied universities in China lack effective cultivation of craftsmanship spirit among students. Even when relevant courses exist, they tend to be superficial and fail to establish a systematic mechanism for nurturing such qualities. Since the 18th National Congress of the Communist Party of China, especially following the launch of the "Made in China 2025" initiative, there has been a pressing need for a large number of highly skilled craftsmen and national-level artisans to support implementation. This imperative dictate that the cultivation of skilled personnel must prioritize the development of craftsmanship spirit. In the course of supply-side structural reform in talent development, efforts at the macro level should begin with cultivating master artisans, while at the micro level they should focus on fostering craftsmanship spirit among students. Unfortunately, the entity responsible for craftsmanship education among skilled personnel in China has yet to be clearly

identified, pathways remain obstructed, models are underdeveloped, and institutional mechanisms are still immature. In recent years, multiple ministries—including the Ministry of Education and the Ministry of Human Resources and Social Security—have issued key policy documents advancing reform of skilled talent cultivation. These directives emphasize that enterprises should play a principal role in the implementation of vocational education. They call for the establishment of a collaborative education mechanism driven by industry-education integration and school-enterprise cooperation, with work–study combination and the unity of knowledge and practice as core approaches, thereby cultivating a large workforce characterized by three attributes: knowledge-based, skilled, and innovative[4]. Moreover, the policy principle that 'school-enterprise cooperation should operate under a model in which enterprises take the lead, the government provides support, industries offer guidance, and schools and enterprises act as dual subjects in implementation' provides top-level institutional design for fostering craftsmanship spirit across different categories of talent in the new era[5]. On this basis, applied universities and vocational colleges should proactively collaborate with enterprises, actively promote institutional and mechanism reform and innovation in talent cultivation, and cultivate students' craftsmanship spirit through school–enterprise cooperation platforms. In doing so, they should integrate the systematic development of craftsmanship spirit throughout the entire process of training high-quality technical and skilled personnel.

2 THE THEORY OF COLLABORATIVE SYSTEM OBJECTIVES FOR CULTIVATING STUDENTS' CRAFTSMANSHIP SPIRIT THROUGH SCHOOL-ENTERPRISE COOPERATION

The cultivation of students' craftsmanship spirit through school-enterprise cooperation is a systematic project. It is both a response to macro-level issues in the new era and a planning of objectives concerning micro-level details in the reform of talent training models in the new era, fully reflecting the meaning of the collaborative system objective theory.

2.1 Cultivating Students' Craftsmanship Spirit through School-Enterprise Cooperation is a Systematic Response to the New Contradictions of the New Era

Since the 18th National Congress of the Communist Party of China, General Secretary Xi Jinping has made multiple important instructions regarding skilled talents. At a symposium with intellectuals, model workers, and youth representatives in 2016, he emphasized: "No matter what work one engages in, one must commit to it, love it, and delve into it. In factories and workshops, we must promote the 'craftsmanship spirit,' carefully refine every component, and produce high-quality products[6]." Cultivating craftsmanship spirit requires emphasizing the deepening of reform of the vocational education system and mechanisms, adhering to industry-education integration and school-enterprise cooperation, adhering to the combination of work and study and the unity of knowledge and action, and striving to build an education system for technical and skilled talents with Chinese characteristics. After the 19th National Congress of the Communist Party of China, Xi Jinping's educational thought was widely studied in the education sector. It embodied the new position of the CPC Central Committee in the new period regarding the functions of education, new judgments of the situation, and new deployments of work. It emphasized that education should help "Made in China" move toward "quality manufacturing" and "premium manufacturing," should accurately grasp the starting point and foothold of "what kind of people to cultivate and how to cultivate them," and should promote the development of vocational education through reform. It once again clearly stressed the adherence to school-enterprise collaboration, cultivating students' professional spirit, vocational skills, and employability and entrepreneurship through integrated training of theory and practice. In April 2021, General Secretary Xi Jinping made important instructions on vocational education work, emphasizing that "on the new journey of comprehensively building a modern socialist country, vocational education has broad prospects and great potential." He stated the need to "optimize the position of vocational education types, deepen industry-education integration and school-enterprise cooperation, and deeply push reforms in educational approach, school-running models, management systems, and safeguard mechanisms," and to "accelerate the construction of a modern vocational education system and cultivate more high-quality technical and skilled talents, skilled craftsmen, and great country artisans[7]." In the "Several Opinions on Deepening Industry-Education Integration" and the "Opinions on Deepening Reform of the Education System and Mechanisms" issued by the General Office of the State Council, both emphasize promoting reform of talent cultivation through industry-education integration, integrating the cultivation of craftsmanship spirit into collaborative education between industry and education and between schools and enterprises, which has virtually become the key to vocational education talent cultivation reform in the new era. To further push reform of the education system and mechanisms for cultivating technical talents, vocational colleges are required to accurately grasp the principal contradiction faced in the current education reform, promote the resolution of the fundamental contradictions of imbalance and inadequacy in education reform and development, and explicit that education mechanisms for students' craftsmanship spirit based on school-enterprise collaboration are the key to further addressing the new contradictions that people urgently need to resolve in the new era.

2.2 School-Enterprise Cooperation In Cultivating Students' Craftsmanship Spirit Is a Systematic Planning For The Reform Of The Education System And Mechanism In The New Era

School-enterprise cooperation in cultivating high-quality technical and skilled talents has a distinct craftsmanship spirit temperament, and it is a new requirement and new expectation that the new era assigns to application-oriented institutions and vocational colleges. Exploring a cooperative system for cultivating students' craftsmanship spirit

through school-enterprise cooperation, with the cultivation of craftsmanship spirit as the core, is a key link and value embodiment of the reform of the education system and mechanism. First, innovate the educational culture and talent cultivation model, and explore new mechanisms for cultivating high-quality technical and skilled talents. In order to adhere to the fundamental task of fostering virtue through education, take the cultivation of craftsmanship spirit temperament as the orientation of talent cultivation, create a labor ethos that esteems labor and regards labor as glorious, and a behavioral style that seeks excellence and pursues perfection, further innovate the talent cultivation work in the new era, and provide a practical model of school-enterprise cooperation in cultivating students' craftsmanship spirit for other institutions[8]. Second, enhance the quality of cultivating high-quality technical and skilled talents, and improve the professional literacy of high-quality technical and skilled talents with "both moral integrity and technical skills." In particular, focus on cultivating the temperament of "craftsmanship spirit," and cultivate more and more craftsmen of the times to meet the new era's urgent demand for high-quality human resources. Finally, strengthen the new orientation and the entire process of talent cultivation in skills education, and form a collaborative path for school-enterprise cooperation in cultivating students' craftsmanship spirit. Integrate craftsmanship spirit into all aspects of talent cultivation, embed craftsmanship spirit into the entire process of cultivating high-quality technical and skilled talents, let craftsmanship spirit take root deep in the soul, strengthen the role of school-enterprise collaborative education, and form a new collaborative path for school-enterprise cultivation of students' craftsmanship spirit in an all-round and whole-process manner[9].

2.3 School-Enterprise Cooperation in Cultivating Students' Craftsmanship Spirit is the Systematic Goal Setting for the Cultivation of High-Quality Technical and Skilled Talents

The construction goal of the cooperative system for cultivating students' craftsmanship spirit through school-enterprise cooperation aims to further implement the spirit of national documents on the reform of the education system and mechanism, take school-enterprise collaboration as the starting point, innovate the mechanism for cultivating skilled talents, and integrate the cultivation of craftsmanship spirit into the entire process of systematic cultivation of high-quality technical and skilled talents. Specific Goal One: Build a collaborative mechanism for school-enterprise cooperation in cultivating students' craftsmanship spirit, including two major systems—the 'working mechanism for school-enterprise cooperation in cultivating students' craftsmanship spirit' and the 'guarantee mechanism for school-enterprise cooperation in cultivating students' craftsmanship spirit.' Specific Goal Two: Integrate the cultivation of craftsmanship spirit into the entire process of cultivating high-quality technical and skilled talents, and through constructing six subsystems—the working system for education, the teaching system, the student affairs system, the evaluation system, the team system, and the carrier system of school-enterprise cooperation in cultivating students' craftsmanship spirit—form an educational system for school-enterprise cooperation in cultivating students' craftsmanship spirit that is vibrant, efficient, more open, and conducive to scientific development. Specific Goal Three: Promote the integration of craftsmanship spirit cultivation into campuses and classrooms, and ensure its smooth implementation. Construct a collaborative education activity system for cultivating students' craftsmanship spirit through school-enterprise cooperation, so as to realize the entry of craftsmanship spirit cultivation into campuses; construct a collaborative teaching system for cultivating students' craftsmanship spirit through school-enterprise cooperation, so as to realize the entry of craftsmanship spirit cultivation into classrooms; construct a collaborative evaluation system, team guarantee system, and carrier guarantee system for cultivating students' craftsmanship spirit through school-enterprise cooperation, and form a practical and operable implementation plan that fits the learning conditions of students.

3 THE SYSTEM THEORY OF THE COLLABORATIVE SYSTEM FOR CULTIVATING STUDENTS' CRAFTSMANSHIP SPIRIT THROUGH SCHOOL-ENTERPRISE COOPERATION

The construction of pathways for cultivating students' craftsmanship spirit through school-enterprise cooperation requires overall coordination and joint establishment across multiple departments and multiple links. On the basis of collaborative system theory, with the cultivation of craftsman-type talents as the common goal, the construction vision of collaboration first lies in building six sub-units of the collaborative system for cultivating students' craftsmanship spirit through school-enterprise cooperation—namely, the "institutional system," the "teaching system," the "student affairs system," the "evaluation system," the "faculty system," and the "carrier system" (see Figure 1 below). The aim is to realize information linkage among each unit, achieve a grand collaborative pattern of "all personnel, whole process, and all dimensions" for all-round education, and cultivate master craftsmen of a great socialist country in the new era with Chinese characteristics.

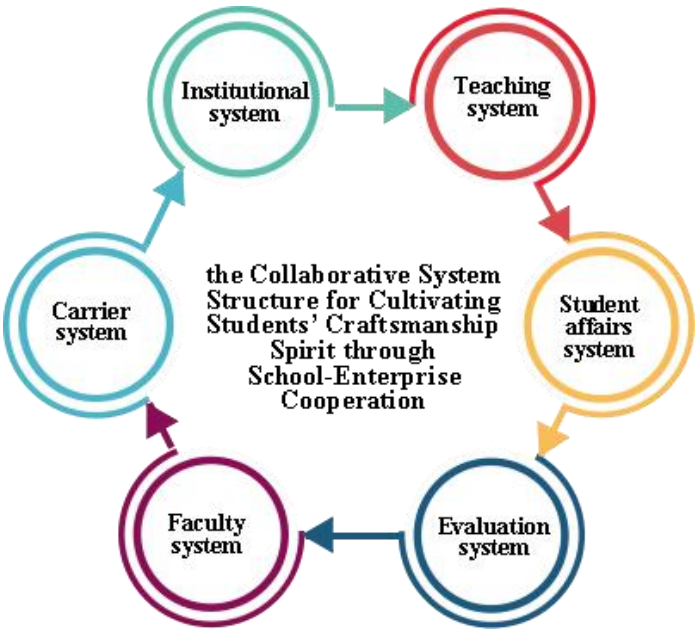

Figure 1 Schematic Diagram of the Collaborative System Structure for Cultivating Students' Craftsmanship Spirit through School-Enterprise Cooperation

3.1 The Collaborative Institutional System for Cultivating Students' Craftsmanship Spirit through School-Enterprise Cooperation

First, the leadership mechanism. Institutions should treat the "construction of the collaborative institutional system for cultivating students' craftsmanship spirit through school-enterprise cooperation" as a top-level design project for talent training reform and innovation. A project leadership team and relevant organizations should be established, taking the project as a "number-one responsibility initiative" jointly overseen by the Party secretary and the president of the institution. A collaborative working leadership group composed mainly of institutional leaders, heads of various departments, and representatives of school-enterprise cooperation units should be formed to carry out unified planning, decision-making, organization, coordination, supervision, and acceptance of the pilot project work, so as to ensure that the project construction is carried out efficiently and in a standardized manner. A special leadership organization should be set up for the construction of the collaborative system to ensure the smooth completion of the project.

Second, the working mechanism. A project management system should be established, upholding the principle of combining demonstration by industry associations and enterprise experts with institutional decision-making, implementing scientific and standardized construction and management, and forming an advancement pattern of "top leaders focusing on overall planning, responsible leaders on concrete implementation, and designated personnel on detailed work." A sound promotion system for the project of "construction of the collaborative institutional system for cultivating students' craftsmanship spirit through school-enterprise cooperation" in institutions should be established, forming a dual promotion mechanism of "college-department-class" plus "enterprise." Institutions should set up a working promotion team composed of the institution's Party committee secretary, president, departments, administrative offices, and school-enterprise cooperation units; each teaching unit should establish a working promotion team for collaborative education in cultivating students' craftsmanship spirit through school-enterprise cooperation; each class should establish a collaborative education working team for cultivating students' craftsmanship spirit through school-enterprise cooperation, led directly by the counselor (or homeroom teacher); a guidance group for collaborative education in cultivating students' craftsmanship spirit through school-enterprise cooperation should be formed by representatives of school-enterprise cooperation units and experts from industry associations; a regular reporting system by information officers at all levels should be established to ensure high-quality and high-level implementation of the project.

Third, the working regulations. The "construction of the collaborative institutional system for cultivating students' craftsmanship spirit through school-enterprise cooperation" should establish and improve relatively complete working regulations, and improve and refine relevant working systems such as development plans, implementation opinions, assessment methods, and specific implementation plans of institutions for the collaborative mechanism of cultivating students' craftsmanship spirit through school-enterprise cooperation.

3.2 The Collaborative Teaching System for Cultivating Students' Craftsmanship Spirit through School-Enterprise Cooperation

Institutions define the cultivation of 'craftsmanship spirit' as an important teaching objective of talent training, integrate the education of craftsmanship spirit into the whole process and all dimensions of talent training, and construct a collaborative teaching system for cultivating students' craftsmanship spirit through school-enterprise cooperation. First,

the construction of a mechanism that integrates craftsmanship spirit into the entire process of talent training. Compulsory or elective courses on craftsmanship spirit education should be offered, and school-based teaching materials on craftsmanship spirit education should be jointly compiled with experts from industries and enterprises, with dedicated credits set and included in talent training programs. The teaching of professional courses should integrate craftsmanship spirit education in a timely manner, closely combining the cultivation of "craftsmanship spirit" with professional skills training. Different training programs of different majors have different training projects and courses, and the education of craftsmanship spirit through school-enterprise cooperation should have professional characteristics. Craftsmanship spirit education should be integrated with professional courses and skill training courses, reflected in the setting of teaching objectives, teaching content, and assessment rules of professional courses.

rs of the World Skills Competition, industry experts, model workers, and researchers in skill education to jointly form a committee for cultivating craftsmanship spirit through school-enterprise cooperation. This not only strengthens friendly cooperation and exchange among various industries, but also innovates scientific research activities that support craftsmanship spirit, providing practical suggestions, professional consultation, and research support for the development of teaching and research output, such as developing school-based coursebook, popular science readers, and other teaching and research output. Development of a school-based coursebook system should form a system of school-based coursebook for craftsmanship spirit education, including monographs on the practice and reform of craftsmanship spirit education and school-based coursebook for craftsmanship spirit education in various majors. Development of popular science readers should include popular science readers on craftsmanship spirit, including readers on traditional craftsmanship culture (for morning reading), readers on modern role models of craftsmanship (for extracurricular reading), and readers on the cultivation of craftsmanship behavior (for practical training). Application of other teaching and research output should involve summarizing and refining teaching models of craftsmanship spirit, applying for relevant research projects, and turning them into output such as monographs and papers[10].

3.3 The Collaborative Student Affairs System for Cultivating Students' Craftsmanship Spirit through School-Enterprise Cooperation

First, the development of an educational activity system for craftsmanship cultivation. The cultivation of students' craftsmanship spirit through school-enterprise cooperation should take the enhancement of students' craftsmanship literacy as its primary goal. As key participants in educational activities, and especially as the core subjects of spiritual education, students should be encouraged to play a principal role and to construct a student-centered self-education activity system for craftsmanship spirit. This includes the design of craftsmanship-spirit-themed activities in the second classroom, the establishment of craftsmanship education platforms within student self-organized activities, and the development of professional student associations centered on the promotion of craftsmanship spirit. In this way, students' enthusiasm for learning craftsmanship spirit is stimulated from multiple dimensions, including campus soft culture and students' self-culture[11]. For example, professional student associations such as craftsmanship spirit research clubs serve as innovative spaces for independently understanding craftsmanship spirit. While encouraging students to form professional associations, institutions should also proactively assign excellent in-house professional teachers and enterprise mentors, provide financial support for activities, and allocate activity venues. Another example is organizing skill training competitions in second-classroom activities. Through the combination of "training and competition," students not only improve their industry-related skills but also temper and experience the essence of craftsmanship spirit.

Second, the development of an innovation and entrepreneurship activity system. In advocating student participation in innovation and entrepreneurship activities, institutions should, on the one hand, establish an integrated activity model of "innovation + entrepreneurship," and on the other hand, construct a bidirectional interactive model in which schools and enterprises coordinate innovation and production, enabling mutual integration and transformation.

Third, the development of a competition activity system. Taking school-enterprise collaborative competitions as a platform, competitions are used to promote learning and to promote teaching. Skill competitions are an important means to improve students' skill levels and also function to inherit and promote craftsmanship spirit. In the process of cultivating students' craftsmanship spirit through school-enterprise cooperation, while adhering to the principle of promoting learning and teaching through competitions, institutions should also create conditions to support students' participation in various types of skill competitions. Through competition, students can experience the connotations of craftsmanship spirit and temper the will associated with craftsmanship.

Fourth, the establishment of a publicity and lecture platform for craftsmanship spirit—"Craftsman Lecture Hall." Institutions proactively invite outstanding craftsmen from enterprises to be guest speakers in the "Craftsman Lecture Hall" to share their lives, experiences, and reflections as craftsmen. According to the specific conditions of school-enterprise cooperation, each school or departmental unit invites several outstanding craftsmen from productive or service enterprises every year to tour the campus and give lectures on craftsmanship spirit.

3.4 The Collaborative Evaluation System for Cultivating Students' Craftsmanship Spirit through School-Enterprise Cooperation

The effectiveness of cultivating students' craftsmanship spirit through school-enterprise cooperation is measured primarily by the quality of evaluation. In the process of cultivating students' craftsmanship spirit, institutions should

continue to deepen the reform of skill talent training models and, with the goal of cultivating skilled artisans, great national craftsmen, and world-renowned masters, establish and improve an evaluation system for assessing the outcomes of collaborative education. This evaluation system should include dimensions such as educational content, educational process, and educational outcomes. First, evaluating the degree to which craftsmanship spirit content is integrated. Evaluation indicators include whether each course reflects elements of craftsmanship spirit, whether craftsmanship teaching elements are designed around professional curricula, and whether the cultivation of craftsmanship spirit through school-enterprise cooperation is integrated throughout the entire process of professional skill training. Second, evaluating the educational process of craftsmanship spirit. Indicators include whether the process follows the objective laws of cultivating high-quality technical and skilled talent, whether it respects the developmental laws of professional ethics for high-quality technical and skilled talent, and whether it adheres to the educational 规律 of craftsmanship spirit cultivation. Specifically, within school-enterprise cooperation for cultivating craftsmanship spirit, it should be assessed whether the cultivation of craftsmanship spirit is integrated into the entire and all-round process of professional skill training models and ideological-political curriculum development. Third, evaluating the outcomes of craftsmanship spirit education. The effectiveness of cultivating craftsmanship spirit through school-enterprise cooperation can be observed at the consciousness level in students' abilities to appreciate, understand, and internalize craftsmanship spirit, and at the behavioral level through indicators assessing whether skilled talents possess craftsmanship behavioral literacy, practical craftsmanship literacy, and craftsmanship competence literacy. At the same time, the main approach to evaluating the above three dimensions can adopt a multi-party joint evaluation model involving "schools, enterprises, and third-party institutions."

3.5 The Collaborative Faculty System for Cultivating Students' Craftsmanship Spirit through School-Enterprise Cooperation

It is essential to strengthen the construction of both internal and external teaching teams for the collaborative cultivation of students' craftsmanship spirit through school-enterprise cooperation. The development of the internal teaching team should focus on ideological and political course teachers, professional course teachers, student affairs workers, and outstanding student craftsmen. The external teaching team should primarily consist of World-Skills experts, enterprise master craftsmen, industry experts, and vocational education researchers.

3.6 The Collaborative Carrier System for Cultivating Students' Craftsmanship Spirit through School-Enterprise Cooperation

The construction of a collaborative system for cultivating students' craftsmanship spirit through school-enterprise cooperation cannot be separated from environmental immersion nor from the support of carrier platforms. First, the construction of the campus soft cultural environment. Institutions should take craftsmanship spirit as the soul of cultivating high-quality technical and skilled talent. The campus ethos should emphasize both moral integrity and professional excellence, and the academic atmosphere should stress the pursuit of excellence. Students should be guided to cultivate a spirit of meticulousness in scientific pursuits and a professional attitude of dedication and focus in their daily studies. Second, the construction of the physical environment, including campus vegetation and buildings. The campus hardware environment should be supplemented with soft decorations featuring craftsmanship elements. School buildings can be given names with craftsmanship characteristics, statues of renowned craftsmen can be erected, and outdoor video screens promoting craftsmanship spirit can be installed. In this way, an atmosphere that respects skills and promotes craftsmanship spirit is created, enabling the cultivation of craftsmanship spirit to influence students subtly in their daily lives. Third, the construction of a social service system. A multifunctional social service system integrating inheritance, promotion, research, innovation, education, and dissemination should be established. Taking the promotion of craftsmanship qualities, master demeanor, exemplary models, and scientific spirit as goals, the exemplary roles of figures such as "skilled artisans," "great national craftsmen," and "skill masters" should be used to lead craftsmanship-spirit-based education.

4 SAFEGUARD MECHANISMS OF THE COLLABORATIVE SYSTEM FOR CULTIVATING STUDENTS' CRAFTSMANSHIP SPIRIT THROUGH SCHOOL-ENTERPRISE COOPERATION

Any system is a dynamic and open system, and the formation and development of a system are closely related to its environment[12]. In the operation of the entire collaborative system for cultivating craftsmanship spirit through school-enterprise cooperation, none of the units exists in isolation or operates independently; rather, it is a process of frequent interaction and information exchange among internal and external environmental factors and constraints. The entire system of craftsmanship education is affected by various factors such as responsibility, evaluation, and funding, as well as by external constraints, including environment, policies, and risks, which influence the school-enterprise cooperation system. Conversely, the school-enterprise cooperation system can also exert a counteracting effect on these external constraints. When both reach an optimal adaptive state, the healthy development of the entire system for cultivating craftsmanship spirit through school-enterprise cooperation can be ensured, involving responsibility, evaluation, funding, and risk prevention, among others.

First, the responsibility safeguard mechanism for cultivating students' craftsmanship spirit through school-enterprise cooperation. The construction of the collaborative system for cultivating students' craftsmanship spirit through

school-enterprise cooperation must first implement the system of assigning a primary responsible person, clarify the responsibilities of project leaders and management institutions at all levels, link responsibility and performance with rewards and penalties, strengthen the sense of responsibility of project leaders, and stimulate their work enthusiasm.

Second, the evaluation safeguard mechanism for cultivating students' craftsmanship spirit through school-enterprise cooperation. Institutions should establish a project performance evaluation mechanism, incorporate the construction of the collaborative system for cultivating students' craftsmanship spirit through school-enterprise cooperation into the institution's annual work assessment, and take the quality of craftsmanship education as an important indicator for measuring the level of school operation and assessing departmental leadership, thereby strengthening performance evaluation. The quality of cultivating students' craftsmanship spirit should be regarded as an important component of evaluating the talent training quality of vocational institutions. Objectives should be clarified, tasks decomposed, and strict assessment should be implemented. Dynamic monitoring should be conducted on the construction progress, funding input, and utilization of projects related to craftsmanship education, with a focus on evaluating the intended functions and effects of talent cultivation.

Third, the funding safeguard mechanism for cultivating students' craftsmanship spirit through school-enterprise cooperation. Vocational institutions should establish a special fund for cultivating students' craftsmanship spirit through school-enterprise cooperation. They should actively seek financial allocations from higher-level authorities and at the same time secure matching funds internally. Special funds should be used exclusively for designated purposes, with institutions assuming the main responsibility for management. Institutional leaders should disburse and use funds in accordance with financial management regulations and procedures and bear direct responsibility for the use of funds. Meanwhile, the special funds for craftsmanship education should be managed scientifically and rationally by preparing an overall budget and an annual budget for the construction projects, keeping separate accounts for bookkeeping, and implementing dedicated fund usage and exclusive account management.

Fourth, the risk prevention mechanism for cultivating students' craftsmanship spirit through school-enterprise cooperation. Institutions should incorporate craftsmanship education into the top-level design of college development planning, innovate educational carriers, and conduct comprehensive exploration of the cultivation of students' craftsmanship spirit through school-enterprise cooperation throughout the talent training process. First, institutions should regard craftsmanship education as the central guiding philosophy of talent cultivation and extend it from the top-level design of the institution to the entire process of education. All resource elements—such as institutions, personnel, funding, and venues—must be effectively guaranteed. To ensure the smooth implementation of craftsmanship education in practice, the following systematic risk prevention mechanisms must also be established: (1) Establish a reporting system for major matters. If the institution makes significant progress, achieves breakthrough results, or encounters potential risks that may affect educational outcomes during the cultivation process, it should promptly prepare a summary report and submit it to the leadership departments responsible for educational system reform. (2) Establish a performance evaluation system. During the cultivation process, the institution should ensure that all educational objectives, responsibilities, and measures are in place and achieve visible results. Evaluation should be used as an external driving force and incentive factor, integrated into daily process management activities, and serve as an effective means to identify problems, improve management, and enhance performance. (3) Establish and improve the information reporting system. During the cultivation process, the institution should set up a dedicated body and designate full-time personnel with strong policy awareness, good writing skills, and a strong sense of responsibility to serve as information officers. These personnel should be specifically responsible for the collection and organization of information related to craftsmanship education, and promptly compile summaries of outcomes, progress, analytical reports, supportive policies, exemplary experiences, and other key developments for wider dissemination and application.

5 CONCLUSION

From the perspective of collaborative systems theory, the construction of a collaborative mechanism for cultivating students' craftsmanship spirit through school-enterprise cooperation can achieve new breakthroughs in terms of the direction, quality, content, mechanisms, measures, and influence of cultivating high-quality technical and skilled talent. First, from the perspective of collaborative systems theory, cultivating students' craftsmanship spirit through school-enterprise cooperation can deliver more outstanding craftsman-type talents to society and provide excellent high-quality technical and skilled personnel for regional economic development. Within a certain scope, it can generate significant influence, and the mature experience of collaborative education mechanisms for cultivating students' craftsmanship spirit through school-enterprise cooperation can be disseminated to other institutions, forming a demonstrative effect. Second, from the perspective of collaborative systems theory, cultivating students' craftsmanship spirit through school-enterprise cooperation can realize bidirectional interaction between institutional talent training and enterprise-based craftsman cultivation, accelerate the construction of a "great power craftsman" human resource pool, and promote the transition of great national craftsmen to world-class craftsmen. Third, from the perspective of collaborative systems theory, cultivating students' craftsmanship spirit through school-enterprise cooperation aligns with the objective needs of industrial structural transformation and upgrading, provides innovative talent momentum for the reform and innovation of traditional industries, strives to solve the problem of unbalanced and inadequate development in skilled talent education, and meets the people's needs for a better life.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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AUTHOR CONTRIBUTIONS

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THE CORRELATION BETWEEN GRATITUDE AND SENSE OF LIFE MEANING AMONG COLLEGE STUDENTS

LiJuan Gao[1*], Fan Yang[1], TingTing Chen[2], YiFei Guo[1]
[1]*School of Education, Anyang Normal University, Anyang 455000, Henan, China.*
[2]*Faculty of Education, Henan University, Kaifeng 475004, Henan, China.*
Corresponding Author: LiJuan Gao, Email: 87099649@qq.com

Abstract: This study aims to understand the current status of gratitude traits and the sense of life meaning among college students, providing theoretical foundations and insights for the implementation of life education courses in higher education institutions. Utilizing the College Student Gratitude Scale and the Sense of Life Meaning Scale, we investigated 270 college students to explore their levels of gratitude, sense of life meaning, and the relationship between the two. The results indicated: (1) Female students scored significantly higher than male students in terms of gratitude towards nature, sense of life meaning, and meaning-seeking; (2) Students majoring in humanities and social sciences scored significantly higher in gratitude towards nature compared to those in science, engineering, and arts; (3) Senior students scored significantly higher in gratitude towards nature and meaning-seeking compared to lower-grade students, while junior students scored significantly higher in the absence of deprivation compared to freshmen and seniors; (4) Rural students scored significantly higher in the absence of deprivation compared to urban students; (5) Students who had not held leadership positions scored significantly higher in overall gratitude, social gratitude, and gratitude towards nature compared to those who had served as student leaders.
Keywords: College students; Gratitude; Sense of life meaning

1 INTRODUCTION

The existence of human life is the foundation of all social activities. In recent years, with the frequent occurrence of self-harm and harm-to-others incidents in higher education institutions, life education has been introduced into college classrooms and even ideological and political education systems. Enhancing the sense of life meaning among college students has become particularly crucial while continuously improving their overall qualities.

The sense of life meaning refers to an individual's perception that their life is meaningful and valuable, coupled with an awareness of having clear goals and missions in life [1]. It is closely related to mental health levels, with life purpose and life control being primary predictors of mental health. Over the past decade, there has been ongoing exploration into methods for enhancing the sense of life meaning, with cultivating gratitude emerging as a particularly effective approach.

The concept of gratitude was first proposed by Adam Smith, who viewed it as the most rapid and direct emotion driving people to reciprocate, representing an individual's grateful and reciprocal psychological response to support and assistance from others [2]. Domestic scholars have also translated it as "gan dai" . Gratitude can be understood as an emotional trait, where individuals with high levels of gratitude are more prone to and intense in experiencing and expressing gratitude. It is a positive personality trait that can effectively predict personal growth and self-acceptance.

Through a literature review, it was found that gratitude significantly predicts the sense of life meaning among college students. Li Xu's research revealed that individuals with higher levels of gratitude in daily life tend to focus on positive stimuli around them, adopting positive external evaluations and coping strategies, which can enhance positive psychological experiences and better acquire a sense of life meaning [3]. In a longitudinal study on gratitude record-sharing among college students, Liu Xiangling et al. found that cultivating gratitude thinking and strengthening gratitude awareness can effectively reduce negative emotional experiences and enhance the sense of life meaning [4].

Furthermore, foreign scholars such as Kleiman et al. conducted a prospective survey on college students and found that gratitude buffers suicide risk by enhancing their sense of life meaning [5]. Tongeren et al.'s study demonstrated that college students who express gratitude through writing thank-you letters experience a greater sense of life meaning [6].

2 PARTICIPANTS, TOOLS, AND METHODS

2.1 Participants

A total of 290 questionnaires were distributed, with 270 valid questionnaires used for statistical analysis. Among them, there were 100 males (37%) and 170 females (63%); 80 students majoring in humanities and social sciences (29.6%), 119 in science and engineering (44.1%), 55 in arts (20.4%), and 16 in other majors (5.9%); 44 freshmen (16.3%), 67 sophomores (24.8%), 90 juniors (33.3%), and 69 seniors (25.6%); 95 only children (35.2%) and 175 non-only children (64.8%); 122 rural students (45.2%) and 148 urban students (54.8%); 92 students who had served as student leaders (34.1%) and 178 who had not (65.9%).

2.2 Research Tools

2.2.1 College Student Gratitude Scale (GART)

Adopting the revisedCollege Student Gratitude Scaleby Sun Wengang et al., the scale comprises 34 items divided into three dimensions: absence of deprivation, gratitude towards society, and gratitude towards nature. The absence of deprivation dimension contains 16 items, gratitude towards society includes 11 items, and gratitude towards nature comprises 8 items. The scale uses a 5-point Likert scale, with 1-5 points representing "strongly disagree," "disagree," "neutral," "agree," and "strongly agree," respectively. Higher total scores indicate higher levels of gratitude[7]. In this study, the Cronbach's α coefficient for the scale was 0.775.

2.2.2 Sense of Life Meaning Scale (MLQ-C)

Adopting the Chinese version of theSense of Life Meaning Scale(MLQ-C) adapted by Wang Xinqiang from Steger's originalMeaning in Life Questionnaire(MLQ), the scale consists of 10 items divided into two subscales: presence of meaning and search for meaning. Item 2 uses reverse scoring [8]. In this study, the Cronbach's α coefficient for the scale was 0.866.

2.3 Statistical Analysis

Data were entered and organized using SPSS 26.0. Group comparisons were conducted using t-tests or ANOVA, and correlations between gratitude and the sense of life meaning among college students were explored using correlation analysis.

3 RESULTS AND ANALYSIS

3.1 Control and Inspection of Common Method Bias

Given that this study utilized self-reported data from students, procedures were implemented to control for common method bias, including procedural controls during data collection, reverse scoring of individual items, and Harman's single-factor test. Initially, participants were informed through instructions that the questionnaire was solely for academic purposes, with strict confidentiality guaranteed, encouraging honest responses. Subsequently, Harman's single-factor test was conducted, incorporating all items from the two measurement tools into an exploratory factor analysis without rotation. The results showed that eight factors had eigenvalue values greater than 1, with the first factor explaining 23.98% of the total variance, below the critical threshold of 40%, indicating no significant common method bias in this study, allowing for subsequent analysis.

3.2 Demographic Differences in Relevant Variables

3.2.1 Gender differences

As shown in Table 1, significant gender differences were observed in gratitude towards nature, sense of life meaning, and meaning-seeking. Specifically, female students scored significantly higher than male students in these three dimensions, while no significant gender differences were found in other dimensions.

Table 1 Test of Differences in Variables by Gender

	Male(n=100)		Female(n=170)		
	M	*SD*	*M*	*SD*	*t*
Gratitude	113.31	20.21	116.56	11.76	-1.47
The absence of a sense of deprivation	42.43	9.93	42.82	9.30	-0.33
Gratitude to society	40.25	9.49	41.44	6.36	-1.11
Gratitude for natural things	30.63	7.27	32.31	5.03	-2.04*
Sense of life meaning	44.29	10.26	46.87	7.85	-2.17*
Meaningful	22.08	5.67	22.39	5.09	-0.45
Seeking meaning	22.21	6.48	24.48	4.86	-3.04**

Note: *p<0.05, **p<0.01.

3.2.2 Major differences

As depicted in Table 2, significant major differences were found in gratitude towards nature. Post-hoc tests revealed that students majoring in humanities and social sciences scored significantly higher in gratitude towards nature than those in science, engineering, and arts, with no significant differences observed among other majors.

Table 2 Test of Differences in Variables by Major

	Literature and History (n=80)		Science and Engineering (n=119)		Art-related (n=55)		Other (n=16)		
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*t*
Gratitude	116.41	11.65	114.48	16.86	116.25	14.74	113.56	23.43	0.38
The absence of a sense of	41.83	8.55	43.43	9.66	43.62	10.40	38.13	9.18	1.88

deprivation									
Gratitude to society	41.68	6.72	40.11	8.10	41.80	7.14	41.44	10.33	0.96
Gratitude for natural things	32.91	4.89	30.94	5.96	30.84	6.48	34.00	8.33	2.94*
Sense of life meaning	46.74	9.03	46.02	8.17	45.27	9.16	43.25	12.18	0.81
Meaningful	21.99	5.69	22.71	4.86	22.36	5.18	20.13	6.63	1.24
Seeking meaning	24.75	5.64	23.30	5.48	22.91	5.31	23.13	7.08	1.55

Note: *p<0.05.

3.2.3 Grade differences

Table 3 illustrates significant grade differences in the absence of deprivation, gratitude towards nature, and meaning-seeking. Post-hoc tests indicated that junior students scored significantly higher in the absence of deprivation than freshmen and seniors, while no significant differences were found between sophomores and other grades. In terms of gratitude towards nature and meaning-seeking, senior students scored significantly higher than freshmen, sophomores, and juniors, with no significant differences observed among the latter three grades.

Table 3 Test of Differences in Variables Across Grades

	Freshman (n=44)		Sophomore year (n=67)		Junior year (n=90)		Senior year (n=69)		
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*t*
Gratitude	111.59	21.92	115.03	14.43	117.24	12.86	115.62	14.55	1.335
The absence of a sense of deprivation	41.11	9.17	42.40	9.23	44.96	9.85	40.97	9.21	2.929*
Gratitude to society	40.27	9.57	41.04	7.53	41.38	7.12	40.91	7.28	0.206
Gratitude for natural things	30.20	7.55	31.58	5.61	30.91	5.48	33.74	5.49	4.236**
Sense of life meaning	44.45	11.76	45.49	8.69	45.37	7.86	47.97	8.05	1.807
Meaningful	22.95	5.85	22.55	5.57	22.02	4.72	21.90	5.44	0.484
Seeking meaning	21.50	6.90	22.94	5.61	23.34	4.57	26.07	5.21	7.364**

Note: *p<0.05, **p<0.01.

3.2.4 Only child status differences

As presented in Table 4, no significant statistical differences were found in gratitude, its dimensions, or the sense of life meaning and its dimensions based on only child status.

Table 4 Differences in Variables Among Only Children

	Only child(n=95)		Non-only child(n=175)		
	M	*SD*	*M*	*SD*	*t*
Gratitude	115.78	15.49	115.13	15.52	0.33
The absence of a sense of deprivation	43.62	9.36	42.17	9.60	1.20
Gratitude to society	40.20	8.53	41.43	7.15	-1.19
Gratitude for natural things	31.96	5.95	31.54	6.05	0.55
Sense of life meaning	45.03	9.44	46.39	8.56	-1.20
Meaningful	22.07	5.46	22.38	5.23	-0.46
Seeking meaning	22.96	5.55	24.01	5.63	-1.48

3.2.5 Family residence differences

Table 5 shows significant differences in the absence of deprivation based on family residence. Specifically, rural students scored higher in the absence of deprivation than urban students, with no significant differences observed in other dimensions.

Table 5 Test of Differences in Variables by Household Location

	Town(n=122)		Countryside(n=148)		
	M	*SD*	*M*	*SD*	*t*
Gratitude	114.21	16.82	116.30	14.28	-1.11
The absence of a sense of deprivation	41.14	9.67	43.95	9.24	-2.42*
Gratitude to society	41.11	8.63	40.91	6.82	0.21
Gratitude for natural things	31.97	6.26	31.45	5.80	0.70
Sense of life meaning	46.51	9.32	45.43	8.52	1.00
Meaningful	22.65	5.28	21.97	5.31	1.05
Seeking meaning	23.86	5.96	23.46	5.32	0.58

Note: *p<0.05.

3.2.6 Leadership position differences

As indicated in Table 6, significant differences were found in gratitude, gratitude towards society, and gratitude towards nature based on whether students had held leadership positions. Specifically, students who had not held leadership positions scored significantly higher in these three dimensions than those who had served as student leaders, with no significant differences observed in other dimensions.

Table 6 Test of Differences in Various Variables Based on Whether One Serves as a Student Leader

	Served as a student leader(n=92)		Has never served as a student leader(n=178)		
	M	*SD*	*M*	*SD*	*t*
Gratitude	111.91	18.88	117.14	13.10	-2.38*
The absence of a sense of deprivation	42.00	9.07	43.03	9.76	-0.84
Gratitude to society	39.50	8.46	41.77	7.13	-2.32*
Gratitude for natural things	30.41	6.98	32.34	5.34	-2.32*
Sense of life meaning	45.09	9.91	46.34	8.31	-1.10
Meaningful	22.04	5.33	22.39	5.30	-0.51
Seeking meaning	23.04	6.25	23.95	5.25	-1.26

Note: *p<0.05.

3.3 Correlation Analysis of Relevant Variables

As shown in Table 7, correlation analysis between gratitude, its dimensions, and the sense of life meaning and its dimensions revealed significant positive correlations between gratitude, gratitude towards society, gratitude towards nature, and the sense of life meaning and its dimensions.

Table 7 Descriptive Statistics and Correlation Analysis of Variables (n=270)

	M	*SD*	1	2	3	4	5	6	7
1.Gratitude	115.36	15.48	-						
2.The absence of a sense of deprivation	42.68	9.53	0.585**	-					
3.Gratitude to society	41.00	7.67	0.732**	-0.047	-				
4.Gratitude for natural things	31.69	6.00	0.716**	-0.018	0.683**	-			
5.Sense of life meaning	45.91	8.89	0.471**	-0.042	0.596**	0.520**	-		
6.Meaningful	22.27	5.30	0.279**	-0.179**	0.517**	0.343**	0.802**	-	
7.Seeking meaning	23.64	5.62	0.483**	0.103	0.455**	0.499**	0.826**	0.326**	-

Note: **p<0.01.

3.4 Regression Analysis of Relevant Variables

A multiple regression analysis was conducted with gratitude and its dimensions as independent variables and the sense of life meaning as the dependent variable. In the regression equation, only gratitude towards society and gratitude towards nature had regression coefficients with significance levels below 0.05, indicating that these two factors could be included in the regression equation, while other factors were not significant and were removed. The final regression equation model had an R^2 of 0.374, explaining 37.4% of the variance in the dependent variable.

Table 8 Variance Analysis of the Regression Equation of Gratitude and Sense of Life Meaning

Model		Sum of squares	df	MS	F	p
2	Return	8058.616	2	4029.308	81.524	0.000
	Residual	13196.424	267	49.425		
	Total	21255.041	269			

As shown in Table 8, the regression equation's F value was 81.52, with a p-value < 0.001, rejecting the null hypothesis and indicating the regression equation's validity for further analysis.

Table 9 Coefficient a of the Independent Variable in the Regression Equation

	B	Bata	t	p
(Constant)	14.550		5.779	0.000
Gratitude to society	0.523	0.452	6.839	0.000
Gratitude for natural things	0.313	0.211	3.199	0.002

Note: Dependent variable: Sense of life meaning

As shown in Table 9, the results of the stepwise regression method showed that both the constant and independent variables were significant in the regression equation, establishing the regression equation: Sense of Life Meaning = 14.550 + 0.523 * Gratitude Towards Society + 0.323 * Gratitude Towards Nature. This indicates that the predictor variables positively predict the sense of life meaning, with gratitude towards society having the strongest predictive ability. A coefficient of 0.523 for gratitude towards society suggests that for each one-point increase in this dimension, an individual's sense of life meaning increases by 0.523 points. Similarly, a coefficient of 0.313 for gratitude towards nature indicates that when gratitude towards society remains constant, a one-point increase in gratitude towards nature leads to a 0.313-point increase in the sense of life meaning.

4 CONCLUSION

(1) In gender difference tests, female students scored significantly higher than male students in gratitude towards nature, sense of life meaning, and meaning-seeking, with no significant gender differences observed in gratitude, absence of deprivation, or gratitude towards society.
(2) In major difference tests, students majoring in humanities and social sciences scored significantly higher in gratitude towards nature than those in science, engineering, and arts, with no significant differences observed among other majors.
(3) In grade difference tests, senior students scored significantly higher in gratitude towards nature and meaning-seeking than freshmen, sophomores, and juniors, while junior students scored significantly higher in the absence of deprivation than freshmen and seniors.
(4) In family residence difference tests, rural students scored higher in the absence of deprivation than urban students, with no significant differences observed in other dimensions.
(5) Whether students had held leadership positions significantly impacted gratitude, gratitude towards society, and gratitude towards nature, with students who had not held leadership positions scoring higher in these three dimensions than those who had served as student leaders.

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