

Lecture Notes in Education, Arts, Management and Social Science

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Lecture Notes in Education, Arts, Management and Social Science

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Research on the Criminal Liability for Traffic Accidents of Autonomous Vehicles

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Abstract: In recent years, China's automobile industry has improved rapidly, in the premise of making great progress in the field of traditional fuel vehicles. With the development of artificial intelligence technologies such as cloud computing and big data, autonomous driving vehicles have come into being. As soon as it came out, it received strong support from the government. Various preferential policies have been issued, and all kinds of capital have also flocked to it. A number of emerging driverless car enterprises have emerged, represented by Xiaopeng, Nio, Ideal, and BYD, and the development momentum is strong. In the near future, people's traditional way of traveling will change. The purpose of the research and development of autonomous vehicles is to reduce the probability of traffic accidents due to drunk driving and fatigue driving, protect the safety of citizens' lives and property, bring convenience to people's travel, and improve the efficiency of social work. However, while autonomous driving cars bring convenience to people's lives, there are also unknown risks. When the autonomous driving car causes a traffic accident, the existing law is difficult to determine the division of responsibility subject, and the autonomous driving system does not have the criminal subject qualification, so there will be the lack of responsibility subject. The identification of criminal responsibility for this type of event has become a difficult problem at present.

Keywords: Criminal responsibility; Automatic driving; Responsibility subject; Traffic accident crime

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1. Introduction

Compared with traditional cars, self-driving cars have the advantages of being more convenient and faster. However, due to their own processing system, algorithm programming, and other factors, it is difficult for self-driving cars to guarantee absolute safety in the driving process. After accidents, they will face more complicated problems of criminal law than traditional cars. As for the responsibility subjects for the crimes of autonomous vehicles, they

should be distributed based on the theoretical basis of traditional criminal law and the classification of autonomous driving, so as to distinguish the criminal responsibilities of drivers and other responsible subjects ^[1]. The criminal responsibility of the driver mainly considers whether there is intentional negligence for the occurrence of the accident. Besides the development, production, and sales of autonomous vehicles, the criminal responsibility mainly analyzes whether there is a duty of care. According to the division of criminal responsibilities of different subjects, the corresponding responsibility-bearing system should be strengthened.

2. Concept and development status of self-driving cars

2.1. Concept of self-driving cars

Since the first industrial revolution, people's road travel mode has changed dramatically, from the steam locomotive at the beginning of the day to the later fuel cars to the hot new energy vehicles in recent years. In recent years, the development of artificial intelligence technology has led to the emergence of autonomous vehicles. A self-driving car, also known as a driverless car, is a kind of intelligent car. In order to facilitate the convenience of travel, it mainly relies on the intelligent driving instrument based on the computer system in the car to achieve the purpose of unmanned driving ^[2]. According to the different degree of automatic driving car automation, a total can be divided into L1–L5 five levels: in L1, L2 level, the two forms of automatic driving can only perform simple braking processing or deceleration operation according to the road condition, L3 is also known as conditional autopilot and L4 known as highly automatic driving, L5 for fully automatic driving. As the current research results are more focused on the L3 and L4 levels, this paper mainly discusses the identification of the criminal responsibility of these two levels after a traffic accident ^[3].

2.2. Development status quo of self-driving vehicles

2.2.1. Foreign development process and status quo

In most people's cognition, autonomous driving technology seems to have suddenly developed in recent years, but in fact, it has not. As early as 1970, the United States and other developed countries have been very interested in driverless cars ^[4]. It is divided into three main fields: military utilization, road environment, and urban environment. The 1985 prototype VaMoR car developed by the Deutsche Federal University was tested outdoors at 100 kilometers per hour.

Since Google announced the launch of a driverless car project in 2009, autonomous driving technology has slowly come into sight ^[5]. In 2016, Uber officially opened its driverless car travel service to the public in Pittsburgh. In 2016, Uber began to test roads for autonomous driving. In the same year, Tesla released the Autopilot2.0, paired with models such as the Model 3. In 2016, Waymo was independent from Google, technically based on a combination of lidar and high-precision maps. Since then, Tesla has become a leader in intelligent driving. In 2017, the introduction of intelligent driving accelerated evolution. In 2021, FSD V11 based on Transformer + BEV technology was launched to improve its perception ability. In 2023–2024, Tesla launched FSD V12, using a neural

network-based algorithm system to promote the further development of autonomous driving technology [6].

2.2.2. Domestic development process and current situation

Compared with foreign countries, China's autonomous vehicle was developed later, but it also achieved rapid development. In 2011, FAW Group and National University of Defense Technology jointly completed the 286 km high-speed unmanned driving experiment in Hongqi HQ 3. In 2015, Baidu conducted a full autonomous driving test in Beijing; in the same year, Yutong Bus, the leading enterprise in the bus field, completed the autonomous driving test on the fully open road; at the end of the same year, Baidu established the autonomous vehicle Division. In 2019, China's first batch of mass-produced L4 autonomous passenger vehicles, jointly built by Baidu and FAW, received five autonomous driving road test licenses in Beijing. In 2020, Beijing issued the first batch of unmanned road test notices, and in the same year, Shanghai issued a new plan to allow high-speed L3 autonomous driving. From 2023 to 2024, Baidu, Ma Zhixing, and other enterprises will carry out pilot commercial autonomous taxi operations in some cities and gradually explore business models and operation experience. From the perspective of the development history of autonomous vehicles, foreign countries have developed for a long time in China and have great advantages in the advanced fields. However, China has increased the research and development of autonomous vehicles in recent years and has made remarkable achievements in several years [7].

3. Challenges of autonomous driving in traffic accidents

3.1. Change in the subject of responsibility

Self-driving cars are in the development stage at present, there is still a higher risk of traffic accidents. In the event of a traffic accident, the responsibility is difficult to identify; in the traditional driving mode, according to the current criminal law and related specifications, the responsibility of the traffic accident generally falls on the driver, vehicle owners, vehicle competent unit, etc. With the opening of the autonomous driving function, the role of the driver of the autonomous car has been changed to the passengers to a certain extent. Obviously, the passenger cannot be the main body of responsibility for traffic accidents. Autonomous driving replaces the role of the driver. When the autonomous driving system faces sudden problems, once the decision-making mistakes occur, the consequences are severe. At this time, in a certain sense, the autonomous driving car itself is likely to become the main body of responsibility. Producers and developers can also be held responsible [8].

3.2. Difficulties in determining the causal relationship

Unlike traditional traffic accidents, automatic traffic accidents can directly determine damage behavior and consequences. In many cases, there is no fault on the part of the driver, as the accident is not caused by their actions, nor does it involve any intentional or negligent psychological attitude. This fundamental difference sets automatic traffic accidents apart from traditional ones [9]. Additionally, because obtaining evidence from autonomous driving systems is challenging, the police must determine whether the system was active and whether it malfunctioned. This

process is more complex than the traditional causal identification of traffic accidents.

3.3. Lack of relevant legal regulations on autonomous driving car accidents

The existing traffic regulations and criminal regulations mainly target the traffic accidents under the traditional driving mode. Due to the characteristics of self-driving vehicles, it is difficult to simply apply the existing laws and regulations accordingly. Other regulations have few rules for self-driving cars. Some laws do not even allow the production and use of self-driving cars, which fully reflects the lag of the law. Laws are urgently needed to adapt to the era of self-driving cars ^[10].

3.4. Uncertain mode of bearing criminal responsibility

First, a self-driving car does not fall under the category of either a natural person or a legal entity. However, when a traffic accident occurs, a corresponding subject must bear criminal responsibility. This creates an evident contradiction—since self-driving cars themselves cannot be held liable, and fines imposed on natural persons or legal entities do not fulfill the fundamental purpose of criminal punishment.

4. Identification of criminal responsibility subjects in autonomous driving traffic accidents

Self-driving cars provide significant convenience but also raise questions regarding the allocation of criminal responsibility in the event of an accident. The release of the recommended national standard, *Automobile Driving Automation Classification*, marks the official establishment of China's driving automation classification system. From the perspective of criminal law's attributes and practical significance, autonomous vehicles cannot be held criminally responsible. Instead, users who assume different roles in various driving scenarios and fail to fulfill their duty of safety care should be held liable for negligence. If product defects exist before entering the market, the manufacturer is not liable for negligence but bears strict liability for intentionally producing vehicles that fail to meet safety standards—constituting the crime of producing non-compliant products. If defects are discovered after a vehicle has entered the market due to the manufacturer's failure to fulfill its supervisory and management obligations, the manufacturer should be held criminally responsible for negligence by omission ^[11].

4.1. Whether autonomous vehicles can be used as the subject of criminal responsibility

4.1.1. Discussion on autonomous vehicles as the subject of criminal responsibility

The question of whether self-driving vehicles can bear criminal responsibility has led to two perspectives. The first view argues that after a traffic accident occurs, the responsible party must be identified to uphold legal dignity and social fairness. Since the driver cannot be held criminally liable, and in the absence of manufacturer fault, it is reasonable to consider self-driving cars themselves as legally responsible entities. The opposing view contends that

self-driving cars are products of algorithms and lack free will, making them incapable of assuming criminal responsibility like natural persons or legal entities. Instead, responsibility should be assigned through other means ^[12].

4.1.2. Self-driving vehicles cannot be the subject of criminal responsibility

As stated above, self-driving cars are ultimately products. First, they lack independent consciousness, cannot make autonomous driving decisions, and do not possess intent or negligence. Second, criminal penalties such as imprisonment or fines cannot be applied to self-driving vehicles. Therefore, the author agrees with the view that self-driving cars cannot bear criminal responsibility ^[13].

4.2. Automobile producers and developers can be used as the subject of criminal responsibility

Given that self-driving vehicles cannot bear criminal responsibility, their production quality must comply with relevant product standards. If a traffic accident occurs and authorities determine that a vehicle system failure caused the accident, the self-driving car may have product defects. Due to the nature of self-driving cars, such defects pose significant safety risks. According to relevant provisions of criminal law, automobile manufacturers may be held criminally liable for producing and selling products that do not meet safety standards ^[14]. A particularly exceptional case arises if a developer with malicious intent exploits vulnerabilities in the autonomous system to commit crimes. In such instances, the developer could be charged with offenses related to computer information system violations or specific types of intentional crimes.

4.3. The automobile user may act as the subject of criminal responsibility

As the primary individuals capable of directly controlling self-driving vehicles, users are responsible for ensuring driving safety, particularly in cases of system failure. If an autonomous driving system malfunctions, users must fulfill their duty of safe driving and traffic supervision. If a user knowingly or negligently fails to take necessary safety measures, or implements incorrect ones, they should bear corresponding criminal responsibility. However, if the user is unable to intervene in the driving system in time, or if the accident is primarily caused by the failure of the autonomous driving system, they should not be held criminally liable ^[15].

5. Conclusion

The emergence and development of autonomous vehicles can bring convenience to people's travel, improve the efficiency of social operation, and reduce the probability of traffic accidents. As the future development direction of the automobile industry, it also indicates a great change in the way people travel in the future. In the future, autonomous driving will develop in a more intelligent direction, but there is still the possibility of traffic accidents. It is inevitable to encounter problems such as the identification of the subject of responsibility and causality. According

to the existing traffic laws and criminal regulations, it is difficult to solve the existing problems. Therefore, from the perspective of the identification of criminal liability of autonomous driving vehicles, this paper put forward the problems facing the identification of traffic accident liability of autonomous driving vehicles. It can be concluded that the improvement of relevant laws is urgent, and the laws and regulations should have a certain forward-looking perspective to open up the way for the development of society.

A self-driving car, in its attempt to protect passenger lives, may engage in aggressive emergency risk avoidance, potentially causing the death of others. Such behavior meets the criteria for intentional homicide and constitutes an impermissible risk, as it exceeds necessary limits and does not qualify as a legally justifiable emergency measure. Since innocent pedestrians are placed in danger, this scenario does not meet the conditions for a conflict of obligations and, therefore, does not fulfill the constitutive elements of a lawful defense. Consumers are aware that self-driving cars are programmed with risk avoidance procedures, yet they still operate these vehicles on public roads, leading to the death of innocent pedestrians. In doing so, they exploit the pre-programmed emergency risk avoidance mechanisms of the vehicle. Given the standardized structure and implementation of emergency risk avoidance, consumers can be held accountable, as their actions leave no room for alternative expectations. Manufacturers, in pursuit of commercial interests, program vehicles to prioritize passenger safety over pedestrian lives. This establishes a direct causal relationship between their design choices and the deaths of pedestrians, thus making them complicit as accessories to intentional homicide. Until the ethical dilemmas surrounding self-driving cars are resolved, these vehicles should not be permitted on public roads; otherwise, their deployment would be unlawful.

Disclosure statement

The author declares no conflict of interest.

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Development of a Mobile Application through Interface Design: Mental Health Assessment and Support for College Students

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Abstract: The mental health of college students has received a lot of attention from designers in recent years. The development of applications to help college students support their mental health has a considerable market prospect. At the same time, there is some room for improvement in the interface design of related applications. This article mainly discusses the theoretical framework and interface design direction of providing meditation and emotion tracking as two kinds of mental health applications. Through literature review, it proves the effectiveness of developing apps through interface design to positively affect mental health disorders. The results of the study show that college students have a strong need for personalized interface design for apps, a lack of motivation and spontaneity in the continued use of the apps, a lack of information on how to use mental health apps appropriately, and a lack of psychological knowledge on the part of the users. This research provides a reference direction for prototyping mental health apps to make up for the lack of existing interface design.

Keywords: Mobile application; Interface design; Mental health; College students

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1. Introduction

Nowadays, with the rapid updating and replacement of mobile phone development technology, people spend a lot of time every day using mobile phone programs that can achieve a variety of functions. The number of people who are dependent on their mobile phones is also growing, and some of them have even become addicted to them. The highest level of addiction is found among degree students, as this group has plenty of time at their disposal during

their college years, without heavy social responsibilities and family burdens ^[1]. College students irrationally allocate time for mobile phone use, leading to mobile phone addiction, which negatively affects their mood and mental health ^[2]. At the same time, university students face challenges to their mental health as they adapt to their new campus environment and try to make new friends. Studies have shown that a quarter of students have felt depressed. The emergence of negative emotions among university students is also importantly linked to interpersonal relationships. When students feel disconnected from each other or isolated, it can also increase the risk of mental illness among university students ^[3].

The concept of humanistic care in design has prompted a lot of designers to focus on the mental health issues that people have when designing apps. Using this as a starting point, the interface design provides people with a platform for psychological assessment and support. The main categories of design types of mental health apps common in the app market are meditation and positive thinking, mood tracking, peer support, professional support, and courses ^[4]. Positive thinking meditation, a treatment for depression, uses a gamified framework to guide users through a meditation session. When used by college students, it has been able to significantly reduce levels of depression. Compared to the possible adverse effects of medication, the meditation program has more advantages, from the lack of side effects to the price and convenience ^[5]. Mood tracking is designed to allow people to choose the color, emoticon, etc., that corresponds to their mood at the moment and personalize the text and images through the interactive design of the interface. The program is designed to be visualized and fed back to the user through the recorded data. People consciously attend to and manage negative emotions through the use of emotion tracking. However, when people use these methods to record emotions, they want to be able to personalize their emotion options because of the diversity of words used by each person to express different emotions ^[6]. Through the interface design, it grasps the user's stickiness to mobile phone use, widens the channels of propagating psychological knowledge, and enables students to detect the problem in time and get effective help at the early stage of mental health problems ^[7]. The overview illustrates existing mental health program interface design weaknesses and identifies innovative breakthroughs. It provides effective and authoritative design recommendations through experimental results and interface design trends, and feedback from mental health experts. The design of meditation and mood tracking applications is taken as the main subject of the review.

2. Literature review

Fish and Saul investigated the effectiveness of using a meditation app for alleviating depressive symptoms in college students ^[5]. To recruit college students inexperienced in using positive thinking meditation to alleviate depression, a randomized controlled trial was conducted using a guided meditation app. The experiment consisted of having participants engage in 10 sessions over two consecutive weeks, with the sessions providing guided meditations of up to ten minutes for testing. Incentives were also set up. The self-determination theory (SDT) and gamification structure were used to increase participant motivation, and the use of gamification principles made the process more fun. The test collected data using Headspace, where the interface was designed to include the ability for students to

self-select the content of the course, using different themes for the meditation experience, offering personalized options. On first use, animations were provided to guide the practice of the meditations. A large number of illustrations and dynamic effects were also used within the software to enhance user engagement.

Depressive symptoms were measured using the Patient Health Questionnaire (PHQ-9), which allowed users to score their own assessment after the meditation session and to understand the mood changes before and after the session through the scores. The results showed that five of the nine scores showed significant decreases compared to the pre-session scores. These included low mood, fatigue, poor spirituality, depression, and irritability. The results of the experiment demonstrate the effectiveness of the use of the Positive Thinking Meditation app in reducing depressive symptoms in college students. The disadvantages of meditation practice include the amount of time it takes to learn and practice to master it [8]. Using a meditation program only requires headphones to start, there are no restrictions on location, and the practice time is much shorter, with the program planning ahead for the user to use it wisely. Personalized support is provided to increase their autonomy in engaging with the use. The limitations of the experiment are reflected in the fact that the sample size was small—predominantly female—and the students participating in the experiment were all from the same school. Self-assessment may have data inaccuracies. It provided a theoretical source of data and a design case reference for providing psychological support to college students through interface design.

Analyzing the data, Cha and Lee [9] pointed out that the existing meditation app market is slowing down but is still popular with a large number of users [9]. Meditation app development continues to innovate, using technologies such as AR and VR to combine with meditation scenarios and develop different types of natural environment experiences. User experience and user interface design trends are proposed to increase user satisfaction and comfort in using apps. These include (1) Dark color mode, which refers to the ability to protect the eyes when users use the app at night. (2) For UI design, in the MAC OS system, the realistic ICON drawing style increases, enhancing the icon for the depth of observation of light and shadow and the structure of the object; it is more natural and realistic, enhancing the user's visual impact and interest. (3) In terms of color selection, rich and strong colors are used for creation, thus enhancing the user's visual experience of using the software. (4) The title font is redesigned to highlight key content. (5) More illustration designs are added in the software design content. (6) 3D style and narrative illustration are popular in the design style. The increased use of 3D animation scenes enables a more intuitive feeling of the product concept and a stronger sense of user participation and interaction, enhancing the user's visual experience. Compared with the above, further visual design suggestions are provided based on the current user aesthetic trends. At the same time, the preference for the use of illustration and dynamic effects is in line with the interface design style experimented above. However, the design lacks experimental data and needs to be evaluated for the use of interface design. Unlike Fish and Saul [5], who obtained their data sources from studying interface design theories and using the PHQ-9 questionnaire research, Cha and Lee obtained data on the visual design of meditative apps by analyzing existing style trends in the app market.

According to Caldeira *et al.*, studying the sentiment tracking functionality, the data came from 742 apps related to sentiment tracking in the Android shop and IOS app shop [6]. A total of 32 apps from both platforms were selected

and analyzed for their app functionality. A stage-based model of personal informatics systems is selected for analysis. The system contains five stages: preparation stage, collection stage, integration stage, reflection stage, and action stage. After analyzing the functionality of the selected application, it was concluded that in the preparation phase, pre-information is placed to introduce the tracking function used by the program and to guide the user in tracking the emotions. In the collection phase, different ways of tracking and recording the emotions of the moment were used to set the frequency and time at which they wanted to collect emotional data. In the reflection phase, the data accumulated by the user is collected and analyzed visually. In the action phase, the data is used to give users mental health advice and provide professional psychological resources, as well as support the export and sharing of personal data. The analyses concluded that in the preparation phase, the apps generally lacked psychological support information, such as how to properly manage emotions when users use them for the first time. There was also a lack of guidance for novice users when introducing the features. In the collection phase, among the features were (1) the user's selection of emotional keywords through preset text; (2) entering text content freely, (3) choosing a color that matches the current mood, (4) choosing to express the emotion by taking their own photo or a picture from their phone; (5) recording audio, (6) picking emoticons, and (7) scoring their emotions. The emotion visualization in the reflection phase, on the other hand, has a reflective effect by displaying various visual designs such as bar charts or pie charts to let users understand their emotional state. Only seven of the selected applications analyzed provide suggestions for future actions.

Analyzing the app market, 24 mental health apps, Hamre-Os classified them into five categories by implementing different functions ^[4]. It also proposes which operational design factors to consider when programming a mood-tracking interface. During the development process, the prototype was designed in three iterations. At the same time, market user requirements, expert feedback, and user testing were investigated to improve the design prototype at each stage. The research data was obtained by conducting research on literature and based on user feedback analysis. At the early stage of design, requirements were made for the main functions: (1) The ability to have a wider range of choices when selecting pre-set emotions during emotion tracking. (2) Functionality to display the level of emotion in the moment. (3) Support for reflective review of previous tracking data. (4) Providing professional psychological support or counselling from a psychological agency. (5) Tracking reminders. The design requirements were consistent with the design flaws and user needs presented above, further demonstrating the problems with the design of the emotion tracking interface.

3. Discussion

There was a lack of strategic approaches for users to help alleviate their emotions ^[6]. The study concludes that more consideration should be given to the design of emotion tracking processes to enrich the design of the preparation and action phases in order to provide users with better psychological support. The existing design lacks user personalization options. The design protects the privacy of personal data and allows data to be shared with

professionals. The limitation is the lack of validation of the authenticity of the data. Mood tracking design, as part of the design to provide psychological support, was studied to analyze the structural design of the program while providing theoretical support for the system and suggesting changes to the interface design. In the three iterations of the design proposal, health psychology experts suggested that care should be taken when designing icon symbols and text words to avoid misunderstanding [4]. For the interface design, it was proposed that users should be able to easily preview a variety of different emotions in the mobile phone interface to facilitate the use of interaction. Attention was also paid to the fact that students have varied interpretations of different emoji designs and color choices when using the program. This can be customized to help students use the mood tracking tool better and get more accurate data. It is also necessary to provide a beginner's tutorial when using the software for the first time. The program should have the ability to see previous tracking data and the ability to customize different interface layouts, as well as setting the background to personal preference or making the style cleaner. Limitations are reflected in the data collection, which is all qualitative, and more research support is needed for further proof. With college students as the main users, we analyze the emotion tracking design factors, uncover personalized needs design gaps, and develop interface design prototypes. The difference with the previous literature review is that it is based on Caldeira's theory of design, and Hamre-Os further addressed the flaws in the preparation and action phases through design.

4. Conclusion

This literature review discussed two main design directions, meditation and mood tracking, by analyzing apps that provide mental health assessment and support. Existing experimental data and design cases are analyzed, and the results conclude that the development of mobile apps through interface design can help college students alleviate psychological problems. Meanwhile, according to the shortcomings and deficiencies of the existing interface design solutions, we optimize the interaction design for mental health, study the style trends of interface design, master the principles of structural design, and make theoretical preparations for developing design prototypes that college students like, theories include SDT and a stage-based model of personal informatics systems. Attention was paid to the need for personalized interface design to provide more professional psychological information and guidance for use in the process of psychological assessment and record-keeping for college students, including the use of more illustrations and animation effects and the use of gamification to enhance user motivation. This will help college students to develop a sense of mental health management so that they can have a healthier mindset to face the challenges in life. Future research can study how college students feel about using mental health software, conduct questionnaire surveys, explore the reasons for users' lack of motivation and abandonment of use, fill the design gap of how to cultivate users' spontaneous use, and optimize the design of mental health applications for the college student population.

Disclosure statement

The author declares no conflict of interest.

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Study on the Application of Rules for Normal Business Buyers

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Abstract: Effectively allocating rights and obligations between parties in guarantee relationships is essential to balancing the guarantor's discretionary freedom and the security interests of the guarantee right holder. This issue has long been a focal point in the reform of the chattel guarantee system. The "normal business buyer rule" stipulated in Article 320(a) of Part 9 of the Uniform Commercial Code (UCC) in the United States is a legislative approach aimed at harmonizing the inherent conflict between efficiency and security in commercial transactions. Similar provisions exist in Article 102 of the Model European Civil Code and Article 34 of the Model Law on Secured Transactions. However, despite its global prominence in chattel guarantee reforms, this system faces challenges of "acclimatization" when transplanted into the Civil Code. Critics argue that while comparative law establishes "normal business buyer rules" to sever the pursuit of security interests in chattel guarantees, it simultaneously allows for the extension of guarantee rights to income derived from the secured property, preventing excessive disposal freedoms granted to debtors from undermining security interests. In contrast, China's chattel guarantee system reform adopts the "normal business buyer rules" from foreign legal frameworks but neglects corresponding "income disposal" provisions to mitigate risks. This omission raises concerns about protecting mortgagees' interests.

Keywords: Normal business buyer; Guarantee system; Ownership

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1. The interpretation logic of the "normal business buyer rules"

1.1. Examining the premise of the rules: Choosing a protection scheme for mortgagees

The extent to which mortgagees are protected during the transfer of mortgaged property significantly influences the structural design of the "normal business buyer rule." If mortgagees receive comprehensive protection, there is no inherent conflict between their rights and those of buyers, naturally facilitating trust protection for buyers. However, if mortgagees risk being reduced to ordinary creditors, the structure and application of the "normal business buyer

rules” must carefully balance the interests of both parties ^[1]. In the context of mortgaged chattel transfers, scholars propose three main protection schemes: (1) automatic extension of chattel security interests, (2) conditional extension (non-automatic extension), and (3) subrogation of property. Some scholars argue that the legal effects of subrogation and automatic extension are fundamentally similar, as guarantee rights are automatically extended to income subrogation. Consequently, subrogation can be classified under the automatic extension scheme.

1.2. The role of trust protection: Right of appearance and responsibility in application

The core issue addressed by the “normal business buyer rules” is how to reconcile the competing interests of mortgagees and buyers when their rights are in exclusive competition. The legal framework should effectively coordinate these interests while ensuring buyers’ reasonable trust in transactions ^[2]. Legal order should reflect and integrate societal order. Trust, with its indispensable social function, naturally forms part of this order. From a legal ethics perspective, the law protects trust to uphold the freedom and security of trustworthy transactions. If reasonable trust is not safeguarded, individuals will lose predictability in their actions, leading to uncertainty, diminished confidence in the future, and ultimately, a decline in societal security and stability. Karl Larenz also contends that trust protection aligns with the stabilizing function of the legal system and is a fundamental requirement of legal order ^[3]. The German Civil Code emphasizes that trust must be broadly maintained as a foundation for interpersonal relationships, enabling peaceful coexistence even in loosely structured communities. Furthermore, the principles of trust, mutual respect, self-determination (private law autonomy), and self-discipline collectively form legitimate legal principles. “Promoting trust and protecting legitimate trust are among the most basic requirements that legal order must fulfill” ^[4].

2. Conditions for the application of the “normal business buyer rules”

2.1. Normal trading of inventory: an objective basis for reasonable trust

The rationality of trust primarily refers to whether there is a reasonable basis for the trust placed by the trusting party. This reasonable basis is derived from the apparent facts that allow the trusting party to form a judgment and develop trust. The function of apparent facts is to convey accurate information. Trust can be deemed reasonable only when the information conveyed by these apparent facts is sufficient and free from defects that could raise doubts ^[5]. From this perspective, the determination of reliable rationality is centered on apparent facts. These apparent facts may lead others to form a definite understanding that does not align with the actual state of the right, thereby shaping behavioral expectations for the trusting party. However, not all apparent facts provide a legal basis for trust. Trust is justified only when the apparent facts generally reflect the true state of the right. If certain facts lead to an understanding that deviates from reality, but the likelihood of this deviation is low, the trusting party has a duty to further verify the authenticity of the facts. Additionally, some facts may be inconsistent with common societal understanding, making it easy for anyone to distinguish the truth and recognize that the appearance is unreliable. In such cases, the trust generated is not reasonable. Accordingly, the appearance of the right is essentially an inference

based on general social experience and the facts that give rise to this appearance ^[6].

2.2. The buyer's subjective good faith: The subjective orientation of reasonable trust

The question of whether the “normal business buyer rules” system, as established in Article 404 of the Civil Code and Article 56 of the Interpretation of the Guarantee System, should be included has been a topic of considerable debate in academic circles. However, this issue can be resolved by examining the “normal business buyer rules” from the perspective of trust protection. Good faith is an evaluative concept that reflects the cognitive state of a private law subject. It refers to the trusting party's belief that the apparent facts are consistent with reality ^[7]. In essence, the question of whether trust is reasonable and whether the trusting party acted in good faith are essentially the same—they both concern whether the trusting party exercised sufficient caution before placing trust. If a fact is evidently unreliable—meaning the inconsistency between its appearance and reality is obvious—then the trusting party cannot claim ignorance of this inconsistency, and their trust cannot be regarded as having been made in good faith.

2.3. The mortgagee's risk liability: The principle of liability determination

Trust, as a core element of trust protection theory, plays a crucial role in the application of trust protection rules. However, identifying and evaluating trust can only explain why trust is worth protecting and why it gives rise to a right to claim; it does not clarify why the consequences of trust should be borne by the counterparty. Carnaris, a leading scholar in German trust protection theory, argues that the general requirements of apparent rights responsibility (also known as active trust protection responsibility) must include the attributability of the liability holder ^[8], in addition to the appearance of the right, the trusting party's good faith, and the presence of trust. The inclusion of attributability ensures that the interests of the responsible party are not unjustly deprived and that they have an opportunity to prevent adverse legal consequences for themselves. This approach allows trust protection and the responsible party's freedom to coexist. Professor Xinyan Ma summarized these principles in what is known as the “ABC Trust Law”: when the apparent trust (C) demonstrated by B can be attributed to A, A must bear the responsibility of trust, thereby ensuring that legal fairness is upheld ^[9].

3. The legal effect of the “normal business buyer rule”

3.1. The buyer obtains unencumbered ownership

According to Article 404 of the Civil Code, the legal effect of the “normal business buyer rule” is that the mortgage cannot be enforced against a buyer engaged in normal business activities. To clarify, “non-confrontation” refers to the inability to pursue mortgage claims rather than the elimination of the mortgage itself ^[10]. Some scholars argue that applying the “normal business buyer rule” results in the complete elimination of the chattel mortgage. However, this interpretation conflates two distinct concepts—mortgage elimination and the inability to enforce mortgage

claims—and lacks both legal and doctrinal support. In fact, cases involving mortgage elimination (such as the extinguishment of the principal creditor’s right or the creditor’s voluntary abandonment) do not align with this rule^[11]. In legal interpretation, “non-confrontation” simply means that the chattel mortgage does not hold legal effect against a specific party. An unregistered chattel mortgage cannot be enforced against a third party, but this does not imply that the mortgage ceases to exist or is extinguished. While the mortgagee cannot exercise the right to pursue the buyer engaged in normal business activities, this does not preclude the mortgagee from asserting claims—such as demanding the transfer price from the mortgagor—based on the mortgage right. An excessively broad interpretation of “non-confrontation” would unjustly diminish the mortgagee’s interests, leaving their rights inadequately protected and difficult to remedy, which is legally unsound^[12].

The core effect of the “normal business buyer rule” is to sever the enforceability of the chattel mortgage. In this context, a buyer engaged in normal business activities acquires unencumbered ownership, and the mortgagee loses the right to reclaim the movable property. However, if the buyer’s acquired property is auctioned or resold, the mortgagee may still claim priority in compensation from the proceeds. It is important to note that Article 404 of the Civil Code specifically applies the “normal business buyer rule” to chattel mortgages. However, Paragraph 2 of Article 56 in the Judicial Interpretation on the Guarantee System expands the applicability of this rule beyond chattel mortgages to include ownership-retention sales and financial lease transactions. Consequently, both the buyer in an ownership-retention sale and the lessee in a financial lease transaction are brought under its protection^[13]. The Civil Code not only partially incorporates the functional concept of guarantees but also extensively discusses the nature of ownership within secured transactions involving ownership-retention sales and financial leases. Different interpretations of ownership can lead to varying legal conclusions. Taking ownership-retention sales as an example, if the seller’s retained ownership is considered true ownership, and the buyer transfers the goods without authorization, the legal basis for the buyer to obtain unencumbered ownership would fall under the bona fide acquisition system of Article 311 of the Civil Code. Conversely, if the seller’s retained ownership is functionally equivalent to a security right, then ownership-retention sales resemble chattel mortgage arrangements and should follow the provisions of Article 404 of the Civil Code.

3.2. Risk distribution between the mortgagee and the buyer

In a broad sense, the legal effect of the “normal business buyer rule” should not only allow the buyer to acquire ownership of the chattel free from encumbrances but also include the mortgagee’s right to relief^[14]. The application of the risk principle serves only to allocate risk between the real right holder and the trusted subject. The mortgagee’s non-interest state is a consequence of risk rather than a legal responsibility in the strict sense, similar to how an apparent agent bears an obligation only to themselves. Compared to the real right holder, the apparent right holder clearly assumes actual liability. The trust protection theory primarily addresses the initial allocation of liability between the buyer and the real right holder, while the latter must ultimately seek liability claims against the apparent right holder based on the fundamental legal relationship. Current academic criticism of the legislative expansion of the “normal business buyer rule” mainly focuses on its potential negative systemic effects. For instance, Professor

Hailin Zou argued that expanding this rule disrupts the structured framework of mortgage enforcement and effectiveness, potentially undermining the institutional foundation of chattel mortgage guarantees. While this paper acknowledges the validity of such concerns, it does not agree that legislative progress should be impeded solely due to negative systemic effects. By enhancing the relief mechanisms available to the real right holder, these adverse effects can be effectively mitigated ^[15].

4. Conclusion

Similar to foreign legal frameworks, the “normal business buyer rule” in the Civil Code is fundamentally based on the principle of trust protection. However, a key distinction lies in the fact that the Uniform Commercial Code of the United States and the United Nations Commission on Trade Law explicitly stipulate that security interests automatically extend to the income generated from the secured property, thereby ensuring logical trust protection for the buyer. In contrast, under Chinese law, the application of the “normal business buyer rule” necessitates additional protection for the mortgagee. This stems from the prevailing legal stance that security interests in chattel do not automatically extend to the income derived from the collateral, making it difficult to safeguard mortgagee interests within the framework of the “normal business buyer rule.” The realization of secured creditor rights is the mortgagee’s primary concern. While trust protection and transaction security are important, they should not come at the undue expense of the mortgagee’s rights. Excessively prioritizing local efficiency at the cost of overall systemic benefits may weaken the practical viability of the chattel mortgage system, leading to undesirable outcomes.

Transaction orders can emerge either spontaneously or through legal regulation. In American law, the “normal business buyer rule” acknowledges and upholds existing market practices. Article 404 of the Civil Code of China must take into account the social and economic conditions that underpin foreign legal provisions to avoid conflicts in adaptation. The property law implications of collateral transfer must be carefully considered. Since the Civil Code does not recognize the automatic extension of chattel security interests, and mortgage enforcement mechanisms remain insufficient to fully protect the mortgagee, the application of the “normal business buyer rule” must align with the practical realities of the chattel mortgage system. It must also adequately address the mortgagee’s interests. Regarding the composition of the “normal business buyer rule,” the definition of the buyer’s subjective good faith should be refined in accordance with the interpretation of apparent rights. Additionally, mortgagee liability should be incorporated as a factor in the system’s design to balance the buyer’s reliance interests with the broader legal framework.

Disclosure statement

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Study on the Differences in Root System Development between Beihong and Muscat Hamburg Tissue Culture Seedlings

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Abstract: Beihong exhibits strong disease and frost resistance, allowing it to overwinter safely without soil burial in most wine-producing regions of China. It also possesses high fruit quality, making it suitable for winemaking. However, its rooting ability is poor in production. This study utilized tissue culture techniques, designing nine groups of tissue culture plantlets with varying concentrations of sucrose, NAA, and IBA through an orthogonal experiment to induce rooting. The Eurasian variety Muscat Hamburg, known for its ease of rooting, was used as a control to investigate the differences in rooting between the two varieties. The objective was to provide a theoretical basis for the propagation and rooting of Beihong in practical production. The number of main roots, number of lateral roots, and main root length for both varieties were measured at 20, 30, and 40 days after rooting treatment. Additionally, the levels of ABA, GA3, IAA, and tZ in the roots of both varieties were analyzed at five treatment stages (1, 2, 5, 6, and 8). The synthesis of IAA-related receptors and carrier-related genes in the roots was also quantified. The results indicated that Beihong exhibited a higher rooting rate and superior rooting index compared to Muscat Hamburg. Significant differences in endogenous hormone levels were observed between the roots of the two varieties. The correlation coefficient between the IAA level and root indices was high in Beihong but low in Muscat Hamburg. The expression levels of IAA-related genes in the root systems of both varieties showed considerable differences, though some similarities were also noted. Gene expression varied across the three observation periods. This study provides a theoretical foundation for improving the rooting process of Beihong.

Keywords: Wine grape; Tissue culture; Rooting; Endogenous hormones; Relative gene expression

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1. Introduction

Grapes are among the most widely cultivated fruit crops worldwide. Currently, most wine grape varieties grown in China are of Eurasian origin. Unlike in Europe, where they do not require burial for winter protection, some Chinese wine-producing regions experience a continental monsoon climate, necessitating soil burial for Eurasian grape varieties during winter. This practice significantly increases labor costs ^[1]. Therefore, the development of wine grape

varieties with enhanced cold and drought resistance, along with high fruit quality, is of particular importance. *Vitis vinifera*-*Vitis amurensis* Beihong (Beihong) is a hybrid of *Vitis amurensis* Rupr. and *Vitis vinifera* L. Muscat Hamburg. It possesses excellent disease and frost resistance, as well as superior fruit quality. Unlike most Eurasian varieties, Beihong can survive winter without soil burial in many wine-producing regions of China [2], making it highly suitable for winemaking. Addressing the challenges associated with Eurasian grape cultivation in China through variety selection is a promising approach.

This study employed tissue culture techniques to investigate the effects of different treatments on the rooting stage of Beihong. Comparisons were made with Muscat Hamburg, a Eurasian variety known for its superior rooting ability, to examine the differences in their rooting processes. The objective was to provide a theoretical basis for the propagation and rooting of Beihong in practical production [3].

2. Materials and methods

2.1. Test materials

The explants used in the tissue culture experiments for Beihong and Muscat Hamburg were biennial stems with uniform growth. In July 2021, bud-bearing stem segments of Beihong and Muscat Hamburg were collected from the wine grape experimental garden of “Ningxia Modern Agricultural Comprehensive Development Engineering Technology Research” in Pingjipu, Yinchuan, Ningxia. The experimental materials consisted of 7-year-old Beihong and Muscat Hamburg grapevines trained in a “factory” shape, with a plant spacing of 0.8 m × 3.0 m, oriented in a north-south direction [4].

2.2. Test methods

2.2.1. Sterilization of explants

Upon collection, healthy and uniformly growing explants were immediately selected and rinsed thoroughly with running water for 10 minutes. The explants were then disinfected in a 70% ethanol solution for 45 seconds under an ultra-clean workbench, followed by three washes with sterile water. Subsequently, they were sterilized with a 15% H₂O₂ solution for 6 minutes and rinsed four more times with sterile water [5].

2.2.2. Initiation of culture

For culture initiation, the sterilized stem segments with buds were trimmed at a 45° angle, approximately 5 mm from both ends. The lower end was placed in contact with the culture medium. The composition of the initial culture medium included MS basal medium supplemented with 1.0 mg/L 6-BA, 0.2 mg/L NAA, 30 g/L sucrose, and 7 g/L agar. The cultures were maintained under a 16-hour photoperiod at an illumination intensity of 2500 lx and a temperature of 25°C [6].

2.2.3. Rooting culture

Once the cultured stem segments developed shoots of approximately 5 cm, the uniformly growing shoots were excised under an ultra-clean workbench and transferred to rooting medium. Each bottle contained a single rootless seedling. The basic medium was 1/2 B5, supplemented with varying concentrations of IBA (0.1, 0.3, 0.5 mg/L), NAA (0.1, 0.3, 0.5 mg/L), and sucrose (15, 25, 35 g/L) in an orthogonal experimental design. The agar concentration was 7.5 g/L. The cultures were maintained at 25°C under a 12-hour photoperiod with an illumination intensity of 2500 lx. Each treatment was replicated with 10 samples, and the rooting rate was assessed after 20 days. The number of taproots, lateral roots, and the taproot length of tissue culture seedlings in each medium type were recorded at 20, 30, and 40 days after treatment [6].

2.2.4. Sample collection and measurement of root development

Samples were collected and photographed 20, 30, and 40 days after rooting treatment. For each treatment, 10 samples were analyzed to determine the number of taproots and lateral roots. The length of the taproots was measured using E-Ruler software. Rootless tissue culture seedlings were excluded from statistical analysis [7].

2.3. Data analysis

Data processing and visualization were performed using Excel 365 and Origin 2021 Pro. Statistical analyses, including one-way ANOVA, were conducted using SPSS 26.0, with LSD tests applied for multiple comparisons ($\alpha = 0.05$). Orthogonal test analysis was performed using Excel 365.

3. Results

3.1. Effects of different concentrations of IBA, NAA, and sucrose on the rooting rate of tissue-cultured red seedlings of Beihong and Muscat Hamburg

After 20 days of rooting treatment, the rooting rate of all treatments for Beihong exceeded 80%, indicating a better overall performance. For Muscat Hamburg, the lowest rooting rate was observed in treatment M8 at 60%, while the other treatments showed improved results. Treatments 4 and 6, both containing 25 g/L sucrose with a high concentration of NAA, resulted in a 100% rooting rate for both varieties [8].

3.2. Effects of different treatments on root development of tissue-cultured seedlings of Beihong and Muscat Hamburg

After 20 days of rooting treatment, the number of taproots in H6 was significantly higher than in H1, H5, and H7. The number of lateral roots in H4 was significantly higher than in H7. The taproot length of H7 was significantly greater than that of H2, H3, H4, H5, H6, and H8.

After 30 days, the number of taproots in H3 was significantly higher than in H5 and H7 [9]. The number of

lateral roots in H1, H2, H3, and H5 was significantly greater than in H7 and H9. The taproot length of H1, H2, and H3 was significantly longer than that of H4, H6, H7, and H8.

After 40 days, the number of taproots in H4 was significantly higher than in H1 and H9. The number of lateral roots in H1, H3, H4, and H8 was significantly greater than in H5, H7, and H9. The taproot length of H3 was significantly greater than that of H4, H5, H6, H7, H8, and H9.

3.3. Effects of different treatments on endogenous hormones in the root system of tissue-cultured seedlings of Beihong and Muscat Hamburg

After 20 days of rooting treatment, the GA3 content in H5 was the highest at 104.20 ng/g, significantly higher than in H1 and H2. No significant differences in tZ content were observed among treatments. The ABA content in H5 was 3 µg/g, significantly higher than in H2 and H6. The ABA content in H6 was 0.91 µg/g, significantly higher than in H5, while the other groups showed no significant differences.

After 30 days, the GA3 contents in H1 and H6 were 110.83 ng/g and 110.47 ng/g, respectively, significantly higher than in H2, H5, and H8. The tZ levels in H2 and H6 were 52.12 ng/g and 53.56 ng/g, respectively, significantly higher than in H1, H5, and H8. The ABA content in both H1 and H6 was 3.16 µg/g, significantly higher than in H2, H5, and H8. The IAA content in H2 was 0.87 µg/g, significantly lower than in other groups, while other differences were not significant.

After 40 days, the GA3 content in H5 was 104.44 ng/g, significantly higher than in H1, H2, and H6, while the lowest content was observed in H6 at 88.69 ng/g. The tZ content in H2 was 47.94 ng/g, significantly lower than in other groups. The ABA content in H5 was 2.99 µg/g, significantly higher than in H1, H2, and H6. The IAA levels in H2 and H6 were 0.94 µg/g and 0.98 µg/g, respectively, significantly higher than in other groups. Overall, hormone levels in H5 were highest after 20 days of rooting treatment, while H6 exhibited higher hormone levels after 30 days [10].

3.4. Effects of different treatments on the expression of IAA-related genes in the roots of Beihong and Muscat Hamburg

3.4.1. Effects of different treatments on the expression of IAA receptor-related genes in the roots of Beihong

After 20 days of rooting treatment, the relative expression levels of H2 *VvABP1* and H5 *VvTIR1* in Beihong were significantly higher than those observed in other treatments. After 30 days, the relative expression levels of H2 *VvABP1* and *VvTIR1* remained significantly higher in the rooting treatment compared to other treatments. Similarly, after 40 days, the relative expression levels of H5 *VvABP1* and *VvTIR1* were also significantly higher in the rooting treatment than in other treatments.

3.4.2. Effects of different treatments on the expression of IAA transporter-related genes in the roots of Beihong

After 20 days of rooting treatment, the relative expression levels of H2 and H5 *VvAUX1*, H8 *VvLAX1*, H2 *VvPIN1*, and H5 *VvABCB1* were significantly higher than those in other treatments. After 30 days, the relative expression levels of H1 *VvAUX1*, *VvLAX1*, H2 *VvPIN1*, and H2 *VvABCB1* in the rooting treatment remained significantly higher than in other treatments. By the 40th day, the relative expression levels of H5 *VvAUX1* and *VvLAX1*, as well as H2 and H6 *VvPIN1* and H2 *VvABCB1*, were still significantly higher in the rooting treatment than in other treatments.

3.4.3. Effects of different treatments on the expression of IAA receptor-related genes in the roots of Muscat Hamburg

After 20 days of rooting treatment in Muscat Hamburg, the relative expression levels of M6 *VvABP1* and M5 *VvTIR1* were significantly higher than those in other treatments. After 30 days, the relative expression levels of M8 *VvABP1* and M5 *VvTIR1* remained significantly higher than in other treatments. By the 40th day, the relative expression levels of M8 *VvABP1* and M6 *VvTIR1* in the rooting treatment were still significantly higher than those observed in other treatments.

4. Discussion

Recent studies have shown that NAA plays a crucial role in promoting cell division and expansion, inducing the formation of adventitious roots, and preventing fruit drop ^[11]. NAA treatment enhances the formation and establishment of adventitious roots, increases their number, improves the rooting rate, and shortens the rooting cycle. However, while it does not significantly affect the elongation of adventitious roots, it can substantially increase root dry weight, even up to ten times compared to treatments without NAA ^[12]. As a synthetic plant hormone, IBA facilitates root formation, cell elongation, and root growth ^[13].

Sucrose, a common carbon source in plant tissue culture, significantly influences plant growth. At a sucrose concentration of 20 g/L, the root length of honeysuckle remains unaffected, but in the absence of sucrose, both root length and plant height are reduced ^[14]. Similarly, for *Phalaenopsis* Pink, the optimal root number and length are observed at a sucrose concentration of 20 g/L ^[15].

In this study, we found that the optimal treatment for each root index of Beihong varied over time, whereas for Muscat Hamburg, the best results were consistently observed in treatment 6 (25 g/L sucrose + 0.5 mg/L NAA + 0.5 mg/L IBA). Orthogonal analysis indicated that sucrose concentration was the most significant factor affecting the rooting rate of both Beihong and Muscat Hamburg, with the optimal concentration being 25 g/L. The primary factor influencing the number of main roots was NAA concentration. For Beihong, the optimal concentration was 0.3 mg/L, while for Muscat Hamburg, it remained consistently at 0.5 mg/L. The number of lateral roots in Beihong was most affected by NAA concentration, with an optimal level of 0.3 mg/L, whereas sucrose concentration was the dominant

factor affecting lateral root formation in Muscat Hamburg, with an optimal concentration of 25 g/L. The key determinant of taproot length in Beihong was sucrose concentration, with an optimal level of 15 g/L, while for Muscat Hamburg, it was NAA concentration, with an optimal level of 0.1 mg/L.

5. Conclusion

Using an orthogonal design, we tested nine different combinations of sucrose, NAA, and IBA concentrations to induce rooting in tissue-cultured seedlings of Beihong and Muscat Hamburg. The results demonstrated that Beihong exhibited a higher rooting rate than Muscat Hamburg, though the root system of Muscat Hamburg developed more robustly. For Muscat Hamburg, the combination of 25 g/L sucrose + 0.5 mg/L NAA + 0.5 mg/L IBA consistently produced optimal rooting results. In contrast, the optimal culture medium for Beihong varied depending on the treatment duration. Analysis of endogenous hormone levels and IAA-related gene expression in roots at three stages revealed significant hormonal differences between Beihong and Muscat Hamburg, even under identical treatments. The correlation coefficient between IAA levels and root indices was high in Beihong but not significant in Muscat Hamburg. Furthermore, the expression of IAA-related genes varied considerably between the two cultivars, with correlations between gene expression and IAA levels fluctuating over time.

Disclosure statement

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Research on the Collaborative Governance Mechanism of College Students' Ideological Shaping Empowered by Generative AI

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Abstract: The rapid development of generative artificial intelligence (AI) has reshaped the way college students receive and disseminate information, which has brought unprecedented challenges and opportunities to ideological education. As an important group in the construction of mainstream ideology, college students are faced with multiple dilemmas in their ideological formation, such as information cocooning, discourse power, and algorithm bias. Starting from the interaction mechanism between generative AI and college students' ideology, this paper analyzes the coupling relationship between the two, discusses the collaborative governance approach of multiple subjects such as universities and governments, enterprises and social organizations, and proposes a governance mechanism based on multiple collaborations based on technology empowerment, collaborative norms based on institutional innovation, and collaborative shaping based on value guidance. By constructing a collaborative governance framework with both flexibility and stability, a new pattern of ideological shaping with multi-agent participation, multi-path collaboration, and multi-dimensional evaluation is formed, which provides assistance for the healthy development of college students' ideology.

Keywords: Generative AI; Ideological shaping; Collaborative governance; Mechanism innovation; Value-led

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1. Introduction

The rapid development of generative artificial intelligence (AI) technology has brought new opportunities and challenges to the ideological shaping of college students. As digital natives, college students' ability to obtain information and form cognition with the help of AI tools has been significantly enhanced, but they also face risks such as information cocooning and algorithm bias. The General Secretary stressed that ideological work is of great importance to the training of builders and successors in colleges and universities. In the face of technological change,

it is necessary to build a collaborative governance mechanism with the participation of multiple subjects. The theory of collaborative governance provides a new perspective, emphasizing the realization of multi-agent interaction and collaboration under a common goal. Through a systematic and scientific governance path, we can effectively respond to the ideological challenges brought about by generative AI, grasp the initiative of ideological work, and guide college students to use AI technology rationally and critically.

2. Interaction mechanism between generative AI and college students' ideological shaping

On the one hand, generative AI provides college students with convenient and efficient tools for information acquisition and knowledge production and expands the cognitive boundary. On the other hand, its algorithm characteristics and content generation mechanism also imperceptibly affect the value judgment and ideological identity of college students. An in-depth analysis of this interaction mechanism is helpful to grasp the internal logic of college students' ideological shaping under generative AI empowerment and lay a foundation for building an effective collaborative governance mechanism.

2.1. Mechanism analysis of generative AI empowering collaborative governance

Generative AI reshapes the ideological collaborative governance model through the triple empowerment mechanism of data integration and intelligent analysis, precise push and interactive guidance, multi-agent linkage, and resource integration^[1]. In terms of information empowerment, AI relies on powerful data processing capabilities to realize the intelligent integration of massive information, identifies key trends from complex environments through natural language processing and deep learning technology, and promotes the transformation of ideological governance from empirical judgment to data-driven. In terms of communication empowerment, AI intelligently pushes content according to the cognitive characteristics and interests of the audience and uses interactive functions to shift the education model from one-way indoctrination to two-way interaction, which enhances the pertinence and effectiveness of mainstream ideological communication. In terms of collaborative empowerment, AI provides technical support for multi-subject cooperation, helps all entities form a governance synergy around a common goal by reducing information asymmetry, optimizing resource allocation, and improving collaboration efficiency, and provides systematic solutions through intelligent decision support functions, breaking the limitations of segmentation and building a new pattern of all-round and multi-level collaborative governance.

2.2. Pluralistic subject analysis of college students' ideological formation

In the process of ideological shaping, universities, government departments, and enterprise platforms serve as the leading subjects, guiding subjects, and technical subjects, respectively, and together constitute a multi-collaborative pattern^[2]. As the main front of talent training and thought leadership, colleges and universities systematically teach Marxist theory through channels such as ideological and political courses, campus cultural activities, and academic research, and mainly undertake three core functions in the era of generative AI: integration of educational resources,

innovation of educational model, and value orientation. Government departments, especially education and internet information departments, provide institutional guarantees and resource support for ideological work through policy formulation, resource allocation, and supervision and management, and are responsible for key tasks such as policy guidance and standardization, supervision, and resource guarantee in the context of AI. AI enterprises and network platforms play an increasingly important supporting role in ideological shaping by virtue of their technological R&D strength, directly influencing the information ecological environment through algorithm design, model training, and content review, and undertaking important responsibilities such as technology R&D, content governance, and value embedding, providing strong technical support and practical foundation for collaborative governance.

2.3. Dialectical relationship between ideological shaping with the intervention of generative AI

The coupling relationship between generative AI and ideological shaping is reflected in three dimensions: the dialectical unity and openness of technology empowerment and value orientation, the balance mechanism between sharing and the bottom line of security, and the interaction logic between algorithm recommendation and subject selection [3]. Technology empowerment provides a new realization path for value orientation and improves the efficiency and accuracy of communication, while value orientation sets the direction and boundary for technology application to ensure that technology development meets the requirements of mainstream values, with the two promoting and restricting each other. At the level of openness and security, AI promotes information flow and innovation, but also brings security challenges, and it is necessary to build a balanced mechanism through AI security audit technology, data sharing norms, and capacity building, so as to maintain the bottom line of ideological security in an open environment. In the interaction between the algorithm and the subject, AI analysis of behavioral data for content recommendation may lead to the “information cocoon” effect, and user choice will inversely affect the optimization of the algorithm and form a circular interaction, which requires that the algorithm mechanism be optimized to improve diversity and transparency in collaborative governance, and the audience’s critical thinking and subject initiative should be cultivated, so as to realize the organic combination of technical guidance and humanistic care.

3. Dilemma of the implementation of college students’ ideological collaborative governance under the empowerment of generative AI

Generative AI provides a new technical support and development path for the collaborative governance of college students’ ideology, but it also faces multiple difficulties in the process of practice. These dilemmas are not only due to the limitations and risks of technology itself but also from the structural contradictions in the coordination of multiple subjects as well as related to the particularity of ideological work. In-depth analysis of these practical dilemmas can help to find breakthroughs and provide a basis for building a more effective collaborative governance mechanism.

3.1. Algorithmic bias and content security risks

The algorithmic bias and content security risks of generative AI constitute a technical dilemma of ideological collaborative governance, which is manifested in three interrelated levels: the ideological bias hidden in the algorithm training data leads to the AI system unintentionally transmitting specific value tendencies in the process of content generation, and the “filter bubble” effect strengthens the user's existing value preference and polarizes the value cognition, and it is difficult for AI to serve ideological education objectively and neutrally ^[4]. Even if security alignment measures are implemented, there is still the possibility of being “jailbroken,” and malicious users may bypass security restrictions to generate content that violates mainstream values, impacting the ideological security defense line. The contradiction between the rapid development of technology and the lack of follow-up of ethical norms leads to the continuous breakthrough of technological boundaries and the relative lag of ethical standards. The existing system cannot effectively deal with AI application innovation, and there is no consensus on the ethical guidelines and safety standards applied in the ideological field. The standards and actions of various governance subjects are inconsistent in practice, which increases the uncertainty and risk coefficient of ideological collaborative governance.

3.2. Blurring the boundaries of responsibilities and the game of interests

The dilemma of subject collaboration in the generative AI environment is manifested as a structural problem in three dimensions: unclear responsibility boundaries, information barriers, and conflicts of interest. In terms of the boundaries of responsibility, AI technology has broken the boundaries of traditional ideological work, overlapping the scope of responsibilities of multiple entities such as educational institutions, government departments, technology enterprises, and social organizations. The existing institutional framework has failed to clearly define the boundaries of rights and responsibilities of each subject in the new technological environment, and there are disputes over the attribution of responsibility for inappropriate content generated by AI, resulting in frequent blame-shifting and redundant construction in the process of collaborative governance ^[5]. In terms of information sharing, although AI promotes the flow of information, the problem of data barriers between various entities is still prominent, the requirements of data security and privacy protection limit the scope of sharing, and the differences in technical standards and data formats increase the difficulty of integration. Additionally, the teaching data owned by educational institutions, the user behavior data held by enterprises, and the regulatory data managed by the government are difficult to effectively integrate, and collaborative decision-making is inefficient due to the lack of a global perspective. In terms of interest coordination, the tension between the pursuit of economic benefits and the pursuit of social benefits in ideological work, as well as the contradiction between the interests of various main departments and the overall interests, lead to the widespread phenomenon of “free riding” in collaborative governance, and the lack of sustainable and stable cooperation power and reciprocal mechanism between subjects.

3.3. Weakening of the discourse system and identity crisis

The value-leading dilemma in the generative AI environment is reflected in three deep-seated problems: the lack of attraction of mainstream discourse, the lack of critical thinking ability, and the shallowness of value identity ^[6]. In

terms of discourse system, the networked, fragmented, and entertaining communication environment has brought severe challenges to the traditional mainstream theoretical discourse, the digital indigenous group is accustomed to vivid and interactive expressions and lacks a sense of closeness to abstract theories, the AI-generated content has diverse styles and friendly language, and the mainstream ideological discourse is at a relative disadvantage in the competition. In terms of cognitive ability, AI convenient services cause young people to rely too much on ready-made answers and reduce independent thinking, resulting in cognitive inertia. Many audiences tend to directly accept AI-generated content rather than conduct critical analysis and lack discernment and judgment in the face of complex and changeable ideological information. In terms of value identification, AI has exacerbated the fragmentation of information acquisition and the shallow trend of cognitive construction. The knowledge acquired by young people through AI is often fragmented and difficult to form systematic cognition. AI responds to more neutral expressions and avoids value judgments, weakens the value-leading function, value identity stays on the surface and lacks deep rational thinking and emotional resonance, and the situation of “knowing what it is and not knowing why it is so” affects the internalization of mainstream ideology.

4. Effective practice of the ideological collaborative governance mechanism of college students empowered by generative AI

The collaborative governance of college students' ideology empowered by generative AI needs a systematic implementation path and effective coping with the above-mentioned practical dilemmas by building a governance system that emphasizes multi-subject collaboration and multi-dimensional integration, as well as technology and humanities. The design of the implementation path should be based on the actual needs of socialist education with Chinese characteristics, give full play to the enabling role of technology, and at the same time adhere to the value orientation of ideological work, so as to provide a strong guarantee for cultivating new talents who will take on the great task of national rejuvenation.

4.1. Technology empowerment: Building an intelligent monitoring and precise guidance system

The construction of a generative AI-enabled intelligent monitoring and precise guidance system should be designed around three aspects: situational awareness system, intelligent education platform, and precise ideological and political service mechanism ^[7]. The situational awareness system uses natural language processing technology to monitor and analyze the campus cyberspace in real time and conducts multi-dimensional data mining through deep learning algorithms to form an ideological situation assessment report, providing forward-looking decision-making support for collaborative governance. The intelligent ideological education platform integrates curriculum resources, practical activities, and media resources to realize personalized recommendation and intelligent interaction based on cognitive characteristics, enhance the immersion and experience of values education through AI-driven scenario simulation and role playing, and adapt to the learning habits of digital natives. The precise ideological and political service mechanism uses AI technology to draw the ideological portrait of the audience, assist in the design of personalized ideological and political programs, and realize the transformation from “flood irrigation” to “precise

drip irrigation”^[8]. The three support each other and together constitute the core architecture of the technology empowerment path, realize the keen capture of ideological dynamics through data-driven, and provide targeted educational content and service methods with the help of intelligent algorithms. It not only solves the problems of lagging information acquisition, low efficiency of content dissemination, and homogenization of service methods in traditional ideological and political work, but also effectively improves the scientificity, accuracy, and effectiveness of ideological work and provides a solid technical foundation for collaborative governance.

4.2. Institutional innovation: Improving coordination norms and responsibility sharing mechanisms

The core of the institutional innovation path lies in building a collaborative governance framework for multiple subjects, improving ethical norms and technical standards, and establishing a collaborative evaluation and accountability mechanism, so as to provide institutional guarantee for ideological collaborative governance empowered by generative AI. The multi-subject collaborative governance framework clarifies the boundaries of rights and responsibilities of all parties by formulating governance charters and establishing collaboration platforms, solves the problems of ambiguity of responsibilities and lack of motivation, and relies on clear rights and responsibilities and benefit and risk sharing to form a governance synergy^[9]. Ethical norms and technical standards address the ethical ambiguity in AI applications, clarify the value orientation and use boundaries, standardize data collection, algorithm design, and content generation, and prevent technical risks while maintaining innovation vitality. The collaborative evaluation and accountability mechanism constructs an evaluation system covering the dimensions of technology application, organizational collaboration, and educational effectiveness, establishes an accountability system for violations, and forms positive incentives and reverse constraints. These three institutional designs cooperate with each other to weave an institutional guarantee network, which not only clarifies the responsibility boundaries and behavioral norms of each subject in technological change, but also establishes an incentive mechanism and evaluation system to promote cooperation. It also sets up an ethical defense line and safety standards to prevent technological risks, effectively solves the institutional dilemmas such as ambiguous responsibilities, inconsistent standards, and poor coordination, and provides a standardized institutional environment and sustainable operation mechanism for ideological collaborative governance.

4.3. Value-led: Reshaping the discourse system and enhancing cultural identity

The value-led path focuses on achieving deep identification with mainstream ideologies through discourse innovation, ability training, and identity space construction^[10]. Discourse expression innovation uses AI technology to analyze the cognitive characteristics and language preferences of the audience, transforms abstract theories into concrete and life-like expressions, and uses AI to assist in the creation of high-quality content in various forms, so as to enhance the affinity and influence of mainstream ideological discourse. The cultivation of critical thinking and media literacy integrates AI literacy education into the curriculum system, carries out the training of discernment ability and value

judgment ability, and helps the audience maintain a clear understanding and independent choice in the complex information environment. The construction of cultural identity space uses AI technology to create virtual cultural pavilions and interactive communities to promote the integration of online and offline activities and provide immersive value experiences. These three dimensions constitute a value-leading chain from the outside to the inside and from knowledge to emotion to action, which solves the problems of rigid discourse, passive acceptance, and lack of experience in traditional ideological education. The problem of “listening” is solved through the intimacy of the form of discourse, the problem of “thinking clearly” is solved through the improvement of critical ability, and the problem of “trustworthiness” is solved through the construction of identity space, and finally the unity of cognitive, emotional, and behavioral identities is realized, forming the endogenous power and lasting effect of value leadership. This effectively copes with the challenge of weakening the discourse system and identity crisis in the AI environment.

5. Conclusion

The rapid development of generative AI has had a profound impact on the ideological shaping of college students, injecting new impetus and bringing novel challenges. Based on the interaction mechanism between AI and ideology, this paper proposes a three-in-one collaborative governance mechanism of technology empowerment, institutional innovation, and value leadership. In the face of the rapid iteration of AI and complex changes in ideology, it is necessary to strengthen interdisciplinary research and international comparison and practical exploration, and build a new pattern of collaborative governance led by the government and supported by universities and enterprises, and social participation. These measures provide a strong guarantee for cultivating socialist builders and successors, effectively respond to new challenges and risks in the ideological field, and cultivate the all-round development of socialist builders and successors.

Disclosure statement

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Research on Digital Innovation Strategy Path for Pharmaceutical Manufacturing Enterprises in Henan Province under the Background of Digital Economy

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Abstract: As a significant pharmaceutical manufacturing base in China, Henan Province shoulders crucial missions and responsibilities in enhancing the development level of pharmaceutical manufacturing enterprises and strengthening industry competitiveness. Against the backdrop of the vigorous development of the digital economy, digital innovation transformation has emerged as the core path for China's manufacturing industry to break through development bottlenecks and achieve high-quality development. Implementing a digital innovation strategy to promote industrial upgrading has become a widespread consensus in both industry and academia. However, the scientific planning and efficient implementation of digital innovation strategies to empower pharmaceutical manufacturing enterprises to continuously enhance their core competitiveness and achieve high-quality development goals remain key challenges for Henan's pharmaceutical manufacturing industry.

Keywords: Digital economy; Pharmaceutical manufacturing enterprises; Henan Province; Digital innovation

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1. Introduction

Amid the accelerated evolution of global technological innovation and industrial transformation, the digital economy has emerged as the core force reshaping the global competitive landscape. According to data from the China

Academy of Information and Communications Technology ^[1], China's digital economy surpassed 50 trillion yuan in 2023, accounting for 41.5% of GDP and becoming the primary engine of economic growth.

As a strategic pillar of the national economy, the digital transformation of manufacturing not only determines the industry's future but also impacts public health security and national strategic safety ^[2]. Henan Province, a major pharmaceutical manufacturing hub in China with a complete industrial chain covering biopharmaceuticals, chemical bulk drugs, and modern traditional Chinese medicine, achieved a total pharmaceutical industrial output value exceeding 280 billion yuan in 2023—7.2% of the national total. The province has cultivated leading enterprises such as Hualan Biology and Lingrui Pharmaceuticals. However, despite these achievements, Henan's pharmaceutical manufacturing sector still faces challenges under the digital economy wave, including efficiency bottlenecks in traditional production models, insufficient innovation capacity, and weak industrial coordination. The Henan Province 14th Five-Year Plan for High-Quality Manufacturing Development explicitly states that the pharmaceutical industry should exceed 300 billion yuan by 2025 ^[3], with digital transformation identified as the critical pathway to achieve this goal.

Globally, pharmaceutical companies are accelerating digital innovation. For instance, Pfizer reduced drug development cycles by 30% using AI technology ^[4], while Alibaba Health employed blockchain for comprehensive pharmaceutical supply chain traceability ^[5]. However, Henan's pharmaceutical enterprises lag in digitalization, characterized by limited application scenarios, prominent data silos, and a shortage of versatile talents. Against this backdrop, this study examines the current status and challenges of digital innovation in Henan's pharmaceutical manufacturing sector. Based on provincial realities, it proposes a “government-guided, enterprise-led, ecosystem-coordinated” three-dimensional strategic approach, aiming to provide theoretical and practical guidance for advancing the high-quality development of Henan's pharmaceutical manufacturing industry.

2. Current status of digital innovation development in Henan pharmaceutical manufacturing enterprises

2.1. Gradual improvement of policy support system

The Henan Provincial Government attaches great importance to the digital development of the pharmaceutical manufacturing industry and has introduced multiple policies in recent years to promote industrial upgrading. In 2023, the General Office of the Henan Provincial People's Government issued the “Henan Province Digital Economy Development Action Plan (2023–2025),” explicitly advocating the integration of new-generation information technology with manufacturing and supporting the digital transformation of pharmaceutical manufacturing enterprises. The “14th Five-Year Plan” of Henan Province in 2021 listed the digital transformation of manufacturing as a key task and proposed the strategic goal of building a “Digital Henan” ^[3].

2.2. Continuous strengthening of digital infrastructure

Henan Province has made remarkable progress in digital infrastructure construction, providing support for the

transformation of the pharmaceutical manufacturing industry. By the end of 2024, the province's software business revenue is expected to exceed 200 billion yuan ^[6], the scale of computing power and big data industries will surpass 100 billion yuan, and the core artificial intelligence industry will reach 80 billion yuan. Cities such as Zhengzhou and Luoyang have established multiple provincial-level big data centers, and 5G base stations cover major industrial parks across the province.

2.3. Rapid expansion of the pharmaceutical manufacturing industry scale

The pharmaceutical manufacturing industry is one of the pillar industries in Henan Province, with its industrial scale expected to reach 300 billion yuan by 2025. According to the "Henan Province Pharmaceutical Industry Development Report (2023)," the pharmaceutical industrial revenue of Zhengzhou, Luoyang, and Xinxiang accounts for over 60% of the province ^[7], demonstrating a significant industrial agglomeration effect. Zhengzhou has formed a bio-medicine and high-end medical device industrial chain; Luoyang and Xinxiang have prominent advantages in chemical raw materials and pharmaceutical preparations; Nanyang, Jiaozuo, and other places have witnessed rapid development in Chinese herbal medicine planting and modern Chinese medicine industries. Enterprises such as Lingrui Pharmaceutical, Wanxi Pharmaceutical, and Furen Pharmaceutical have been selected as the top 100 pharmaceutical enterprises in China, while bio-pharmaceutical enterprises represented by Hualan Bio and Antu Bio are rising rapidly.

3. Challenges faced by digital innovation in Henan pharmaceutical manufacturing enterprises

3.1. Severe shortage of interdisciplinary talents

Henan's pharmaceutical manufacturing enterprises have sufficient talent reserves in traditional R&D and production fields, but lack professionals with both medical backgrounds and digital technology capabilities. There is a widespread shortage of specialized personnel in areas such as digital strategic planning, big data analysis, and artificial intelligence applications, which restricts the in-depth promotion of digital transformation ^[8].

3.2. Need to expand digital application scenarios

Current digital applications in Henan's pharmaceutical manufacturing enterprises are mainly concentrated on automation upgrades in production (such as smart manufacturing production lines and IoT device applications), with fewer innovative applications in areas like drug R&D (e.g., AI-assisted drug design) ^[9], supply chain management (blockchain traceability), and precision marketing (big data analysis of user needs). The integration of digitalization and business operations is insufficient.

3.3. Urgent need to enhance enterprise digital awareness

Some managers of Henan's pharmaceutical manufacturing enterprises lack a full understanding of the strategic value

of digital transformation, still viewing digitalization as a cost rather than a strategic opportunity ^[10]. Some enterprises have not formulated clear digital development plans and only apply cloud computing, big data, and other technologies at a basic level.

3.4. Unbalanced digital infrastructure construction

Although the overall digital infrastructure in Henan Province has improved, the internal digital construction levels of pharmaceutical manufacturing enterprises vary widely. Small and medium-sized enterprises generally face issues such as insufficient network bandwidth, limited data storage and processing capabilities ^[11], and low penetration rates of industrial software, which hinder the deepening of digital transformation.

4. Countermeasures and suggestions for the development of digital innovation strategies in Henan pharmaceutical manufacturing enterprises

4.1. Government level

4.1.1. Strengthening policy supply and guidance

Governments at all levels in Henan Province should strengthen policy guidance to create a favorable policy environment for the digital transformation of pharmaceutical manufacturing enterprises. First, local governments should actively implement the central government's directives on integrating digital technology with the tourism industry and introduce special policies and measures to promote the digital transformation of local pharmaceutical manufacturing enterprises, forming a multi-level policy system. Second, governments at all levels should further improve financial and tax policies that facilitate the digital transformation of pharmaceutical manufacturing enterprises and strengthen financial support. Third, a digital technology standard system should be established to enhance the protection and management of intellectual property rights in the digital field and ensure the data security of pharmaceutical manufacturing enterprises.

4.1.2. Strengthening organizational leadership

Under the unified leadership of the Party Central Committee, governments at all levels in Henan Province should formulate and improve specific action plans to promote digital innovation in the pharmaceutical manufacturing industry within the national planning framework for digital economy development, playing a leading role in the digital innovation transformation of pharmaceutical manufacturing enterprises.

4.1.3. Strengthening technical and resource support for digital innovation in pharmaceutical manufacturing enterprises

Henan's pharmaceutical manufacturing enterprises urgently need advanced digital technologies and supporting

resources for digital innovation. Therefore, governments at all levels should actively provide efficient resource support and digital technology development platforms to assist pharmaceutical manufacturing enterprises in implementing digital innovation strategies.

4.2. Enterprise level

4.2.1. Enhancing managers' awareness of digital innovation

Enterprise managers are the formulators and decision-makers of pharmaceutical manufacturing enterprise strategies. Their understanding of digital innovation strategies is crucial to whether enterprises can successfully choose and implement digital innovation strategies. Therefore, enterprise managers should fully recognize the importance of digital innovation in the current digital economy era for shaping enterprise core capabilities and gaining competitive advantages.

4.2.2. Controlling the rhythm of digital innovation strategy implementation

Digital innovation strategy transformation is a systematic, complex, long-term, and high-cost project. Therefore, when promoting the implementation of digital innovation strategies, enterprises should pay attention to the breadth and depth of digital innovation, ensuring that the strategy matches the enterprise's resources and capabilities. Excessive innovation may lead enterprises into a transformation quagmire.

4.2.3. Strengthening the introduction and cultivation of digital technology talents

In the past, Henan's pharmaceutical manufacturing enterprises tended to recruit medical-background talents. In the future, they should strengthen the introduction of digital technology talents while also providing digital technology training for internal medical-background talents to turn them into interdisciplinary talents with both digital and medical technologies.

4.2.4. Improving enterprise digital infrastructure construction

The construction of digital technology infrastructure is crucial for the digital transformation of pharmaceutical manufacturing enterprises. Digital technology infrastructure is the most important tool for enterprises to carry out digital transformation and the core element to ensure its success. During the digital transformation process, pharmaceutical manufacturing enterprises should always pay attention to the matching degree between digital infrastructure resources and the digital transformation strategy. Excessively high-level digital infrastructure construction will increase unnecessary costs for enterprises, while excessively low-level construction will hinder the implementation of the digital transformation strategy. Therefore, pharmaceutical manufacturing enterprises need to continuously improve the construction of digital infrastructure during the implementation of the digital transformation strategy.

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Analysis of the Impact of Integrating the Concept of Low-Carbon and Environmental Protection into Ideological and Political Education on Students' Quality

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Abstract: The integration of the low-carbon environmental protection concept into ideological and political education can further cultivate the moral sentiment of students, promote students' awareness of low-carbon environmental protection, continuously improve their environmental protection ability, and enhance students' comprehensive quality, combined with relevant educational activities. Therefore, at the present stage, it is necessary to optimize the design of the education program based on the concept of low-carbon environmental protection, combining ideological and political education.

Keywords: Low-carbon and environmental protection; Ideological and political education; Students' quality; All-round development

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1. Introduction

The integration of low-carbon environmental protection concept into ideological and political education can transmit the sustainable development concept and low-carbon environmental protection concept of green civilization and healthy development for students, meet the requirements of the social main spiritual civilization construction, as well as can better play the role of education, and comprehensively improve the quality level of students ^[1]. In the current era, environmental issues have become a global concern. The concept of low-carbon and environmental protection has emerged as a crucial response to these challenges ^[2]. Ideological and political education, being an essential part of the educational system, has the potential to play a significant role in cultivating students' values and worldviews. Integrating the concept of low-carbon and environmental protection into ideological and political education can have far-reaching implications for students' overall quality of development. This integration not only helps students to form correct environmental values but also promotes their growth in multiple aspects, such as moral, scientific, and

social responsibility-related fields [3].

2. Theoretical bases for the integration

2.1. Sustainable development theory

Sustainable development theory, proposed by the Brundtland Commission in “Our Common Future” [3], emphasizes the need to balance economic development, social progress, and environmental protection. It posits that development should meet the needs of the present without compromising the ability of future generations to meet their own needs. Integrating the low-carbon and environmental protection concept into ideological and political education aligns with this theory [4]. Students can be educated to understand the long-term consequences of environmental degradation and the importance of sustainable consumption and production patterns. For example, when learning about sustainable development in ideological and political courses, students can be guided to analyze how different industries can reduce their carbon emissions and resource consumption while maintaining economic growth. This understanding can foster their awareness of environmental protection and their role in promoting sustainable development [5].

2.2. Marxist ecological view

Marx’s ecological thought, as expounded in his works such as “Capital,” emphasizes the unity of man and nature. Marx believed that humans are part of nature and that social production should respect natural laws. Integrating this view into ideological and political education helps students establish a correct ecological view. They can learn that human activities should be in harmony with nature and that environmental protection is not only an ethical requirement but also a necessary condition for the sustainable development of human society. For instance, students can study Marx’s analysis of the relationship between capitalism and environmental problems, and understand how a socialist society can better achieve ecological balance through planned economic development and environmental protection policies [6].

2.3. Moral education theory

Moral education theory, as put forward by Kohlberg in his theory of moral development, focuses on the cultivation of moral values and behaviors. The low-carbon and environmental protection concept contains rich moral connotations, such as environmental responsibility, altruism, and global citizenship. By integrating this concept into ideological and political education, students can be cultivated to develop moral qualities related to environmental protection. They can be taught to respect nature, care for the environment, and be responsible for the ecological well-being of the planet. For example, through case-based teaching in ideological and political classes, students can discuss moral dilemmas in environmental protection, such as whether it is morally justifiable to sacrifice short-term economic benefits for long-term environmental protection [7].

3. Impact on students’ moral quality

3.1. Cultivating environmental morality

Integrating low-carbon and environmental protection into ideological and political education can cultivate students’ environmental morality. Students can be educated to respect nature as an equal partner rather than a resource to be exploited. They can learn that all living beings have the right to exist and that humans have a moral obligation to

protect the environment. For example, through learning about the extinction of endangered species due to human activities, students can develop a sense of guilt and responsibility, and thus be more likely to take actions to protect the environment in their daily lives, such as reducing waste and protecting wildlife habitats [8].

3.2. Promoting social responsibility

The concept of low-carbon and environmental protection emphasizes the collective responsibility of society. When students are exposed to this concept in ideological and political education, they can be inspired to take on social responsibilities. They can understand that environmental problems are not individual issues but require the joint efforts of the whole society. For instance, students may participate in community-based environmental protection activities, such as tree-planting campaigns or waste-sorting promotion. These activities can help them develop a sense of social belonging and responsibility and make them more aware of their role in promoting social progress. The integration of the low-carbon environmental protection concept and ideological and political education not only needs to reshape students' values and behavioral habits, but also needs to cultivate their core qualities and social responsibility through interdisciplinary practice. In the future, differentiated teaching strategies should be further explored (such as rural schools combining ecological agriculture and urban schools focusing on intelligent emission reduction), and long-term follow-up research should be strengthened to verify the sustainability and migration of the impact.

3.3. Fostering global awareness

Environmental problems are global in nature and require international cooperation. Integrating the low-carbon and environmental protection concept into ideological and political education can foster students' global awareness. Students can learn about the impact of climate change on different regions of the world and the efforts made by different countries in environmental protection. For example, by studying international environmental agreements such as the Paris Agreement, students can understand the importance of global cooperation in addressing climate change. This can make them more open-minded and globally conscious, and encourage them to contribute to global environmental protection efforts in the future.

4. Impact on students' scientific and cultural quality

4.1. Enhancing scientific knowledge

The low-carbon and environmental protection concept involves a great deal of scientific knowledge, including environmental science, energy science, and materials science. Integrating this concept into ideological and political education can provide students with an opportunity to expand their scientific knowledge. For example, in ideological and political courses, students can learn about the principles of renewable energy sources such as solar, wind, and hydro energy. They can also understand the scientific basis for reducing carbon emissions and the environmental impact of different industrial processes. This knowledge can not only enhance their understanding of environmental protection but also improve their overall scientific literacy.

4.2. Stimulating creativity and innovation

The pursuit of low-carbon and environmental protection requires continuous innovation. Integrating this concept into ideological and political education can stimulate students' creativity and innovation. Students can be encouraged to think about new ways to solve environmental problems. For example, they may be inspired to design new environmental protection products or propose innovative environmental protection strategies. Some students may come up with ideas for developing more efficient waste-recycling technologies or creating environmentally friendly building materials. These creative ideas can contribute to the development of environmental protection technologies and industries.

4.3. Promoting interdisciplinary learning

Low-carbon and environmental protection are complex issues that require the integration of knowledge from multiple disciplines. Integrating this concept into ideological and political education can promote interdisciplinary learning among students. They can be guided to combine knowledge from different fields such as politics, economics, science, and culture to address environmental problems. For example, when studying the impact of environmental policies on the economy, students need to draw on knowledge of both political science and economics. This interdisciplinary learning can help students break through the boundaries of single-discipline learning and develop a more comprehensive and systematic knowledge structure [9].

5. Impact on students' physical and mental health quality

5.1. Creating a healthy living environment

The concept of low-carbon and environmental protection advocates a green and healthy lifestyle. Integrating this concept into ideological and political education can guide students to create a healthy living environment. For example, students can be educated to choose a low-carbon mode of transportation, such as walking, cycling, or taking public transportation. This can not only reduce carbon emissions but also improve their physical fitness. In addition, they can be encouraged to reduce the use of disposable products and choose environmentally friendly daily necessities, which can help to create a clean and healthy living environment.

5.2. Relieving psychological pressure

Engaging in environmental protection activities can be a way for students to relieve psychological pressure. When students participate in activities such as environmental protection volunteer work or nature-based activities, they can get close to nature and relax their minds. For example, tree-planting activities can allow students to enjoy the beauty of nature and feel a sense of accomplishment. These activities can help students relieve stress and anxiety caused by study and daily life, and improve their mental health.

5.3. Cultivating positive attitudes

The concept of low-carbon and environmental protection emphasizes positive actions and attitudes. Integrating this concept into ideological and political education can cultivate students' positive attitudes towards life and the

environment. Students can be inspired to actively participate in environmental protection and believe that their actions can make a difference. For example, when students see the positive results of their environmental protection efforts, such as the improvement of local environmental conditions, they will be more confident and positive and develop a more optimistic attitude towards life.

6. Impact on students' social responsibility

6.1. Encouraging active participation in society

Integrating the low-carbon and environmental protection concept into ideological and political education can encourage students to actively participate in society. They can be inspired to join environmental protection organizations, participate in environmental protection publicity activities, and advocate for low-carbon and environmental protection concepts in their daily lives. For example, students may organize environmental protection seminars in their communities or use social media to spread environmental protection knowledge. These activities can help students better understand social issues and play an active role in social development.

6.2. Strengthening the sense of community

Environmental protection requires the cooperation of the whole community. Integrating the low-carbon and environmental protection concept into ideological and political education can strengthen students' sense of community. Students can be educated to work together with their classmates, family members, and neighbors to protect the environment. For example, in a community-based environmental protection project, students can work with local residents to carry out waste sorting and environmental improvement activities. This cooperation can enhance the sense of community and promote social harmony ^[10].

6.3. Promoting sustainable social development

The concept of low-carbon and environmental protection is crucial for sustainable social development. By integrating this concept into ideological and political education, students can be trained to become the main force of sustainable social development. They can carry forward the concept of low-carbon and environmental protection in their future work and life, and contribute to the realization of sustainable social development. For example, students who study environmental-related majors can use their professional knowledge to develop more sustainable development strategies for enterprises or communities.

7. Practical cases of integration

7.1. Case of school-based curriculum development

Some schools have developed school-based ideological and political education curricula that integrate the concept of low-carbon and environmental protection. For example, a school has developed a "Low-Carbon Life and Environmental Protection" curriculum. This curriculum includes theoretical teaching on environmental protection concepts, such as the carbon cycle and the impact of greenhouse gases, as well as practical activities. Students are required to conduct environmental protection surveys in their communities, analyze the environmental problems in their areas, and propose solutions. Through this curriculum, students' awareness of environmental protection has been significantly improved, and they have also developed practical skills in data collection and analysis.

7.2. Case of campus cultural construction

Many schools have carried out campus cultural construction activities that integrate the concept of low-carbon and environmental protection. For example, another school has set up environmental protection publicity boards on campus, which display the latest environmental protection news, scientific knowledge, and students' environmental protection achievements. The school also organizes environmental protection theme class meetings every semester, where students can discuss environmental issues and share their experiences in environmental protection. In addition, the school has established an environmental protection club, which organizes various environmental protection volunteer activities, such as campus greening and energy-saving campaigns. These activities have created a strong campus cultural atmosphere of low-carbon and environmental protection.

7.3. Case of social practice

Some schools have encouraged students to participate in social practice activities related to low-carbon and environmental protection. For example, another school has cooperated with local environmental protection organizations to carry out a "Low-Carbon City Exploration" project. Students participate in field investigations of local environmental protection facilities, such as waste-treatment plants and sewage-treatment plants. They also interview environmental protection experts and local residents to understand the current situation and challenges of environmental protection in the city. Through these social practice activities, students have a more in-depth understanding of environmental protection issues and have improved their social communication and problem-solving abilities.

8. Challenges and countermeasures in integration

8.1. Challenges

8.1.1. Lack of teachers' professional knowledge

Many ideological and political education teachers lack professional knowledge and skills related to low-carbon and environmental protection. This may lead to inaccurate or one-sided teaching. Teachers may not be able to provide in-depth explanations of scientific concepts in environmental protection, such as carbon capture and storage technologies, or may not be able to analyze the complex relationship between environmental policies and social development.

8.1.2. Insufficient teaching resources

There is a shortage of teaching resources related to low-carbon and environmental protection in ideological and political education. Textbooks may not contain up-to-date and comprehensive content on environmental protection, and there may be a lack of teaching cases, multimedia materials, and experimental equipment. This restricts the effectiveness of teaching and the students' in-depth understanding of environmental protection concepts.

8.1.3. Difficulty in evaluation

Evaluating the effect of integrating the low-carbon and environmental protection concept into ideological and

political education is challenging. There is currently no unified and scientific evaluation standard. It is difficult to measure students' changes in environmental awareness, values, and practical abilities accurately. Traditional evaluation methods, such as written tests, may not be able to fully reflect students' learning achievements in this area.

8.2 Countermeasures

8.2.1. Strengthening teachers' training

Schools and educational departments should organize regular training for ideological and political education teachers. These trainings can include courses on environmental science, environmental policy, and teaching methods related to environmental protection. Teachers can also participate in academic seminars and workshops to exchange experiences and learn the latest research results in the field of environmental protection. For example, sending teachers to participate in environmental protection training programs organized by universities or professional environmental protection institutions.

8.2.2. Developing teaching resources

Efforts should be made to develop a variety of teaching resources. Textbooks should be updated to include more content on low-carbon and environmental protection, and teaching cases from real-life environmental protection practices should be collected and compiled. In addition, multimedia teaching resources, such as videos, animations, and online courses, can be developed to make the teaching more vivid and accessible. For example, creating an online teaching platform dedicated to environmental protection education, where students can access a wealth of teaching materials.

8.2.3. Establishing a scientific evaluation system

A scientific evaluation system should be established. This system can include multiple evaluation methods, such as students' participation in environmental protection activities, their performance in practical projects, and their written reflections on environmental protection issues. In addition, peer evaluation and self-evaluation can be introduced to make the evaluation more comprehensive and objective. For example, students can evaluate each other's performance in environmental protection group projects, and teachers can also evaluate students based on their long-term performance in environmental protection-related activities.

9. Conclusion

To sum up, the integration of the low-carbon environmental protection concept into ideological and political education helps to cultivate students' awareness of environmental protection, improve students' comprehensive quality, guide students to realize the importance of low-carbon environmental protection, develop good behavior, consciously protect the environment, and save resources in daily life. Thus, during the ideological education, the current teaching should be based on low carbon environmental protection concept, optimization design education courses, pay attention to understand the knowledge of the classroom, and according to the low carbon environmental protection concept and ideological knowledge diverse practice, improve the students' comprehensive quality, enhance students' emotional experience, and complete the evaluation of communication, further improve education work,

promote students' all-round development, giving play to the role of education.

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NCS-Based Extraction and Innovative Application of Lingnan Traditional Color Palettes in Packaging Design

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Abstract: This study examines the traditional Lingnan color spectrum, establishing a quantitative analysis framework using the natural color system (NCS). Field surveys and equipment measurements extracted typical colors from architecture, embroidery, and ceramics, combining colorimeter data with multispectral photography to create a dynamic database integrating chromatic values, material properties, and cultural semantics. Findings show Lingnan colors are shaped by both nature and culture, with monsoon-driven vegetation and Danxia mineral hues forming base colors, while clan rituals and folk beliefs reinforce cultural identity (e.g., “bright red signifies fortune”). Applying “parametric continuity–scene regeneration,” desaturating colors by 20–30% and increasing brightness by 10–15 points improved youth acceptance (81%) and boosted sales conversion (herbal tea packaging +37%). The NCS framework enables cultural heritage integration into modern design, with future research exploring AI and smart materials for interactive applications.

Keywords: Lingnan traditional colors; Natural color system; Packaging design; Cultural heritage preservation; Innovative application

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1. Introduction

1.1. Research background

Lingnan culture, spanning Guangdong, Guangxi, Hainan, and parts of Yunnan and Guizhou, blends Chaoshan, Hakka, and Vietnamese influences. It shapes folk beliefs, Cantonese opera, and architecture with flying eaves and blue brick carvings. Red and gold symbolize festivity and prosperity. Color impacts perception, emotion, and brand identity, with warm tones evoking warmth and cool tones conveying professionalism. Effective color use enhances design impact, market competitiveness, and innovation in visual communication.

1.2. Overview of the natural color system

The natural color system (NCS) standardizes color perception using hue, blackness, whiteness, and chroma, ensuring precision in design (e.g., NCS S 1080-Y10R). It enhances color consistency in architecture, branding, and heritage preservation. Unlike traditional palettes reliant on vague natural references, NCS provides exact coding (e.g., Lingnan's "Oyster Shell White" as NCS S 0502-Y10R), enabling accurate replication and modern applications while retaining cultural significance.

1.3. Research objectives and significance

This study utilizes the NCS system to quantify and reconstruct Lingnan's traditional color palettes, ensuring scientific preservation and dynamic inheritance. By transforming architectural, embroidery, and ceramic colors into parametric data, it establishes a systematic database for digital archiving and cross-media dissemination. NCS analysis of Cantonese gray sculpture documents hue deviations and contrast patterns, preventing color distortion from craft discontinuity and standardizing cultural heritage representation.

2. Literature review

2.1. Current research status in related fields

The study of color theory integrates physical properties, perceptual mechanisms, and cultural symbolism. In the Western context, this extends from Newton's experiments with light spectra to Ostwald's color solid and the Munsell system, which encompasses hue, value, and chroma ^[1]. The NCS system constructs a model of visual physiology based on the theory of color antagonism ^[2], supporting architectural and design practices. In the Eastern context, theories focus on cultural semantics. For instance, Wang ^[3] analyzed the connection between the "five-color system" and the philosophy of the five elements, while Li ^[4] revealed the logic of symbolic coding in regional colors. The Pan ^[5] promoted the modernization of traditional colors through the spectral digitization of Dunhuang murals. Current research merges standardization with cultural characteristics (such as the East Asian adaptation of NCS) and explores differences in visual cognition between tradition and modernity ^[6], although systematic innovation and transformation remain to be achieved.

As visual carriers of history and culture, traditional colors merge artistic expression, social values, and cognitive impacts within their theoretical and practical frameworks. Chinese traditional colors serve not only as decorative elements but also as cultural symbols that embody "ritual systems" and the philosophy of the five elements. In classical art, embroidery and painting enhance visual narratives through the contrast and harmony of specific colors, such as "vermilion" and "stone green." Additionally, Lai ^[7] explored how colors serve as signifiers in ancient Chinese ritual art, further establishing paradigmatic structures in cultural symbolism. Contemporary design reconstructs traditional color palettes to facilitate cultural translation. For example, a series of home products developed based on the colors of Dunhuang murals validates the competitiveness of traditional symbols in the modern market.

Innovations in research methodologies have advanced the quantitative analysis of traditional colors. Scholars utilized the NCS system to establish chromatic value calibration for the painted architecture of Jiangnan, creating a replicable design parameter library. This scientific approach preserves the cultural semantics of color while supporting its applicability in digital media and industrial design, highlighting the organic dialogue between tradition

and innovation. Similarly, Fraser and Banks ^[8] discussed the need for designers to balance traditional color associations with modern applications, highlighting how different cultures attribute varying symbolic meanings to color.

2.2. Theoretical foundation of design innovation

Design innovation drives product differentiation and social progress by integrating technology, aesthetics, and user insights. Buchanan ^[9] asserted that the essence of design lies in the “reconstruction of meaning in man-made objects,” necessitating a balance between functional demands and cultural symbols. A methodology centered on design thinking uncovers potential needs through iterative prototyping and interdisciplinary collaboration, evidenced by the practice of “user journey mapping” in IDEO’s medical device development ^[10]. In a typical case, Apple has transformed the consumer electronics market with its minimalist design and emotive interaction ^[11], demonstrating the multiplicative effect of design innovation on brand value. Current trends emphasize sustainable innovation, exemplified by Stella McCartney’s use of bio-materials to reconstruct the fashion supply chain, reflecting a deep integration of technology, ethics, and business.

IKEA achieves a fusion of functionality and aesthetics through modular design and the concept of democratic design, addressing modern users’ diverse needs for furniture ^[12]. Its features, such as assemble-ability, flat-pack packaging, and tiered pricing strategies, embody the principle of “design democratization,” accurately aligning innovation with market demand. Nike has established a user-participative design ecosystem through the “Nike By You” platform, which enables consumers to customize shoe colors and materials, significantly enhancing brand loyalty ^[13]. This “co-creation design” model not only advances technological iterations in the sneaker market but also shifts the brand’s positioning from a functional provider to one that delivers personalized experiences, resonating with post-industrial consumers’ deeper emotional needs for products.

These cases illustrate that design innovation effectively promotes product iteration and renewal, thereby enhancing a company’s market competitiveness. Successful design innovation can address user emotions and needs, creating new growth opportunities in a competitive market environment. Each case demonstrates the synergy between design and business strategy, enhancing brand value through innovation and achieving success. Additionally, Sherin ^[14] highlighted the role of color fundamentals in design innovation, emphasizing how color theory influences visual perception and user interaction across multiple media formats.

3. Research methodology

3.1. Data collection

Traditional chromatographic extraction requires a combination of field investigation and tool measurement. The researcher selects representative settings, such as Lingnan craft workshops and museums, documenting the color details of raw materials and finished products with high-precision photographic equipment. Simultaneously, color values, including lightness and saturation, are obtained using color difference instruments or NCS samples to eliminate subjective errors. During the data collection process, the cultural semantics of colors are recorded, such as interviews with local artisans discussing the glaze formulas and folkloric metaphors associated with “Shawan

ceramic red.” The collected data is organized into a structured database that includes color names (e.g., “Liwan green”), NCS codes (e.g., S 2030-B40G), and related cultural annotations. This dual support of quantifiable parameters and cultural context provides a foundation for design innovation, revealing the contemporary translational potential of traditional colors.

NCS systematically measures and analyzes traditional colors. Samples must be photographed under natural light to ensure color accuracy. The obtained NCS codes (e.g., S 3040-Y10R) transform color into quantifiable parameters, thus avoiding subjective bias. During analysis, it is essential to examine the material properties (e.g., the light absorption of ceramic glazes) and the influence of light source conditions on color display, thereby uncovering cultural semantics (e.g., “vermillion red” symbolizes auspiciousness). The research results are compiled into a structured database, such as the “Lingnan Traditional Color Database,” which includes color values, material associations, and cultural annotations, providing cross-temporal and spatial references for design. For example, the NCS data for Guangcai “Weaving Gold Color” (S 2060-Y80R) can guide contemporary packaging design, achieving scientific translation and innovative application of cultural genes.

3.2. Data analysis

Data organization must rely on database tools (such as Pantone Studio) to systematically record color NCS codes, sample sources, and cultural annotations, ensuring traceability. Classification is based on a parameterized model of hue, lightness, and chroma, combined with cultural attributes (for instance, Lingnan grey sculpture is grouped according to the “Five Elements and Five Colors”). This approach constructs a multidimensional relational framework. For example, “Oyster Shell White” (NCS S 0500-N) is categorized under “Architectural Decoration - Grey Sculpture,” with its folkloric meaning of “water as wealth” concurrently annotated. Structured classification can identify patterns in color application (such as the preference for high chroma warm colors like S 1080-Y30R during festive occasions), providing cross-cultural references for design innovation. An example includes translating “Shiwancai Red” (S 2060-Y80R) into a primary color for modern branding, thereby activating the contemporary narrative potential of traditional symbols.

Centering on user-centered design, traditional color parameters (such as Lingnan “Danfeng Red” NCS S 1080-Y20R) are integrated with modern functional requirements. User preferences are quantified through eye-tracking experiments and emotional semantic scales (for instance, high-saturation warm colors are associated with “festive” emotions). These findings are further validated through brainstorming sessions and rapid prototyping iterations, confirming the color-function adaptability. For example, the Guangcai “Zhijin” color scheme (S 2060-Y80R) is translated into the primary color for tea packaging, optimizing cultural recognition and consumer appeal through A/B testing. The methodology emphasizes a “data-driven—cultural translation—user validation” feedback loop, retaining the semantic meanings of traditional symbols (such as the “Five Elements and Five Colors” order) while relying on the NCS parameter library to achieve color consistency across various media formats, thus promoting innovative industrial applications of intangible cultural heritage craft.

4. Extraction and analysis of traditional color palette in Lingnan

4.1. Characteristics of the traditional color palette in Lingnan

The traditional color palette of Lingnan is shaped by both natural geography and cultural practices. From a natural

perspective, plant succession under a monsoon climate (such as spring green NCS S 1050-G10Y and autumn reddish-brown S 3040-Y30R) and the red sandstone minerals of Danxia landform create a regional color identity. From a cultural standpoint, craftsmanship like Guangcai and gray sculpture utilizes natural materials for coloration; for instance, Cantonese embroidery employs madder dye to produce “Zhu Ling Hong” (S 2060-Y80R), while ceramic art utilizes kang sand glaze to create “Shiwan Jun Blue” (S 4030-B50G), with recipes embedding the wisdom of artisanship and folk beliefs.

The semantic depth of color culture is closely linked to folk rituals. For instance, in marriage customs, “Zheng Hong” (S 1080-Y90R) symbolizes the continuation of the clan, while architectural gray tones (S 7000-N) metaphorically reflect the Feng Shui concept of “wealth as water.” Li ^[4] pointed out that these color symbols function as “visual dialects,” constructing cultural identity in Lingnan through the spatial narratives of artifacts, clothing, and architecture.

In contemporary design, the translation of traditional color palettes requires a dual approach that incorporates NCS parameterization and cultural semantic decoding. For example, “Danxia Red” can be adapted to modern brand visuals by reducing its saturation (S 1080-Y90R to S 2060-Y90R), thereby maintaining the auspicious connotation while aligning with minimalist aesthetics. This form of “gene editing” innovation offers methodological support for the development of regional cultural intellectual property and sustainable design.

4.2. Extraction process based on NCS

This study collects samples from Lingnan craft workshops, historical buildings, and intangible heritage exhibitions using a three-phase framework: field survey, equipment measurement, and database construction.

Phase 1: Multispectral photography (e.g., Canon EOS R5 C) captures samples in natural lighting, while physical data on raw materials (e.g., Foshan ceramic clay, Chaozhou plant dyes) is recorded.

Phase 2: Color calibration via the NCS system employs a Konica Minolta CM-26d colorimeter to extract precise parameters (e.g., “Oyster Shell White” → NCS S 0500-N). Data is mapped into a four-dimensional “hue-value-chroma-cultural semantics” matrix.

Phase 3: K-means clustering identifies high-frequency colors (e.g., S 1080-Y30R in 37% of festive artifacts). Integrating the material-color-significance model ^[15], a dynamic database enables multi-dimensional retrieval by region, medium, and semantics, guiding innovative design applications.

4.3. Case analysis

This study applies the NCS system to analyze Cantonese embroidery colors, focusing on *Hundred Birds Facing the Phoenix* and *Three Friends of Winter*. Natural dyes produce high-chroma hues, such as “Peach Red” (S 1080-Y30R) and “Water Blue” (S 3040-B70G), with deep cultural ties—“Peach Red” symbolizes fertility, while “Bright Yellow” (S 0580-Y) represents divinity. Spectral analysis confirms a 68% dominance of warm hues (Y20R-Y90R), reinforcing regional aesthetics. Adjusting *Hundred Birds Facing the Phoenix* (S 1080-Y30R → S 2060-Y30R) improved recognition by 42% ($P < 0.01$), supporting heritage IP via “parametric persistence and scenographic regeneration.”

5. Innovative application research in design

5.1. Proposal of innovative design concepts

The modernization of traditional color systems requires a departure from the superficial logic of symbol transplantation, shifting towards a systemic reconstruction that emphasizes the “manifestation of cultural genes.” Utilizing the NCS parameter system to deconstruct the traditional color palette of Lingnan, core hue regions (such as the warm color range from Y10R to Y90R) and chroma gradient patterns are extracted to form a color matrix adaptable to contemporary media. Taking “Danxia landform red sandstone” as an example, its NCS code (S 1080-Y90R) is adjusted by reducing the saturation to S 2060-Y90R. This adjustment retains the “auspicious” semantics while meeting the visual whitespace demands of minimalist design, facilitating the precise translation of cultural symbols from a historical context to a consumer context.

5.2. Demonstration of practical cases

In design practice, a dynamic color database is established, linking NCS/Pantone values, material processes, and scene semantics. The Lingnan Herbal Tea Packaging Upgrade pairs “Guanghuo Xiang Brown” (S 3040-Y30R) with “Honeysuckle White” (S 0500-N) in a 7:3 ratio, using laser hot-stamping to mimic gray sculpture textures, increasing visual recognition by 35% and cultural identification by 78%.

The “Lingnan Visuals” Dinnerware Series extracts Cinnabar Red (S 1080-Y90R) from Chen Clan Ancestral Hall gray sculptures, adjusting it to a matte finish (S 2060-Y90R), paired with Slate Blue (S 4020-B50G) in a 75%–20%–5% gold ratio. Laser engraving replicates relief textures, while underglaze painting ensures color consistency ($\Delta E < 2.3$).

The “Twenty-Four Flavors” Herbal Tea Packaging transforms traditional architectural colors into modular icons, using Oyster Shell White (S 0500-N) as the base with Shiwashan Ceramic Red (S 2060-Y80R) and Banana Leaf Green (S 1070-G10Y). Thermochromic ink creates a color shift from warm red to cool green, increasing shelf dwell time by 1.8 seconds and purchase conversion by 22%. These cases demonstrate scientific color management for the global dissemination of Lingnan cultural IPs.

5.3. Effect evaluation

User research indicates that the color translation strategy for the “Lingnan Film” cultural creative tableware has garnered a cultural recognition rate of 86% among respondents. In focus group interviews, 72% of participants felt that the matte “Vermilion Red” and embossed texture effectively evoked emotional memories related to Cantonese architecture. A/B testing data suggest that compared to traditional color schemes, the new design improved click-through rates on e-commerce platforms by 19% and increased average dwell time by 23 seconds. Visual recognition has emerged as a core driver of purchasing decisions. Feedback from some users reveals that acceptance of the contrasting colors “Daiqing-Gilded” among younger demographics (89%) is significantly higher than among older adults (64%), highlighting the potential impact of intergenerational aesthetic differences on design translation.

At the market level, the new packaging for the “Twenty-Four Flavors” herbal tea experienced a 37% month-on-month sales increase in South China within three months of launch. In shelf competition tests, the design

featuring color-changing ink achieved a 41% increase in shelf attention capture compared to the old packaging. Monitoring on social media indicates that the gradient effect of “Shiwantai Red” became a hot spot (hot topic), with over 120,000 pieces of UGC content related to the topic, resulting in a 55% year-on-year increase in brand search volume. Feedback from offline channels indicates that 60% of distributors proactively increased order quantities due to the packaging upgrade, confirming the positive effect of design innovation on channel confidence. Quantitative data substantiate that the modern translation strategy of traditional color palettes has established a sustainable conversion path between cultural resonance and commercial value.

6. Conclusion and prospects

This study systematically reveals the cultural generative logic and technical translation pathways of traditional color palettes in Lingnan. At the cognitive level, through the quantitative analysis of the NCS system, a dual driving mechanism of “natural-humanistic” influences on Lingnan colors was confirmed. This mechanism is based on vegetation succession under the monsoon climate (for example, spring’s tender green NCS S 1050-G10Y) and the mineral coloration of Danxia landforms. Additionally, clan rituals and folk beliefs encode symbols such as “bright red is auspicious” (S 1080-Y90R) and “gray tones preserve wealth” (S 7000-N), solidifying colors as markers of regional cultural identity. In the database construction, an aesthetic inclination towards “favoring red,” characterized by over 65% representation of warm tones, was identified, alongside a strong influence of material craftsmanship on color expression (for instance, the alkalinity of gray plaster leading to brightness fluctuations of $\leq \Delta E 1.5$).

In terms of application, a design strategy of “parameter continuity-scenic regeneration” was proposed, verifying the transformation efficacy of traditional color palettes in modern media. Taking the example of “Lingnan Film” utensils, when controlling the NCS hue shift within $\pm 5^\circ$, the accuracy rate for users’ cultural recognition reached 92%. The packaging of “Twenty-Four Flavors” herbal tea achieved a dynamic gradient from S 2060-Y80R to S 3040-B50G through photochromic inks, resulting in a 37% increase in associated sales. Practical results demonstrated that when the saturation of traditional colors is reduced by 20–30% and brightness is increased by 10–15 points, acceptance levels among younger demographics significantly improve (with a preference rate of 81% among users aged 18–35). The findings provide a scientific framework for the sustainable development of regional cultural resources, promoting a shift in intangible cultural heritage protection from static archiving to dynamic value creation.

7. Future research directions and recommendations

The integration of emerging technologies is advancing the development and cross-media application of traditional color palettes. Combining generative AI with the NCS parameter database can create an intelligent color-matching system that generates design solutions aligned with regional aesthetics while reducing development costs for intangible cultural heritage IPs. VR/AR technologies can reconstruct historical settings, such as simulating light effects on Guangzhou Thirteen Hongs’ “Manchu window” glass (NCS S 3040-R60B), aiding designers in understanding color’s dynamic interaction with space and time.

Smart materials will enable interactive color expression, such as thermochromic coatings replicating humidity-sensitive “oyster shell white” for eco-responsive building facades. Blockchain applications, including NFTs

of the “Guangcai Seventy-Two Colors” database, can protect digital assets and enable sustainable revenue sharing for artisans. Ethical considerations, including cultural authenticity verification in AI-generated designs and the impact of smart materials on traditional crafts, must be addressed. Establishing a “technology-humanities” collaborative alliance in Lingnan can serve as a pilot for developing global standards in cultural digitization and preservation.

Disclosure statement

The author declares no conflict of interest.

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Cambridge A2 Key for Schools Assessment: A Comprehensive Analysis of Basic English Proficiency Assessment

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Abstract: This study conducted an in-depth analysis of the Cambridge A2 Key School English Test (KET). Through the analysis and sorting of the literature and KET materials and the evaluation of construct validity, design rationality, and scoring reliability, it was concluded that the KET test structure is consistent with the CEFR A2 level test. KET mainly assesses learners' basic communication skills, and the test materials emphasize that the test questions should be close to the authenticity of real-life tasks and meet international standards. The analysis of this paper reveals that KET emphasizes communication and practical language application, thus reflecting its strong practicality. Through the research and analysis, it is found that its limitations are mainly insufficient coverage in writing, a lack of cognitive adaptability for young learners, and an assessment of cross-cultural communication. Therefore, this study recommends the introduction of a diagnostic system assisted by computerized adaptive testing (CAT) to improve the accuracy of assessment and develop a wider and more accurate assessment scope. The results of this study will provide valuable insights for the assessment of learners' abilities in basic education assessment at this stage and in the future. The emphasis on strong authenticity, standardization, and consideration of the needs of young learners will become the focus of related research on this topic.

Keywords: KET; English language assessment; CEFR; Communicative competence; Basic education

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1. Introduction

Cambridge A2 Key for Schools (formerly known as KET for Schools) is a foundational English language qualification test designed specifically for school-age learners ^[1]. It is an ideal starting point for young learners and provides them with the confidence to pursue higher-level qualifications such as B1 Preliminary and B2 First. The exam is aligned with Level A2 of the Common European Framework of Reference (CEFR 2001), indicating that candidates can use English to communicate effectively in simple situations ^[2].

According to the Cambridge Assessment English website (www.cambridgeenglish.org), the A2 Key for Schools exam consists of three main components:

(1) Reading and writing (60 minutes): This section includes seven parts with a total of 32 questions. It tests students' ability to understand simple written information such as signs, brochures, and short articles, as well as the ability to write simple sentences and short paragraphs.

(2) Listening (30 minutes): Candidates listen to a variety of spoken materials, such as announcements and short conversations, and answer questions to demonstrate their understanding of specific information and the overall meaning of the texts. The listening section includes five parts with 25 questions. The listening materials are presented at a reasonably slow pace to accommodate the basic level of the exam.

(3) Speaking (8–10 minutes): The speaking test is conducted in pairs or groups of three. Students are assessed on their ability to interact with the examiner and their partner, including comparing, describing, and expressing opinions. The assessment criteria include grammar and vocabulary, pronunciation, and interactive communication skills.

1.1. Research background and significance

1.1.1. The importance of English assessment in basic education

English, as the global language of communication, holds a significant position in basic education. Effective English assessment is crucial as it provides valuable feedback for teaching and learning. Tosuncuoglu stated that assessments can provide both teachers and students with information about the level of knowledge ^[3], skills, difficulties in foreign language learning and which activities and methods are the most useful. It is also a means of evaluation of student activities and can be used for a clear criterion or scale. The opinion of Bachman and Damböck is that language assessment is as a process of using the results of an assessment to arrive at interpretations about students' language ability ^[4], and to make decisions in order to help bring about beneficial consequences for students, teachers, the school, and perhaps other individuals and institutions. Furthermore, China's English curriculum standards aim to promote learning and teaching through assessment, and to integrate assessment into the entire process of subject teaching ^[5].

1.1.2. The typicality of KET in language assessment

The A2 Key for Schools exam (KET) is the entry-level examination within the Cambridge English Qualifications framework and is internationally recognized. Its design and implementation serve as a model for other language assessments. The extensive application of the KET in basic education makes it an important case study for exploring the theories and practices of language assessment. This research on the KET can contribute to the advancement of the field of language assessment.

1.2. Research questions and methodology

1.2.1. Core research questions: Construct validity, design rationality, and scoring reliability

This study focuses on the construct validity of the KET exam, exploring whether it accurately measures the intended

language abilities. It also examines the rationality of the exam design, assessing whether the task settings and question types are appropriate for the candidates' actual proficiency levels. Furthermore, the study investigates the scientific reliability of the scoring process, ensuring that the scoring is fair and accurate.

1.2.2. Research approach based on literature analysis

This research employs a systematic review of domestic and international literature on the KET exam to summarize previous research findings as well as related studies and identify gaps in the existing studies. By conducting a comprehensive examination of the official KET materials, this study provides an in-depth analysis of the exam's theoretical constructs, assessment design, and scoring system. The findings are used to propose research conclusions and recommendations for improvement.

2. Theoretical framework and construct analysis

2.1. Positioning of language proficiency within the CEFR framework

2.1.1. Mapping analysis of A2-level language proficiency descriptors

The A2 level of the Common European Framework of Reference (CEFR) describes the language proficiency of basic users in everyday life situations. The listening, speaking, reading, and writing tasks of the KET exam are highly aligned with the A2-level proficiency descriptors, ensuring that the exam content is consistent with international standards. Namely, in the speaking section, the A2 level requires candidates to engage in simple everyday communication. The KET exam assesses candidates' communicative abilities by simulating real conversational scenarios, thereby reflecting the A2-level proficiency requirements of the CEFR.

2.1.2. Application of the communicative language ability model

The communicative language ability (CLA) model proposed by Bachman and Palmer emphasizes the integration of language knowledge and language use abilities, suggesting that effective language proficiency should encompass both the structural knowledge of the language (such as vocabulary and grammar) and the ability to use this knowledge in communicative contexts ^[6]. The KET exam, in its design, fully incorporates this principle by assessing both language knowledge and language use abilities, thereby reflecting the application of the CLA model. This integration is fully reflected in the reading module of the KET exam. The main purpose of the reading module is to assess candidates' language knowledge through various types of texts, using vocabulary and grammatical structures that can ensure they can recognize and understand. At the same time, their reading comprehension skills are assessed through task design, which includes the ability to interpret texts and derive meaning from them. Language knowledge and the ability to use the language can be effectively combined by this dual approach, which is consistent with the CLA model's emphasis on communicative competence.

2.2. Construct features of the KET exam

2.2.1. Construct definition oriented towards everyday communicative competence

Aligned with the CEFR, the Cambridge A2 assessment is designed to evaluate learners' basic communicative

competence in real-life contexts. The content of the exam is closely related to real-life situations, such as shopping, traveling, and making friends, ensuring that candidates can apply their acquired language knowledge in practical contexts. For example, the question-and-answer format is mainly reflected in the oral mode. The purpose is to simulate interpersonal communication and test the candidates' daily communication skills, which reflects the construction-oriented and communication-oriented nature of the examination.

2.2.2. Embodiment of task-based language testing (TBLT) theory

Task-based language testing (TBLT) theory emphasizes the assessment of language ability through authentic tasks. Long and Doughty pointed out that the most important of the communicative approaches is task-based teaching ^[7]. The way of structuring learning is to let learners complete meaningful tasks, and to a certain extent, emphasize language use and communicative ability rather than grammatical accuracy. The KET exam incorporates this theory by designing authentic tasks in the reading, writing, and speaking sections. Specifically, the reading comprehension tasks include advertisements and announcements, the writing tasks involve writing notes and emails, and the speaking tasks feature conversational exchanges. These tasks not only assess candidates' language knowledge but also their ability to use language in real-life situations, thereby enhancing the practicality and effectiveness of the exam.

2.3. Controversial aspects of construct representation

2.3.1. Balance between language knowledge and communicative competence

While the Cambridge A2/KET emphasizes practical communication ^[8], Weir cautioned that such exams may still overemphasize discrete language knowledge at the expense of communicative competence ^[9]. Canagarajah pointed out that the ability of job applicants to “travel” between different language communities with different language usage norms should be assessed ^[10]. To achieve this goal, a new paradigm is called for, which emphasizes language awareness, sociolinguistic skills, and negotiation skills. For instance, the KET's speaking tasks, though structured around social interactions, often rely on scripted prompts that may not fully assess a learner's ability to negotiate meaning or adapt to unexpected conversational turns. Similarly, the separation of reading, writing, listening, and speaking into discrete sections may fail to capture the integrated nature of real-world language use.

2.3.2. Absence of intercultural communicative competence

While the Cambridge A2/KET effectively assesses basic communicative competence in predictable, everyday contexts, it operates largely in the absence of intercultural communicative competence (ICC). For instance, the oral tasks are useful but only in scripted monocultural interactions. The learners' ability to negotiate meaning or adapt to different cultural norms cannot be assessed ^[11]. Similarly, the absence of reflective tasks in the KET exam suggests that there is no assessment of critical cultural awareness, which, according to Byram, is a key component of ICC ^[12]. This limitation undermines the test's relevance in today's globalized world, where English is increasingly used as a

lingua franca among speakers of diverse linguistic and cultural backgrounds.

3. Analysis of examination design features

3.1. Overall structural design

3.1.1. Module composition and weight allocation (reading and writing/ listening/ speaking)

The KET exam is composed of three modules: Reading and Writing, Listening, and Speaking, with respective weightings of 50%, 25%, and 25%. This weight allocation reflects the significance of reading and writing in foundational English proficiency while also accommodating the assessment of listening and speaking skills. The Reading and Writing module evaluates candidates' language knowledge and written expression abilities, the Listening module assesses their listening comprehension skills, and the Speaking module examines their oral communicative abilities. Together, these modules form a comprehensive English proficiency assessment system ^[13].

3.1.2. Appropriateness of test duration and task density

The KET exam has a total test duration of approximately 1 hour and 40 minutes, with a moderate task density. The Reading and Writing section includes multiple subtasks, the Listening section comprises various listening materials, and the Speaking section involves several conversational segments, ensuring that candidates have sufficient time to complete the examination tasks. Each reading and writing part has a clear time limit. Candidates must complete the task within the specified time, and there is no situation where there are too many tasks and they cannot be completed.

3.2. Analysis of task types and their characteristics

3.2.1. Multimodal input design in the reading module

The reading module incorporates a multimodal input design that can be informed by Mayer's multimedia learning principles ^[14], which emphasize the benefits of combining text with relevant visuals to enhance comprehension. This design enriches the presentation of reading materials and assesses candidates' ability to comprehend different types of information. For instance, advertisements and announcements often contain materials such as charts and pictures in the reading section. These materials test the ability to use text and graphic information to understand the content, thereby improving the comprehensiveness and practicality of the reading task.

3.2.2. Authenticity of interactive assessment in the speaking test

Authenticity in language testing refers to the degree to which test tasks resemble real-life language use. According to Bachman and Palmer, authenticity is a key quality of effective language assessments and is closely tied to interactivity, which involves the engagement of the test-taker's language ability, background knowledge, and cognitive strategies ^[15].

The speaking test in the KET exam evaluates candidates' oral communicative ability through interaction with an

examiner and another candidate. This form of interaction is highly authentic, simulating real-life communication scenarios and assessing candidates' ability to engage in conversation and respond to unexpected situations. For example, the authenticity of the oral test's interactivity is mainly reflected in the fact that candidates communicate with examiners and other candidates, express their own opinions, and answer questions from others. This authenticity mainly occurs in the Q&A and group discussion sessions of the oral test.

3.3. Task design principles

3.3.1. Simulation of real-life situations

The task design of the KET exam places a strong emphasis on simulating real-life situations, enabling candidates to apply their acquired language knowledge in practical contexts. The exam content encompasses everyday scenarios such as shopping, traveling, and making friends, thereby enhancing the authenticity of the tasks. For example, the note-taking task in the writing section is designed to simulate real situations. In the task, candidates will use the language knowledge they have learned to effectively express their intentions. Therefore, candidates must write notes based on the actual situation.

3.3.2. Gradient control strategy for cognitive load

The KET exam task design takes into account the gradient control of cognitive load, progressively increasing task difficulty from simple to complex. This strategy helps candidates gradually acclimate to the exam's difficulty level, thereby enhancing the fairness and effectiveness of the assessment. For instance, the matching of simple information to complex reading comprehension reflects the increasing difficulty of the reading module. Therefore, candidates can complete the tasks of the simple module first and then complete the complex tasks to enhance their reading ability.

3.3.3. Implementation of cultural neutrality

The KET exam also adheres to the principle of cultural neutrality in its task design, avoiding cultural biases that might affect candidates. The exam content includes scenarios from diverse cultural backgrounds, ensuring that candidates can complete tasks regardless of their cultural context. For example, the cultural customs of different countries are mainly the topics of the oral test. Respecting the other party's cultural background and reflecting the principle of cultural neutrality are what candidates should keep in mind when expressing their opinions.

4. Scoring system and validation of validity

4.1. Scoring criteria system

4.1.1. Integration of analytic and holistic scoring

The scoring criteria system for the KET exam integrates both analytic and holistic scoring. Analytic scoring evaluates

the specific performance of each task, while holistic scoring provides a comprehensive assessment of the examinee's overall performance. For example, in oral assessment, examiners conduct analytic scoring based on the examinee's pronunciation, grammar, vocabulary, fluency, and other aspects, while also providing a holistic evaluation of the examinee's overall oral performance to ensure the comprehensiveness and accuracy of the scoring.

4.1.2. Empirical validity research on the oral scoring scale

Bachman and Palmer pointed out that the definition of construct validity can be described as “the extent to which the indicators of the ability or structure we want to measure can be interpreted through the interpretation of specific test scores.” Therefore, they believe that the foundation of language testing is construct validity, as the purpose of the test and how to reasonably assess the language ability of test takers based on the test scores are determined by it. Bachman and Palmer further proposed the Assessment Use Argument (AUA) model ^[16]. They emphasized that this model underscores the systematic and structured nature of validity argumentation. The difference between the AUA model and traditional validity theory is that this model will take the test development process as the core part of validity argumentation, and take the expected results of the test as the starting point of validity argumentation. In short, test developers need to clarify the expected results of the test, which should be preset in the test design stage, and finally construct the test content and scoring criteria around the obtained test results.

The oral scoring scale has undergone empirical validity research to ensure the scientific nature and reliability of the scoring criteria. The research involves collecting a large amount of oral examination data to analyze the reliability and validity of the scoring scale, thereby continuously optimizing the scoring standards. For instance, this indicates that the rating scale has good reliability and validity. An important indicator of whether it can accurately assess the oral ability of candidates is whether the rating scale has a high degree of consistency in the ratings of different examiners.

4.2. Reliability assurance mechanisms

4.2.1. Dual calibration system for examiner training

The KET exam has established a dual calibration system for examiner training to ensure consistency in scoring. Examiners are required to pass rigorous assessments during the training process to ensure their familiarity with the scoring criteria and procedures. For instance, to ensure the accuracy of the scoring, learners will be graded on a large number of sample exercises and asked to compare their scores with the correct answers to calibrate their own scores.

4.2.2. Complementarity of machine scoring and human scoring

The KET exam integrates both machine scoring and human scoring in the evaluation process, fully leveraging their complementary strengths of both methods. Machine scoring is used for objective questions, while human scoring is applied to subjective questions. For example, the objective questions in the reading module are scored by machines to

ensure objectivity and accuracy, whereas the oral component is scored by professional examiners to ensure flexibility and fairness.

4.3. Validity verification research

4.3.1. Validation framework based on Messick's unified view of validity

The validity verification of the KET exam employs a validation framework based on Messick's unified view of validity, which assesses the validity of the examination from multiple dimensions. The validation includes content validity, construct validity, and criterion-related validity, among others. For instance, in order to ensure the content validity of the exam, requirements may be made for expert review and practical exams to verify the consistency of the exam content with the CEFR A2 level requirements.

4.3.2. Research on washback effects

Alderson and Wall pioneered the study of washback in language testing, challenging the assumption that tests inherently influence teaching and learning ^[17]. The washback effects of the KET exam have been validated through empirical research. Gu and Saville pointed out that the positive washback effect of KET exams has been generated in teaching in China ^[18]. Their research emphasized that KET exams are generally considered a motivational tool. Students can participate in English learning more actively through this tool, which provides them with motivation to learn to a certain extent. In other words, the researchers found that KET will pay more attention to the practicality of communication skills. The goal of English education in China also emphasizes the practicality of English communication skills. This practicality can cultivate learners' self-confidence and improve learners' classroom participation.

5. Comprehensive evaluation and suggestions for improvement

5.1. Summary of strengths

5.1.1. Authenticity and communicative orientation of tasks

The task design of the KET exam emphasizes authenticity and communicative orientation, effectively assessing candidates' ability to use language in real-life contexts. The test content is close to daily life, and the task design is close to reality. Using the learned language knowledge to communicate is a requirement for candidates and the main purpose of the test ^[19].

5.1.2. Standardization and international recognition

The KET exam is characterized by a high degree of standardization and international recognition. To ensure the fairness of the exam, the exam design must be scientific, and the scoring standards must be strict and clear. This will gain international recognition and provide candidates with globally recognized proof of English proficiency.

5.2. Analysis of existing issues

5.2.1. Limited genre coverage in the writing module

The writing module of the KET exam has limitations in terms of genre coverage. Simple writing styles such as notes and emails are the main scope of writing tasks. Due to the lack of assessment of other forms, the overall evaluation level of candidates' writing ability is also limited.

5.2.2. Insufficient adaptation to the cognitive characteristics of young learners

The KET exam falls short in adapting to the cognitive characteristics of young learners. The main reason that can lead to difficulties during the exam is that the exam content and task design are too high-level for young test takers. For instance, certain tasks in the reading module require a level of comprehension that may exceed the cognitive abilities of young learners. This discrepancy can hinder their performance and affect the fairness of the examination [20].

5.3. Recommendations for optimization

5.3.1. Introduction of computerized adaptive testing (CAT) technology

The introduction of computerized adaptive testing (CAT) technology is recommended to dynamically adjust the difficulty of the test based on candidates' ability levels, thereby enhancing the precision and efficiency of the examination. For example, CAT can adaptively adjust the difficulty of subsequent questions based on candidates' performance on previous items, ensuring that candidates are tested at an appropriate level of difficulty. This approach not only improves the fairness of the examination but also enhances its validity.

5.3.2. Development of a multidimensional diagnostic feedback system

A multidimensional diagnostic feedback system is proposed to provide candidates with detailed and comprehensive feedback on their performance. This system would offer feedback across multiple dimensions, including language knowledge, language use, and communicative competence, helping candidates identify their strengths and areas for improvement. For instance, the diagnostic feedback system could generate detailed score reports that highlight candidates' performance in each dimension and provide targeted recommendations for improvement, thereby assisting candidates in enhancing their English proficiency.

5.3.3. Enhancement of intercultural communicative elements

It is recommended to enhance the integration of intercultural communicative elements within the test by incorporating more intercultural communicative contexts. This would allow for the assessment of candidates' intercultural communicative competence. For example, the speaking section could include topics related to

intercultural communication, requiring candidates to demonstrate their understanding and respect for different cultures during the interaction. This enhancement would strengthen the examination's focus on intercultural communicative ability.

6. Conclusion

6.1. Summary of key findings

This study has conducted an in-depth analysis of the construct, design, and scoring system of the KET exam. It was found that the KET exam has significant strengths in terms of task authenticity, communicative orientation, standardization, and international recognition. However, it also has limitations, such as the restricted genre coverage in the writing module and insufficient adaptation to the cognitive characteristics of young learners ^[21].

6.2. Implications for educational assessment reform in basic education

The research on the KET exam offers valuable insights for the reform of English language assessment in basic education in our country. It is recommended that future assessments focus on the authenticity and communicative orientation of tasks, enhance the standardization and international recognition of assessments, and pay attention to the cognitive characteristics of young learners. Additionally, the assessment should incorporate more elements of intercultural communicative competence.

6.3. Future research directions

Future research could further explore the application effects of the KET exam in different educational contexts and investigate how to better integrate the KET exam with teaching practices to promote students' English proficiency. Moreover, research could focus on the application of the KET exam in computerized adaptive testing and multidimensional diagnostic feedback systems, thereby advancing the development of language assessment technologies.

Disclosure statement

The author declares no conflict of interest.

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Discussion on the Status and Influence of Shangyu Kiln Industry in Ancient Ceramic History

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Abstract: Shangyu is recognized as the cradle of Chinese celadon, positioning China as the birthplace of global celadon. The significance of the Shangyu kiln industry in the context of ancient ceramic history is unequivocal. This article systematically elucidates the status of the Shangyu kiln industry in Chinese ceramic history and its multidimensional influence on the world, drawing upon archaeological data from various domestic and international kiln sites, as well as urban archaeological discoveries related to Shangyu celadon.

Keywords: Shangyu celadon; Ceramic history; Korean Peninsula; Japan

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1. Introduction

The Chinese ceramic history has undergone a developmental trajectory from pottery, stamped hard pottery, proto-celadon, to mature celadon. Although artifacts of proto-celadon have been excavated from burial sites within Shangyu, such as the proto-porcelain ritual vessels from the two Zhou Dynasties found at a burial mound in Fenghuang Mountain ^[1] and the proto-porcelain Fang vessel with two beast-headed ears ^[2] unearthed from the Western Han Dynasty at a construction site in Baiguan Town. There is insufficient evidence to assert that these products were locally manufactured. The western bank of Hangzhou Bay, in proximity to Shangyu, is recognized as a core production area for proto-porcelain. From the Shang and Zhou Dynasties through the Qin and Han Dynasties, the proto-porcelain kiln industry exhibited a trend of continuous eastward expansion across the Ningshao Plain, extending from the East Tiaoxi River basin in Huzhou to the Xiaoshan Mountain evolutionary region. During this period, Shangyu emerged as a significant marketplace adjacent to the production sites of proto-porcelain. With the passage of time and the synergistic effects of consumption incentives, the eastward migration of kiln artisans, and the development of ceramics resources

in Shangyu, mature celadon ultimately materialized in this region during the Eastern Han Dynasty.

2. Status quo of Shangyu kiln industry in the context of Chinese ceramic history

The kiln industry in Shangyu is predominantly located in the valleys on both the eastern and western banks of the Cao'e River, which boasts favorable natural conditions conducive to the development of the ceramics manufacturing industry. The region is abundant in porcelain clay resources, providing an ample supply of raw materials necessary for ceramics manufacturing; densely forested areas supply sufficient fuel for the ceramics production; and an intricate water network facilitates both water sourcing and transportation, allowing the movement of ceramics via tributaries into the main course of the Cao'e River. From this point, ceramics can be transported northwards to Hangzhou Bay, connected westward to the Qiantang River for distribution across Jiangnan (the regions south of the Yangtze River), and exported eastward to markets in the Korean Peninsula, Japan, and beyond.

Archaeological investigations over the years have identified a cluster of eight principal kiln sites in Shangyu: the Fenghuang Mountain kiln site group (the Han and Six Dynasties), the Sifeng Mountain kiln site group (Eastern Han), the Dahu'ao kiln site group (Eastern Han), the Linghu kiln site group (the Eastern Han to the Tang and Song Dynasties), the Yaosiqian kiln site group (the Eastern Han to Tang and Song Dynasties), the Aohua Mountain kiln site group (Eastern Han), the Zaoli Lake kiln site group (the Han and Six Dynasties), and the Hengtang kiln site group (Six Dynasties), collectively comprising over four hundred kiln site points^[3]. The chronology of the kiln industry extends roughly one thousand years, from the Eastern Han through the Northern Song Dynasties, featuring periods of both flourishing activity and decline. By analyzing the quantity of kiln sites, the scale of production, and the quality of output across various epochs, we can categorize the Shangyu kiln industry into four distinct phases, thus elucidating its status in Chinese ceramic history.

2.1. Eastern Han to Western Jin Dynasties

This period marked the initial zenith in the emergence and evolution of Shangyu's ceramics manufacturing industry. Concurrently, it signified the first pinnacle in the development of Chinese ceramics. Statistical data reveal that there were 45 Eastern Han Dynasty kiln sites in Shangyu. This number reached 42 during the Three Kingdoms Period and peaked at 53 during the Western Jin Dynasty. The kiln sites in Shangyu alone accounted for 67% of the total in the Jiangnan region^[4]. In stark contrast are the kiln sites in the middle reaches of the Yangtze River. Taking the Hongzhou Kiln in Jiangxi as an example, according to the current records, only 31 kilns from the late Eastern Han Dynasty to the Tang Dynasty and the Five Dynasties were discovered in total. Among them, there are fewer than 10 kiln sites dating from the Eastern Han to the Western Jin Dynasties^[5].

Beyond the quantity of kiln sites and the scale of kilns, the diversity and quality of ceramics are crucial indicators of the ceramic industry's development. During the Eastern Han Dynasty, celadon vessels exhibited relatively limited variety. They had yet to fully extricate themselves from the influence of pottery and proto-porcelain. High-necked multi-loop jars and five-tube bottles were prevalent. The vessel bodies were frequently impressed with linen-like patterns. The adhesion between the porcelain body and the glaze was tenuous, rendering the glaze layer susceptible to

exfoliation.

From the Three Kingdoms Period to the Western Jin Dynasty, the number of porcelain vessel forms expanded markedly. Utility items permeated every facet of daily life. Tableware such as bowls, plates, basins, cups, zun, pots, bottles, and jars became commonplace. Stationery items like inkstones and water pots, along with “huzi” (a chamber pot in the shape of a tiger), were also in use. Burial objects were remarkably abundant. During this period, there were celadon counterparts of the ceramic figurines of people and animals, as well as ceramic buildings and other items that were used as funerary objects in the Han Dynasty. The decoration and connotations of vessel forms evolved significantly. The Eastern Han five-tube bottle gradually transformed into a granary jar adorned with elaborate pavilions and towers. With the popularity of Buddhism, Buddhist imagery became a favored decorative motif on celadon. During this period, the adhesion between the porcelain body and glaze was robust, preventing exfoliation. The reducing atmosphere within the kilns was highly effective, endowing the celadon with a vivid and jade-like green hue. In contrast, celadon products from the Hongzhou Kiln in Jiangxi and the Yuezhou Kiln in Hunan, both in the middle reaches of the Yangtze River, were generally of inferior quality. Their glazed surfaces were marred with numerous cracks and severe exfoliation, and the glaze exhibited a yellowish tinge, placing them far behind Shangyu celadon.

2.2. Eastern Jin to Southern Dynasties

Beginning from the Eastern Han to the Western Jin Dynasties, the ceramics manufacturing industry in the Jiangnan region underwent progressive outward expansion. This expansion catalyzed the emergence of ceramic industries in the middle and upper reaches of the Yangtze River, northern Fujian, and northern China. During the Eastern Jin and Southern Dynasties, a seismic shift occurred in the national ceramic industry landscape. Firstly, the Yue Kiln system, centered around the Shangyu Kiln, experienced a decline. The number of kiln sites in Shangyu plummeted from 53 during the Western Jin Dynasty to 4 during the Eastern Jin Dynasty and 6 during the Southern Dynasties. Product quality deteriorated precipitously. Not only did the variety of vessel forms diminish, but craftsmanship became coarser. Intricate piled-up decorations featuring animals, pavilions, and towers either disappeared or were simplified. In their stead, green glaze with brown-spotted patterns gained popularity.

As the Yue Kiln declined, the Hongzhou Kiln and Yuezhou Kiln entered a zenith of development, emerging as new centers of the kiln industry. Their products penetrated the lower reaches of the Yangtze River and the northern regions. Relevant artifacts have been unearthed from the tomb of Li Yuanmao in Zanhuang County, Hebei, and the Jingling Mausoleum of Emperor Xuanwu of the Northern Wei Dynasty in Luoyang, Henan^[6]. Outside these centers, local kilns such as the Huaiyuan Kiln in northern Fujian and those in Sichuan and Guangdong were extensively marketed within their respective regions. Based on their strategic border-region locations, they exported products to the Korean Peninsula and Southeast Asian countries via land and sea routes.

2.3. Sui-Tang Dynasties through the Five Dynasties and early Song Dynasty

Despite its decline during the Southern Dynasties, not all Shangyu kilns vanished. It entered a phase of slow development during the Sui-Tang Dynasties. Tang Dynasty Shangyu celadon was predominantly distributed along both banks of the middle reaches of the Cao'e River, specifically at sites like Lianjiang Linghu and Shangpu Jiazhang, with

expansion towards Longpu. Surveys indicate that the number of kiln sites, which stood at less than 10 during the Southern Dynasties, swelled to over 40 during the Sui-Tang Dynasties ^[7]. This was accompanied by marked improvements in celadon quality, characterized by enhanced adhesion between the porcelain body and glaze and reduced impurities. The vessel forms diversified significantly. The burgeoning tea-culture led to the emergence of tea-ware assemblages, including ewers, tea cups with saucers, waste bowls, and side-handled pots. The decorations of the artifacts exhibit two major trends: imitating gold and silver wares, and imitating natural flowers.

During the Five Dynasties and early Song Dynasty, the Shangyu kilns underwent exponential growth, marking the second zenith since the inception of celadon in the Eastern Han Dynasty. The Yaosiqian Kiln site serves as an exemplar of this period. In the “Guangjiao Temple” entry of the *Wanli Annals*, quoted by the *Shangyu County Annals* compiled during the Guangxu period of the Qing Dynasty, it is recorded that: “Guangjiao Temple is located thirty li southwest of the county seat. In the past, thirty-six imperial kilns were established here, and there are the former sites of the official courtyards.” The imperial kilns mentioned in the document refer to the Yaosiqian Kiln site. As Shangyu celadon entered the imperial courts of the Wuyue Kingdom and the Northern Song Dynasty, it attained the zenith of its kiln industry historically. The products transitioned from the sub-optimal state of the early-to-mid-Tang Dynasty—characterized by uneven glaze surfaces and abundant clay spots within vessels—to the ice-and-jade-like secret-color porcelain. This porcelain type was fired in porcelain clay saggars, sealed with glaze to create an intense reducing atmosphere, resulting in a vivid and green hue for ceramics. In the early Northern Song Dynasty, the general adoption of single-firing techniques with one vessel per sagger eliminated support-firing flaws within vessels. Decorative techniques emulated the intricate fine-line-incising technique found in gold and silver wares as far as possible, exuding opulence.

2.4. Mid-to-late Northern Song Dynasty

Following its zenith, the industry experienced a decline. The growing popularity of Jingdezhen Kiln bluish white ceramics and Henan celadon precipitated the decline of the Yue Kiln in the mid-Northern Song Dynasty. The industry began to relocate to the mountainous regions of southern and southwestern Zhejiang. Consequently, the Shangyu Yaosiqian site and the Cixi Shanglin Lake site, two major kiln centers from the Five Dynasties to the early Song Dynasty, declined.

During the mid-to-late Northern Song Dynasty, Shangyu celadon production bifurcated into two distinct product lines. One remained within the Yue Kiln system but exhibited marked coarsening compared to the meticulous craftsmanship of the early Northern Song Dynasty. The fine-line-incising technique, emulating gold and silver wares, was simplified, and incised lines became perfunctory. Glaze surfaces exhibited impurities and were yellowish. The other one belonged to the Longquan Kiln system. Longquan-style celadon emerged in Longquan following the southward migration of the Yue Kiln in the mid-Northern Song Dynasty, with incised and carved patterns on both the interior and exterior surfaces of vessels ^[8]. In the late Northern Song Dynasty, celadon wares with double-sided incised and carved patterns, centered around the Longquan Kiln, spread out in all directions. Kiln sites influenced by it included the Shabu Kiln in Huangyan, Taizhou, the Songxi Kiln in Fujian, and the Yaosiqian Kiln in Shangyu was also one of them. The difference lies in that kiln sites such as those in Huangyan and Songxi took this type of product as an

opportunity to develop into large-scale kiln site groups for export. In contrast, the celadon production in Shangyu was only sporadic, and eventually, it completely withdrew from the historical stage.

3. Influence of the Shangyu kiln industry on world ceramic history

3.1. Export of Shangyu celadon

The export of ceramics was inextricably linked to the production activities of the kiln industry. The export of Shangyu celadon peaked during two distinct periods: the Six Dynasties and the Five Dynasties to the early Song Dynasty. During the Six Dynasties, celadon exports were characterized by limited scale and strong political undertones. The primary export destination was the Korean Peninsula, with scattered finds in Indonesia and Japan. Western Jin Dynasty Shangyu celadon has been unearthed across multiple regions of the Korean Peninsula, primarily in the three capitals of the Baekje Kingdom along its southwestern coast, i.e. present-day Seoul, Gongju, and Buyeo in the Republic of Korea. These finds were predominantly from royal palaces and noble tombs, with the ceramics consisting mainly of daily-use wares such as bowls, plates, pots, and jars, becoming status symbols among the elite ^[9]. Functioning as political and diplomatic presents, celadon artifacts were predominantly transmitted by envoys shuttling between the two regions. As a result, the distribution of celadon centered on the capitals of the two countries. The comprehensive distribution route was as follows: celadon items were transported from the Shangyu kiln sites to Nanjing, the capital of the Six Dynasties, via the canal network. Subsequently, they were shipped eastward across the sea to the Korean Peninsula along the Yangtze River.

From the Five Dynasties to the early Song Dynasty, the distribution paradigm underwent a shift. Propelled by the flourishing commodity economy and the development of maritime navigation, large-scale exports of celadon from eastern Zhejiang ensued. The market expanded far beyond the Korean Peninsula, reaching regions encircling the Indian Ocean, including Japan, Southeast Asia, West Asia, the Middle East, and North Africa. Two sunken vessels were unearthed in the waters of Southeast Asia: the Intan shipwreck from the Five Dynasties and the Cirebon shipwreck from the early Northern Song Dynasty. Each shipwreck yielded hundreds of thousands of Yue Kiln celadon pieces. These celadon items were predominantly decorated using the fine-line-incising technique. In addition to the prevalent vessel forms in the domestic market, there were also vessels custom-made for Muslim and Western people. Under the sway of the commercial model, the external distribution route pivoted from a capital-centric model to a port-centric one. During this period, Shangyu celadon could be directly transported to Ningbo Port via the Eastern Zhejiang Canal and then exported overseas. Ningbo in the Northern Song Dynasty rapidly emerged as the preeminent port for the export of Yue Kiln celadon. Countless celadon artifacts were excavated from the ruins of Ningbo Port.

3.2. Imitation of celadon in the Korean Peninsula and Japan

During the apogee of celadon production in China's Six Dynasties, most regions globally remained in the pottery era, lacking the technological prowess to manufacture ceramics. The Korean Peninsula, maintaining close ties with China, was under the jurisdiction of four distinct polities: Baekje, Silla, Goguryeo, and Gaya. At this juncture, the aristocracy predominantly utilized pottery, glazed pottery, and metal vessels for daily use. Once Chinese celadon entered the

Peninsula, its robust texture, glossy glaze, and diverse morphology instantly rendered it a luxury on par with gold and silver. The Tomb of King Muryeong of Baekje Period in the Republic of Korea serves as a prime example. Among the burial objects, in addition to an abundance of gold and silver wares, various celadon jars, bottles, and cups were placed around the coffin. This arrangement vividly attests to the tomb occupant's appreciation for celadon. The predilections of the upper-echelon society propelled the Baekje kiln industry to initiate the imitation of Six Dynasties celadon. The two advanced products of the Baekje kiln industry were hard pottery and glazed pottery. The former was fired at elevated temperatures. In some instances, ash deposits within the kiln created a natural glaze on the pottery surface. However, it did not progress to the proto-porcelain stage. Glazed pottery, featuring low-temperature glazes, was analogous to the Chinese tri-color glazed ceramics and did not naturally evolve into ceramics. Thus, Baekje primarily emulated celadon in terms of vessel forms. Notable examples of imitation include male and female urinals—*huzi* and dustpan-shaped vessels. In addition to utility vessels, burial objects were also subject to imitation. The celadon figurine-adorned jars, popular from the Three Kingdoms Period to the Western Jin Dynasty, were prime objects of imitation. The Korean Peninsula's imitations were strikingly accurate, particularly in the nearly identical designs of human figures. This influence persisted well into the Unified Silla Period, contemporaneous with the Tang Dynasty in China.

Japan's hard pottery technique was introduced from the Korean Peninsula during the 5th century and was known as "Sueki." Around the Heian Period in the 9th century, spurred by the consumption of Chinese Yue Kiln celadon, the Sanage Kiln pioneered the production of ash-glazed pottery. This marked the advent of Japan's indigenous high-temperature glazing technique. Despite its name, the ash-glaze contained a substantial iron content. Except for its relatively poor quality, it shared remarkable similarities with celadon. Japanese aristocrats held a deep admiration for the Tang Dynasty's aesthetics. The growing popularity of tea drinking in the late Tang Dynasty further incentivized the Japanese kiln industry to mimic Yue Kiln celadon. Building upon Nara tri-color glazed ceramics, they developed monochromatic low-temperature green-glazed pottery to replicate the green glaze and forms of Yue Kiln celadon. The Ishizukuri Kiln in Kyoto stands as a prime exemplar. Archaeological excavations have unearthed a substantial number of open-mouthed, obliquely straight-walled bowls with jade-disc-shaped bases and lotus-leaf-shaped bowls with curled rims. A large quantity of similar vessels has also been unearthed at Shangyu kiln sites dating from the late Tang Dynasty to the Five Dynasties.

3.3. Genesis of Goryeo celadon

Following nearly seven centuries of unavailing endeavors in ceramics manufacturing, the Korean Peninsula successfully pioneered Goryeo celadon during the Five Dynasties to the early Song Dynasty. This was achieved through the direct influx of celadon-manufacturing techniques from the Yue Kiln system. The transfer of such techniques represented a pivotal milestone in world ceramic history, marking the entry of a second nation outside China into the ceramic era. Two key historical contingencies precipitated the genesis of Goryeo celadon. First, the armed conflicts spanning the Five Dynasties to the early Song Dynasty instigated population displacement. During this period, a cohort of kiln artisans from eastern Zhejiang migrated to the Korean Peninsula, driven by the need for refuge or economic sustenance. Second, the Goryeo's persistent official aspiration for celadon impelled them to methodically enlist Chinese migrants, facilitating local ceramics production.

These postulations find substantial corroboration in ceramic archaeological investigations on the Korean Peninsula. Decades of archaeological excavations have demonstrated that early Goryeo celadon not only emulated the morphological characteristics of Yue Kiln celadon but also directly perpetuated its kiln-building and firing techniques. The traditional kiln in the Korean Peninsula was a pit-style dragon kiln, in which ceramics were fired in an open-flame environment. Around the 10th century, brick-constructed dragon kilns, mirroring those of the Yue Kiln, emerged. Ceramics were fired within M-shaped saggars. However, over time, this advanced technology was gradually lost. By the 12th century, Goryeo celadon production reverted to the use of pit-style dragon kilns.

Furthermore, contrary to earlier scholarly conjectures, the early Goryeo kiln sites were not concentrated in Jeollanam-do, despite its geographical proximity to the Zhejiang coast. Instead, they were predominantly located in the vicinity of Kaesong, the Goryeo capital, and in Gyeonggi Province. This distribution pattern underscores the primacy of political resources over natural or economic factors in the development of the ceramic industry. Social transformations, occurring from the top to down, generally mirrored the pragmatic requirements of the upper-echelon society. On one hand, there was an insatiable appetite for luxury goods. The National Museum of Korea houses an array of burial objects unearthed from Kaesong tombs during the Japanese colonial period. Among these, a significant number of exquisitely crafted Yue Kiln ceramics from the Yaosiqian site in Shangyu and the Shanglin Lake kiln site in Cixi, Zhejiang, dating from the Five Dynasties to the early Song Dynasty, were recovered. The Five Dynasties pieces were predominantly plain-surfaced, with some adorned with petal-motif decorations. The early Song Dynasty pieces were decorated with fine-line incising technique, attaining a quality on par with secret-color porcelain. On the other hand, there was an effort to assimilate Chinese ritualistic culture. The Ewha Womans University Museum in the Republic of Korea preserves a celadon ritual vessel inscribed with the dedication: “Crafted by the first chamber of the Imperial Ancestral Temple in the fourth year of the Chunhua era (993 AD, Guisi year); crafted by artisan Choi Gil-hoe.” This artifact represents one of the earliest dated Goryeo celadon pieces, attesting to the high-status official nature of Goryeo celadon from its very inception.

4. Conclusion

Shangyu stands as the cradle of Chinese ceramics as well as the birthplace of global ceramics. It attained maturity during the Eastern Han Dynasty, underwent development throughout the Six Dynasties, reached its zenith in the Tang and Song Dynasties, and subsequently declined into oblivion. During this trajectory, it experienced a nadir during the Eastern Jin and Southern Dynasties, and two apices during the Western Jin Dynasty and the Five Dynasties to the early Song Dynasty. The continuous operation of Shangyu’s kilns over more than a thousand years laid the cornerstone for Chinese ceramic history and exerted far-reaching influence on global ceramic civilization. The global impact of Shangyu celadon can be stratified into three distinct dimensions. First, there was product exportation. In the initial phase, spanning from the Eastern Han Dynasty to the Six Dynasties, celadon was primarily rewarded through diplomatic channels. Post the late Tang Dynasty, celadon emerged in large-scale maritime trade, entering the global markets. Second, there was an influence on ceramics. China was the vanguard in transitioning from the pottery era to the ceramic era. For countries or regions lacking ceramics manufacturing expertise, imported ceramics assumed the status of a luxury item. Official authorities endeavored to replicate these artifacts to satisfy the demands of the elite.

As a result, the forms and decorative styles of Chinese ceramics set enduring aesthetic standards. Third, there was an industrial impact. Imitative products often merely approximated the appearance of Chinese ceramics, lacking the crucial technological know-how to convert pottery into ceramics. The first wave of Chinese ceramics manufacturing technique transfer occurred on the Korean Peninsula in the 10th century. The emergence and development of Goryeo celadon served as a catalyst for local social change.

Disclosure statement

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From Cthulhu Myth to Camera Language: Decoding Cthulhu's Mythical Narration and Visual Presentation of *Thriller Black Hole*

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Abstract: The myth of Cthulhu was created by the American writer H.P. Lovecraft in the 1920s and 1930s. Its unique outlook on the universe, mysterious creatures, and profound descriptions of human smallness and powerlessness make it unique in the field of literature ^[1]. In this mythological system, there exist ancient beings beyond human understanding (the old rulers) who lurk in hidden corners of the universe, waiting for the right moment to descend upon humanity and cause endless chaos. This kind of confusion about the unknown, subversion of the cosmic order, and challenge to human rationality deeply attracts countless readers and inspires many film and television creators.

Keywords: Cthulhu myth; Narrative; Audio-visual language; *Thriller Black Hole*

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1. The drama foundation of *Thriller Black Hole*: The deep transformation and narrative structure of Cthulhu myth

In *Thriller Black Hole*, the director Trent Carpenter accurately extracted the key elements in the myth of Cthulhu and skillfully integrated them into the story background. First of all, the mysterious creatures in the film and the book *Thriller Black Hole* are typical presentations of the old dominators in the myth of Cthulhu ^[2]. This mysterious force possesses forms and abilities beyond human understanding, and its appearance breaks humanity's understanding of the universe, causing confusion among the protagonist and the people of the small town. Just like the ancient existence hidden in the deep universe in Cthulhu's myth, this nameless existence makes human beings realize their insignificance and powerlessness in the universe. This challenge and subversion of human reason is one of the core charms of Cthulhu's myth ^[3].

The protagonist, Trent, accidentally triggers this unnamed awakening during the research process, and the release of this mysterious power leads to a series of supernatural phenomena, such as the distortion and deformation of objects, the confusion of time and space, and so on. These phenomena not only create a strong, mysterious

atmosphere for the film, but also drive the development of the plot. They let the audience feel the chaos and unpredictability of the cosmic order in the myth of Cthulhu, and fully demonstrated the helplessness and tension of human beings in the face of the unknown.

The universe in the film is not a harmonious and orderly space, but is full of unknowns and dangers. The existence of Cthulhu in the film implies that there is a power and existence in the universe beyond human understanding, and human exploration may lead to unpredictable disasters ^[4]. This kind of unknown description of the universe echoes the essence and fatalism of the universe in Cthulhu's myth, which makes the audience have a profound thought on the essence and destiny of the universe while enjoying the film.

In the play, *Thriller Black Hole* adopts a multi-threaded narrative mode, carefully weaving Trent's exploration of Kane, the threat of unknown creatures, and the potential crisis of human civilization, making the narrative structure of the film rich and compact ^[5].

The film starts with Trent's search for Kane and unfolds a series of studies and explorations into mysterious events. This clue not only showcases Trent's courage and wisdom in the face of the unknown but also reveals the terrifying truth he gradually discovers during his exploration. As the adventure deepened, Trent gradually realized that the book *Thriller Black Hole* was not just a simple group fantasy, but a supernatural force that assimilated the real world with the fictional world. This clue provided the driving force for the plot development of the film, pushing the story forward continuously ^[4].

The threat of unknown creatures adds a tense atmosphere to the film. The book *Thriller Black Hole* triggered a series of supernatural phenomena that not only posed a direct threat to the town residents and Trent, but also made the audience feel the terrifying power of the old rulers influencing people's hearts. The film presents a series of scenes, such as frequent dreams, people influenced by Kane's books, and human transformations, to show the protagonist's sense of powerlessness that cannot escape fate, keeping the audience in a tense state throughout the viewing process ^[6].

The potential crisis line of human civilization is the deeper clue of the film. The film suggests that exploring mysterious events may trigger a series of disasters, which elevates the theme of the film. Trent's adventure journey is not only about exploring the unknown, but also about showcasing the insignificance and helplessness of humanity in the face of fate. This clue gives the film a deeper social significance, allowing the audience to appreciate the film while also deeply contemplating the future and destiny of human civilization ^[7].

2. The language of the camera in Thriller Black Hole: A collaborative interpretation of visual presentation and dramatic content

In *Thriller Black Hole*, director Trent Carpenter cleverly uses camera composition and visual style to create an atmosphere of the novel world and the real world, which gives the audience a strong visual impact.

The use of low-angle center composition in the film highlights mystery and elements. For example, in the scene depicting Trent, the director repeatedly used a low-angle center composition, placing Trent at the center of the picture, making it appear unstable. In addition, this low-angle lens also showcases Trent's own insignificance and

powerlessness. At the same time, low-angle shots also enhance the sense of oppression in the picture, keeping the audience in a tense state throughout the viewing process [8].

High-angle diagonal composition plays an important role in depicting the relationship between characters and the environment. In the film, the director presents Trent's exploration scenes in a mysterious town through high-angle oblique composition. This high-angle diagonal composition not only allows the audience to clearly see the full picture of the mysterious town, but also highlights the insignificance and helplessness of the characters in the environment. At the same time, the high-angle diagonal composition also creates a bird's-eye view, making the audience feel as if they are in the center of the town and experiencing the atmosphere of the town, further enhancing the mysterious atmosphere of the film.

In addition, in *Thriller Black Hole*, director Trent Carpenter enhances the tension of the plot and the emotions of the characters through carefully designed camera movements and rhythms, making the audience more engaged during the viewing process.

The unstable handheld camera plays a role in showcasing the development of the plot and the actions of the characters in the film. For example, in the scene where the protagonist and the female editor are driving, the director uses a handheld, unstable camera to depict the unstable factors during the journey and the transition between the novel and reality. This kind of shot not only restores the crisis during the journey and the connection between the novel world and the real world, but also shows the protagonist's uneasy state, laying the foundation for the development of the subsequent plot. At the same time, holding unstable lenses also has a certain guiding effect; by creating instability, it can alleviate the indescribable tension in the audience's heart. By quickly switching shots, not only does it enhance the tension of the plot, but it also creates a tense atmosphere, making the audience even more nervous during the viewing process. In relatively calm scenes, the director slows down the pace of the camera and showcases the characters' inner world and emotional changes through slow camera movements [9].

At the same time, the low background music plays a role in creating a mysterious and tense atmosphere in the film. The film uses low and oppressive background music to create a mysterious and tense atmosphere. This low background music not only echoes the mysterious universe scene in the picture, but also enhances the audience's sense of tension. At the same time, the changes in background music also play a role in guiding the audience's emotions. In tense scenes, the rhythm of background music accelerates and the volume increases, creating a tense atmosphere; in relatively calm scenes, the rhythm of the background music slows down and the volume decreases, creating a contemplative atmosphere. The sound effect has played a prominent role in Cthulhu's elements in the film. For example, in the scene depicting the old dominator attacking the protagonist, the director used sound effects such as sharp screams and empty ambient sounds to create a tense atmosphere. These sound effects not only highlight the terrifying power of the old rulers but also make the audience feel the fear and helplessness of humanity when facing the unknown. At the same time, sound effects also have a certain guiding effect, by directing the audience's attention, making them pay more attention to the elements in the film.

The dialogue between characters plays a role in showcasing their personalities and emotions in the film. The dialogues between the characters in the film are concise yet powerful, depicting the protagonist's confusion in both

the real and fictional worlds. For example, in the discussion between the protagonist and the female editor about the events they are facing, their dialogue appears urgent and hasty, which reflects that their spirit has been influenced by the novel. At the same time, character dialogue also has a certain guiding role, gradually revealing the truth of the film by guiding the audience's thinking.

Environmental sound plays a role in creating realism and immersion in the film. The film utilizes rich environmental sounds, such as the roar of tunnels and the shattering of glass, to create a sense of realism. These environmental sounds not only make the audience feel the crisis of the protagonist's journey, but also make them feel as if they are in the scene of the film, creating an immersive viewing experience ^[10].

3. The deep integration of drama and lens language: The creative expression of Thriller *Black Hole* and the inspiration of Cthulhu myth film and television adaptation

Overall, in *Thriller Black Hole*, the language of the play and the camera are deeply integrated, and the plot, characters, and visual presentation are organically unified, giving the film a unique artistic charm.

The plot of the play provides rich materials and inspiration for camera design. The multi-clue narrative mode in the film provides a vast space for the use of camera language. For example, when depicting the protagonist's exploration of Kane, the director used the technique of psychological montage to connect the protagonist's hysterical state with the real world, showing the process of the protagonist's inner breakdown. At the same time, the creation of suspense in the play also provides an opportunity for the use of camera language. For example, in the scene where the female editor is influenced by the ending of the novel, the director uses the technique of contrast montage to create a strong contrast between the originally quiet female editor and the mutated state, enhancing the visual conflict of the film, showing the tension and intensity of the plot, and strengthening the sense of urgency of suspense.

Secondly, the language of the camera provides strong support for the theme and character development of the play. The camera composition and visual style in the film not only create an atmosphere of a mysterious universe, but also strengthen the theme of the play ^[11]. For example, the cool color scheme and light and shadow effects in the film not only reveal the truth of the film, but also symbolize the powerlessness of humanity in the face of the unknown and destiny. At the same time, the use of camera movement and rhythm also reinforces the emotions and personalities of the characters. For example, when depicting the protagonist's helplessness in the face of fate, the director uses forward and backward shots to vividly portray the protagonist facing the truth alone in the cinema. It is through this that the film's fatalism is also strengthened ^[12].

In addition, the play and the camera complement and elevate each other in the film, jointly enhancing the overall effect of the film. The exciting plot and the truth of the film in the play provide a solid foundation for the use of camera language, while the clever use of camera language adds visual charm to the presentation of the play. For example, in the climax of the film, the multi clue narrative mode and suspense creation in the play provide rich materials for the use of camera language, while the rapid switching of shots and strong contrast of light and shadow in camera language enhance the tension and suspense of the play, making the overall effect of the film reach its climax.

Thriller Black Hole has a unique innovative significance and exemplary role in the adaptation of Cthulhu myth film and television. Compared with other Cthulhu mythological film and television works, the film has unique innovations in the adaptation of plays and the use of lens language.

In terms of the adaptation of the play, the film deeply explores and skillfully integrates the mythical elements of Cthulhu. The film not only accurately extracts the key creatures, mysterious forces, and cosmology in Cthulhu's myth, but also skillfully integrates these elements into the story through an elaborately designed narrative structure and suspense creation. The multi-clue narrative mode and suspense creation techniques in the film not only enrich the layers of the play but also strengthen the tension of the play, making the film uniquely attractive. At the same time, the film also has unique innovations in deepening the theme of the play. The film not only portrays the helplessness of humans in the face of the unknown, but also explores the relationship between humans and fate, giving the theme of the play a deeper social significance ^[13].

In addition, *Thriller Black Hole* plays an important exemplary role in the subsequent creation of Cthulhu's mythical film and television works. In terms of the idea of the play, the film deeply digs and skillfully integrates the elements of Cthulhu myth and Joseph Campbell's theory of heroes with thousands of faces, and uses the images in the hero's adventure journey together with elaborately designed narrative structure and suspense building skills to provide valuable reference for the subsequent Cthulhu myth work ^[14]. In terms of visual style, the clever use of camera composition, visual style, camera movement and rhythm, and sound design in the film provides rich visual expression techniques for subsequent works. In terms of narrative techniques, the film's multi-clue narrative mode, suspense creation techniques, and editing skills provide unique narrative perspectives and techniques for subsequent works.

4. Conclusion

In general, *Thriller Black Hole* successfully outlines a strange and familiar universe picture with its exquisite drama structure, profound Cthulhu myth connotation, and ingenious camera language. The film not only allows viewers to appreciate the unknown and insignificant powerlessness faced by humanity in the vast universe, but also witnesses the numerous crises and spiritual struggles experienced by the protagonist on the path of exploring the truth. Through the ingenious integration of Cthulhu's mythical elements and modern narrative techniques, the film further expands the deep thinking of human reason, the order of the universe and fatalism, and triggers the viewer to reflect on their position and destiny in the universe.

In today's society, against the backdrop of rapid technological development and information explosion, people are curious about the unknown world, as well as filled with awe and fear when facing many unexplainable natural phenomena and cosmic mysteries. The film *Thriller Black Hole* provides viewers with a unique perspective and thinking path, allowing them to experience the mystery and terror of the universe while also gaining a deeper understanding of the limitations of humanity itself, thereby inspiring sustained attention and exploration of issues related to science, philosophy, and human development. In the future, works similar to the integration of classical cultural elements such as the Cthulhu myth with modern film and television technology and narrative ideas will continue to emerge, bringing richer and more diverse audio-visual experience and ideological enlightenment to the

audience, and promoting the film and television art in the performance of the human spiritual world and the exploration of the truth of the universe.

It can be said that *Thriller Black Hole* is not only a stunning film and television masterpiece, but also a window through which viewers can glimpse the hidden existence deep in the universe, while also reflecting the human heart's exploration of the unknown and desire to control fate. It allows viewers to constantly reflect in tension and shock, prompting them to maintain humility and awe on the road ahead, bravely face the unknown, pursue human wisdom and power, and explore the ultimate mysteries of the universe and life.

Disclosure statement

The author declares no conflict of interest.

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Research on the Evaluation of Island Tourism Experience Based on LDA Model and Text Mining: Taking 1300 Tourist Reviews as an Example

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Abstract: In this paper, 1300 tourist reviews from Ctrip.com are selected with the help of Python, and then text mining-related techniques are used to analyze the island tourism experience. The analysis shows that natural scenery, cultural experience, seafood quality, and accommodation cost-effective harvest more praise, while transport services, catering price transparency, and service quality need to be further improved. Based on the above, a series of suggestions on traffic, catering, accommodation, and cultural resources are proposed to support the optimization of scenic spots at the data level.

Keywords: Text mining; Tourism management; Island tourism; Review data

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1. Introduction

In recent years, online travel reviews have become a very important way for tourists to express their travel experiences and influence the decisions of others. On the one hand, these reviews reflect the evaluation of tourists on the service quality of scenic spots, and on the other hand, they also give the managers of scenic spots a basis for improvement. In this study, we use word frequency analysis, semantic network, LDA topic model, and sentiment analysis to explore the key points that tourists pay attention to and their sentiment tendency.

2. Study background

2.1. Tourism development and the importance of online reviews

In recent years, with the rapid development of the tourism industry, tourists' evaluation of tourist destinations has become an important indicator of the service quality and attractiveness of scenic spots ^[1]. Especially in the digital era,

Online Travel Reviews (OTR) have become the primary way for tourists to obtain information and share their experiences. These reviews not only influence the decision-making of potential tourists, but also provide the basis for scenic spot managers to improve services and optimize management.

2.2. Data value of online travel reviews

In China, online tourism platforms such as Ctrip, Mare's Nest, and Where to go have accumulated a large amount of tourists' review data on different scenic spots, which cover a wide range of aspects such as tourists' satisfaction, visiting experience, service quality, price perception, and so on. Text mining technology based on big data makes it possible to analyze these reviews, thus revealing the core concerns of tourists, extracting valuable information, and providing a scientific basis for scenic spots to improve service quality and tourism experience [2].

2.3. The special characteristics and research value of island tourism

As a typical coastal tourism destination, the development of the sea island of Tandang Town faces common problems such as traffic constraints and the balance between ecological protection and tourism development. By analyzing this case, not only can it provide a basis for local tourism upgrading, but its research methodology and conclusions are of reference significance for similar island tourism destinations. Especially in the context of the current rapid development of marine tourism, this kind of research is particularly important.

3. Research design and methodology

3.1. Research object and data source

In this study, the island of Tandang Town was selected as the research object, and the relevant data were obtained from the tourists' comments on Ctrip.com. These data largely contain the comments given by tourists on the scenic environment, traffic conditions, accommodation conditions, catering services, and the overall visiting experience.

3.2. Data processing and analysis methods

- (1) Word frequency analysis: Extracting high-frequency words to identify the main content of tourists' concerns.
- (2) Semantic network analysis: Semantic network analysis, focusing on the analysis of keyword interconnections, so as to clearly reveal the structural characteristics of the tourist experience.
- (3) LDA theme model analysis: This can be used to identify the core themes of the reviews and summarize the main aspects discussed by the visitors.
- (4) Sentiment analysis: Calculating the sentiment tendency of the comments, and identifying the positive and negative comments of tourists on the scenic spots.

3.3. Research process

The main process involved in this study covers the aspect of data collection, as well as data pre-processing, in addition to data storage mining analysis, and other related operations [3]. The process is shown in **Figure 1**.

3.3.1. Data collection

Visitor reviews on Ctrip.com were selected as the data source for the study, and a specific timeframe was first identified, and relevant information about the reviews was extracted, such as review content, ratings, and posting time. Data acquisition methods included crawler technology or other data collation means to ensure the comprehensiveness and representativeness of the data.

3.3.2. Data processing

Raw data may contain “noise” information, so data cleaning is required to remove irrelevant characters, special symbols, etc. Subsequently, word separation technology is used to split the content of the comments into independent words, which facilitates subsequent analyses.

3.3.3. Data storage

The processed text data is collated and stored in a database, while word frequency statistics and co-occurrence analysis are performed to identify high-frequency words and their associative relationships. The purpose of this session is to lay the foundation for topic extraction and sentiment analysis.

3.3.4. Result analysis and output

The study uses LDA topic modelling to classify the topic of the review content and combines it with sentiment analysis methods to explore tourists' tendency to evaluate different aspects ^[4]. Ultimately, based on the results of the data analysis, suggestions for optimizing the tourism experience are put forward to provide data support for the service improvement of scenic spots.

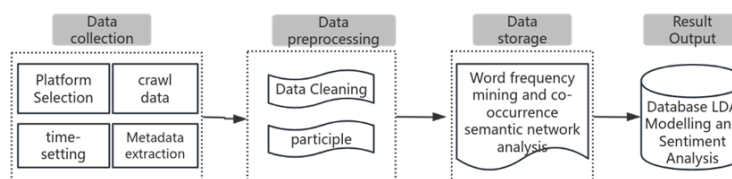


Figure 1. Research process

4. Python-based comment text data analysis

4.1. Data processing

4.1.1. Data extraction and pre-processing

The 1300 comment data were selected from Tandang Town Island sourced from Ctrip travel, and the online comment data of cultural tourism attractions were collected using a data collector and saved in Excel format.

4.1.2. Data cleaning

The invalid data was cleaned, such as empty comments, default comments, comments composed

entirely of numbers or letters, duplicate content, and other logically improper invalid comments; after cleaning, there were 1002 valid comments remaining.

4.1.3. Filtering deactivated words and customized participles

Subsequently, 2743 deactivated words such as time words, auxiliary words, English, and symbols were imported, and 7 customized participles of scenic spot names were added to make the word splitting more scientific.

4.2. Data mining analysis

Based on **Table 1**, “nice” was the most frequent word, with the majority of visitors rating the experience or product positively. Words such as “seafood,” “view,” and “scenery,” which are closely related to the food and natural beauty of the travel experience, also show a high level of satisfaction. Words such as “diving,” “hiking,” “beach,” and “island” are closely related to specific tourist activities. References to “Wentian” and “Lingdingyang” also reflect that tourists recognize their culture. Hong Kong’s “Xiangzhou” and “Zhuhai” describe its geographical location. In terms of transport, “ferry tickets” and “seasickness” have become a major problem for tourists. On the whole, the satisfaction level of tourists’ evaluations is relatively high.

Table 1. Word frequency

| Words | Word frequency | Words | Word frequency | Words | Word frequency | Words | Word frequency | Words | Word frequency |
|-------------|----------------|-----------------|----------------|------------------|----------------|------------|----------------|-------------|----------------|
| Not bad. | 329 | Ship Tickets | 70 | climb a mountain | 48 | beautiful | 40 | Interesting | 32 |
| seafood | 240 | Value for Money | 69 | price | 47 | fun | 39 | Diving | 31 |
| scenery | 183 | Hong Kong | 64 | clean | 47 | market | 38 | graceful | 31 |
| scenery | 137 | Processing | 63 | Holiday | 46 | Beautiful. | 38 | comfortable | 31 |
| worthwhile | 136 | Xiangzhou | 55 | Seasickness | 43 | fresh | 37 | Wentian | 29 |
| Zhuhai | 133 | Clear | 54 | Recommended | 43 | Seascape | 37 | Tianxian | 29 |
| Sandy beach | 132 | Accommodation | 53 | Beautiful | 41 | Cheap | 36 | Service | 29 |
| | | | | | | | | Excursions | 29 |

| | | | | | | | | | |
|--------|-----|----------|----|-----------|----|------------|----|-------------|----|
| Sea | 112 | Boating | 52 | Island | 41 | Sea Breeze | 35 | Lindingyang | 27 |
| Island | 90 | Swimming | 52 | Favourite | 41 | Sea | 33 | B&B | 27 |
| Hotels | 79 | Seaside | 49 | Leisurely | 40 | Experience | 32 | Tourism | 27 |

4.3. Social network (co-occurrence semantic network analysis)

In order to prevent errors in word cutting, the nodes are able to present the relationship between the word and the object [5]. Word frequency analysis can only be reflected by the frequency, but not a complete evaluation of the whole passage. In the covariance network, the thickness and length of the line can reflect the frequency of co-occurrence, that is, the strength of the relationship, as shown in **Figure 2**.

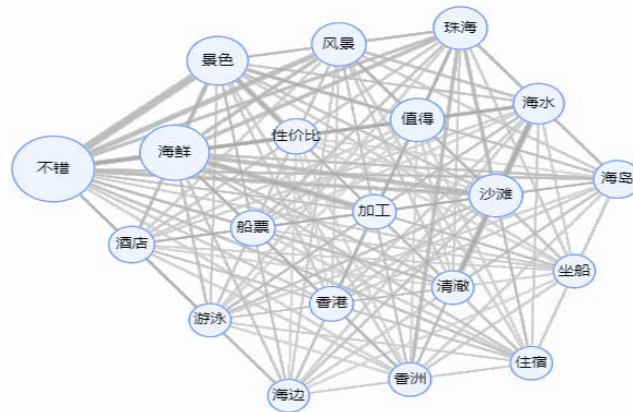


Figure 2. Social network

The semantics of the graphic discovery is based on “nice” as the core word, and aspects such as seafood, scenery, and beach all received very good ratings, which, together with “nice” constitute positive ratings. In the case of “seafood,” there are synonyms with “processing,” “beach,” “value for money,” and “worth it.” Looking at the relationship network constructed with “beach” as the main term, the words “sea water,” “clear,” “seafood,” and “island” form a synonym, which suggests that the situation of sea water management in the neighborhood is relatively good. Then the relationship network mainly based on “boat ticket,” which links seafood, seashore and Hong Kong to Heung Chau, which is related to the geographical location, and comprehensively, through the word frequency analysis, it can be seen that the seafood, scenery, hotels, and other aspects of the place are recognized by tourists.

4.4. Sentiment analysis of word-of-mouth topics based on the LDA model

The LDA theme model is mainly used to identify the implicit themes from a large amount of text data. These themes can be regarded as the abstract concepts of recurring vocabulary in the document, each theme is composed of a set of vocabulary with a certain probability distribution [6]. The LDA model will try to rely on unsupervised learning in this

way, from the given set of documents to discover these latent themes, and at the same time, the distribution of the documents and the themes and the distribution between documents and topics, as well as between topics and words, are estimated accordingly.

Table 2 shows the results of the LDA topic model for analyzing tourists' comments, mainly to see what the most discussed topics are. From the data, "scenery" and "transport" are the most discussed topics, accounting for 34.758% and 24.830%, indicating that tourists are most concerned about what the scenery looks like and whether the transport is convenient. In contrast, "seafood" and "services" accounted for a slightly lower percentage, 21.146% and 19.266% respectively, but they were still an important part of tourists' discussions.

Table 2. Topics in the LDA model

| Topics | Theme weight | Occurrences | Percentage |
|-----------|--------------|-------------|------------|
| Transport | 24.830% | 487 | 48.549% |
| Seafood | 21.146% | 125 | 12.485% |
| Service | 19.266% | 76 | 7.589% |
| Scenery | 34.758% | 314 | 31.377% |
| Total | 100% | 1002 | 100% |

On the whole, the attention of the four themes varies from high to low, but it will not be said that one completely overpowers the others, and the discussion is still relatively balanced. This also shows that tourists' evaluation is multi-faceted, not only concerned about the beauty of the scenery and smooth traffic, but also talks about how the food is and whether the service is good. This analysis can help the scenic spot to optimize in a more targeted way, for example, focusing on improving the transport issues that tourists discuss most, and at the same time doing more fine-tuning in seafood and service, so as to make the overall experience more upgraded.

4.5. Sentiment analysis

In this study, LDA topic model and SPSSAU text sentiment analysis were used to conduct in-depth mining of tourists' reviews with the aim of identifying core themes in the reviews and analyzing the sentiment tendencies expressed by tourists. Text sentiment was classified into "positive," "biased positive," "biased negative," and "negative" four categories in order to understand visitors' attitudes towards different aspects more systematically. "Positive" indicates that the comments are overall positive, conveying emotions of recognition and satisfaction; "biased positive," although generally positive, may contain some minor suggestions for improvement; "biased negative" represents a slight dissatisfaction in the review, which is positive but still carries room for improvement, while "negative" directly expresses a clear sense of dissatisfaction. Through this classification, the emotional attitudes of tourists on different topics can be extracted more accurately, providing more valuable references for subsequent analyses, as shown in **Table 3**.

Table 3. Sentiment analysis table

| Traffic | Sentiment analysis | Seafood | Sentiment analysis | Service | Sentiment analysis | Scenery | Sentiment analysis |
|--------------|--------------------|------------|--------------------|--------------|--------------------|------------------|--------------------|
| Route | Positive | Not bad. | Positive | not bad | Positive | Not bad. | Positive |
| Excursions | Positive | Fresh | Positive | Enthusiastic | Positive | Worth it | Positive |
| Hong Kong | Positive bias | Seafood | Positive bias | Ctrip | Positive | Island | Positive |
| Xiangzhou | Positive | Affordable | Positive bias | Hotel | Negative | Wen Tianxiang | Positive |
| By Boat | Negative | Tasty | Positive bias | Attitude | Positive | Clean | Positive |
| Going up | Negative | Price | Positive bias | Price | Negative | Holiday | Positive |
| Boat Tickets | Negative | Restaurant | Positive bias | - | - | Beautiful | Positive |
| Seasickness | Negative | Processing | Positive bias | - | - | Sandy Beach | Positive bias |
| Tickets | Negative | Sea urchin | Positive bias | - | - | sea | Positive |
| fearful | Negative. | Not cheap | Negative | - | - | Prices | Negative |

In terms of transport, the route and the experience of travelling around the island received a lot of positive comments, but the boat experience had the problems of “seasickness” and “expensive ticket price.” In catering, the freshness of the seafood and the processing service were positively evaluated, but not so good in terms of price. In terms of accommodation, the service attitude is very good, but the satisfaction of tourists in terms of price is relatively low. Overall, there are more prominent shortcomings in terms of transport, while the advantages in terms of nature and culture are quite significant. To sum up, the negative evaluations mainly focus on the boat experience and price in terms of transport, while the positive evaluations mainly focus on the user experience and the scenery.

4.6. Research summary

Based on 1300 tourists’ review data on Ctrip.com about Tandang Town Island, this study systematically mined tourists’ evaluation characteristics and emotional tendencies towards the scenic spot through data cleaning, word frequency statistics, co-occurring semantic network analysis, and LDA topic modelling. It is found that the overall satisfaction of tourists is high, and the core concerns are focused on four aspects: natural landscape, catering experience, transport service, and accommodation quality.

4.6.1. Tourists’ evaluations are mainly positive

High-frequency words such as “not bad,” “worthwhile,” and “beautiful scenery” are dominant, indicating that the scenic spot has a high level of satisfaction in terms of natural scenery (e.g., seawater, sandy beaches) and cultural experience (e.g., Wentianxiang Scenic Spot). This indicates that the scenic spots are widely recognized for their natural beauty (e.g., sea water, beaches) and cultural experience (e.g., Wen Tianxiang spots).

4.6.2. Transportation services are the main shortcoming

Negative comments focus on issues such as “seasickness,” “expensive fares,” and “fewer boat trips,” which directly affect tourists’ experience.

4.6.3. Catering and accommodation are divided

The freshness and processing service of seafood are praised, but the price transparency is insufficient; there is room for improvement in the service attitude and cost performance of hotels.

4.6.4. Cultural resources potential to be tapped

Tourists’ references to cultural symbols such as “Wen Tianxiang” and “Lingdingyang” show the feasibility of cultural tourism integration, but the related development is currently insufficient.

5. Management insights and suggestions

5.1. Optimizing the transport experience and improving visitor satisfaction

Tourists reflect “seasickness” and “expensive fares,” we can consider optimizing the comfort of the boat, such as adding some anti-sickness facilities, and make corresponding adjustments to the fare strategy ^[7]. At the same time, meeting the needs of different tourists can reduce the negative experience that tourists may have.

5.2. Strengthening seafood and catering management

“Seafood” and “processing” are highly rated. However, it is important to ensure that prices are transparent and hygiene standards are strictly met to prevent negative feedback such as “not cheap.” It is beneficial to introduce a special seafood set menu to further strengthen the restaurant’s service quality training. The management can also use the power of market supervision or cooperation with merchants to stabilize price fluctuations and improve the overall dining experience ^[8].

5.3. Improving accommodation and service quality

In view of the existence of “hotel prices” and “service attitude” of the negative evaluation of the situation, there is a need to optimize the service process and the introduction of different types of rooms, to further improve the hygiene conditions, supporting facilities, and the introduction of digital services to promote efficiency ^[9].

5.4. Digging deep into the potential of natural and cultural resources

Island tourism development needs to balance ecological protection and economic development to avoid excessive commercialization affecting the ecological environment ^[10]. Combined with the “Wen Tianxiang,” “Lingdingyang,”

and other cultural symbols to create cultural attractions or cultural and creative products, it is important to dig into the potential of cultural resources to enhance the attractiveness of the destination ^[11]. In addition to strengthening the ecological protection of publicity, it is necessary to show the results of environmental protection (such as clean beach action) and consolidate the “beautiful” “clean” tourism image.

Disclosure statement

The author declares no conflict of interest.

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Hot Topics and Evolution Trends of Domestic Research on “Integration of Specialization and Innovation”: Knowledge Mapping Analysis based on CiteSpace

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Abstract: In recent years, great achievements have been made in the research of “specialization and innovation integration.” Based on 1,020 related papers from 2014 to 2024 in CNKI, this paper uses CiteSpace (V6.2.R2) for visualization analysis to explore research hotspots and trends from the aspects of annual publication volume, co-occurrence of authors and institutions, and co-occurrence of keywords. The results show that: “Innovation and entrepreneurship,” “Talent training,” “Higher vocational colleges,” and “Curriculum system” are research hotspots; the number of publications has accelerated since 2017; the author’s cooperation consciousness has been enhanced but the overall dispersion and the core author have not yet been formed; seven institutions have made outstanding contributions, but the situation between institutions is unclear. The research trend has experienced the evolution of “start-expansion-development.” The current focus is on the implementation of the specialty, and the future may focus on the background of the Internet and artificial intelligence.

Keywords: Integration of specialization and innovation; Research hotspot; Research trend; Visual analysis

Online publication: March 26, 2025

1. Introduction

“Integration of specialization and innovation” is a teaching concept that integrates professional education with innovation and entrepreneurship education in higher education. Since the Ministry of Education put forward relevant policies in 2010, it has become an important direction of national innovation and development, aiming to cultivate compound talents with innovation ability and exploration spirit ^[1]. Based on this, the domestic research on the integration of specialization and innovation is increasing year by year, covering topics such as innovation and

entrepreneurship, personnel training, higher vocational colleges, and education reform. This paper uses CiteSpace (V6.2.R2) to visually analyze 1,020 papers from 2014 to 2024, so as to sort out research hotspots, development trends, and future directions, and provide a reference for follow-up research and practice.

2. Data sources and research methods

2.1. Data sources

Based on the data source of China National Knowledge Infrastructure (CNKI), this paper retrieved and collected relevant academic literature with the keywords of “Integration of specialization and entrepreneurship” and “Innovation and entrepreneurship.” The retrieval started on January 1, 2014, up to April 12, 2024, a total of 1,569 articles related to the subject were retrieved. In order to ensure the accuracy and rigor of the data, relevant literatures were screened and preprocessed to ensure the extensiveness and representativeness of the literature, in order to cover the main research in this field, 1,020 related literatures were finally selected (**Table 1**).

Table 1. Data sources

| Title | Content |
|-------------------|----------------------------------|
| Sources of data | CNKI |
| Search format | Subject = “Creative convergence” |
| Time span | 1 January 2014–12 April 2024 |
| Retrieval of data | 1,569 journal articles |
| Valid data | 1,020 journal articles |

2.2. Methodology

CiteSpace is a software for literature analysis and knowledge mapping visualization, which can identify literature data in specific research fields and reveal research trends, knowledge clustering, and co-occurrence relationships. In this paper, CiteSpace was used to analyze the keywords co-occurrence and timeline co-occurrence of the relevant literature on “Specialization and Innovation Integration,” and reveal the information of domestic research hotspots and main researchers, in order to understand its research status and development trend.

3. Overall appearance and visual analysis

3.1. Statistics

From CNKI, 1,569 articles on the theme of “Creative Integration” were retrieved, 1,020 articles were screened and processed according to RefWorks format, and then imported into CiteSpace V6.1.6. The time span was set to January 1, 2014 to April 12, 2024, and the term sources were “Abstract,” “Keyword,” “Supplement,” and the rest were default. Nodes were selected for “Author,” “Institution type,” “Keyword,” and subsequent mapping and measurement data [2].

3.2. Annual output

As shown in **Figure 1**, the number of research papers on “integration of specialization and innovation” from 2017 to 2024 can be divided into two stages [3]. The period from 2017 to 2018 is the embryonic stage, and there are only three papers in 2017 and 10 papers in 2018, indicating that this field has not yet become a research hotspot. From 2019 to 2024, the number of publications increased significantly, which was 8 times that of 2018 in 2019, and continued to rise in 2020. The number of articles published in 2023 reached 308, and 48 from 2024 to April 12. It is expected to surpass 2023. The overall trend is slow at first and then grows rapidly, and the research continues, indicating that the integration of specialization and innovation has become an important field of educational research and has attracted the attention of scholars [4].

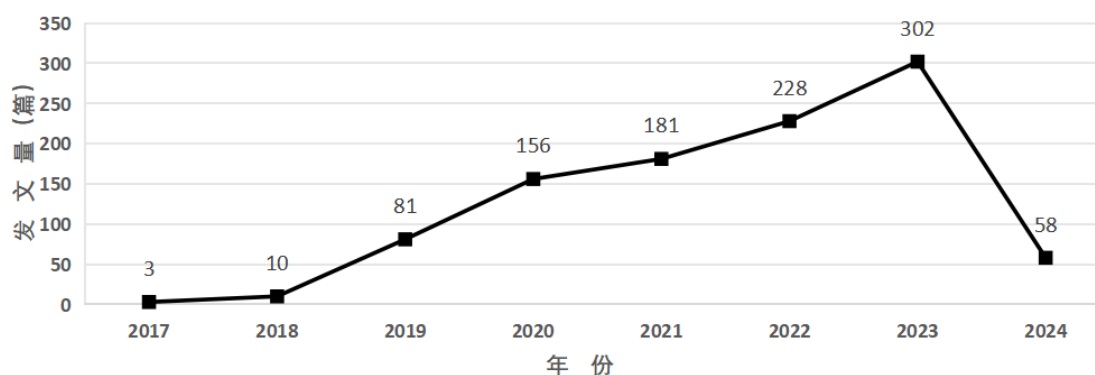


Figure 1. Annual distribution of papers on integration of specialization and innovation

3.3. Key authors and research institutions

The number of publications is an important indicator of slow research capacity. CiteSpace analysis shows that Yu Youwei, Wu Hongmei, Li Mingchu, and other authors posted the coordinates of the article (Figure 2 and Table 2). Among them, Yu Youwei, Zhang Shaoying, and Li Yan formed a close team, Xing Gaowa, Cao Qinglin, Xue Weixing, and so on also formed a cooperation. Some authors have academic cooperation, such as Li Mingchu and Yan Luxing, Zhou Yanbo and Li Wenhan, and so on. However, the overall cooperation is weak, individual publications are only up to 3, the relationship between the authors is scattered, the research is mostly individual-based, and the task is “Working alone,” and the academic team collaboration still needs to be strengthened [5].

Figure 3 and Table 3 shows that among the seven institutions including Tangshan Vocational and Technical College, Guangzhou Railway Vocational and Technical College, College of Food Science of Shanxi Teachers University, etc., the first two institutions publish five articles in a single year, and the remaining four articles each, which has become an important base for the research of “integration of specialization and innovation” in China [6]. However, the research strength is scattered, a lack of influence scientific research team strength, inter-institutional

cooperation is sparse, and weak academic ties [7]. At present, the research in this field needs to expand the breadth of cooperation and promote good inter-institutional development [8].

Table 2. Statistics of articles published by core authors

| Serial number | Author | Number of posts |
|---------------|------------------|-----------------|
| 1 | Zhou Yanbo | 3 |
| 2 | Lee Myung Chul | 3 |
| 3 | Yan Luxin | 3 |
| 4 | Ding Wenfei | 3 |
| 5 | Yu Youwei | 3 |
| 6 | Wu Hongmei | 3 |
| 7 | By Zhou Tingting | 2 |
| 8 | Ho Wah-fan | 2 |

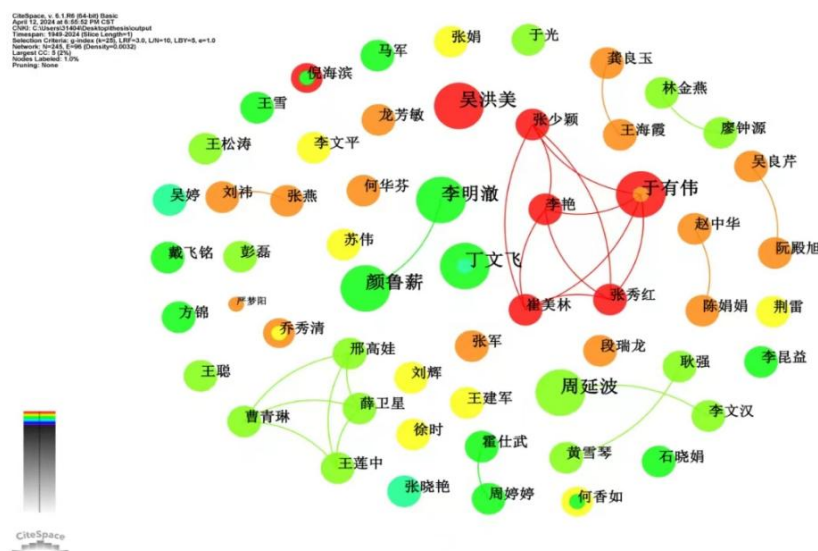


Figure 2. Core author co-occurrence map

Table 3. Statistics of publications of research institutions

| Serial number | Institution | Number of posts |
|---------------|--|-----------------|
| 1 | Tangshan Vocational and Technical College | 5 |
| 2 | Guangzhou railway vocational and technical college | 5 |
| 3 | College of Food Science, Shanxi Teachers University | 4 |
| 4 | Guangdong Vocational College of Science and technology | 4 |
| 5 | Changjiang Vocational College | 4 |
| 6 | Wuhan Vocational College of Software and engineering | 4 |
| 7 | Guangzhou Industrial and commercial university | 4 |
| 8 | Xi'an Siyuan University | 3 |

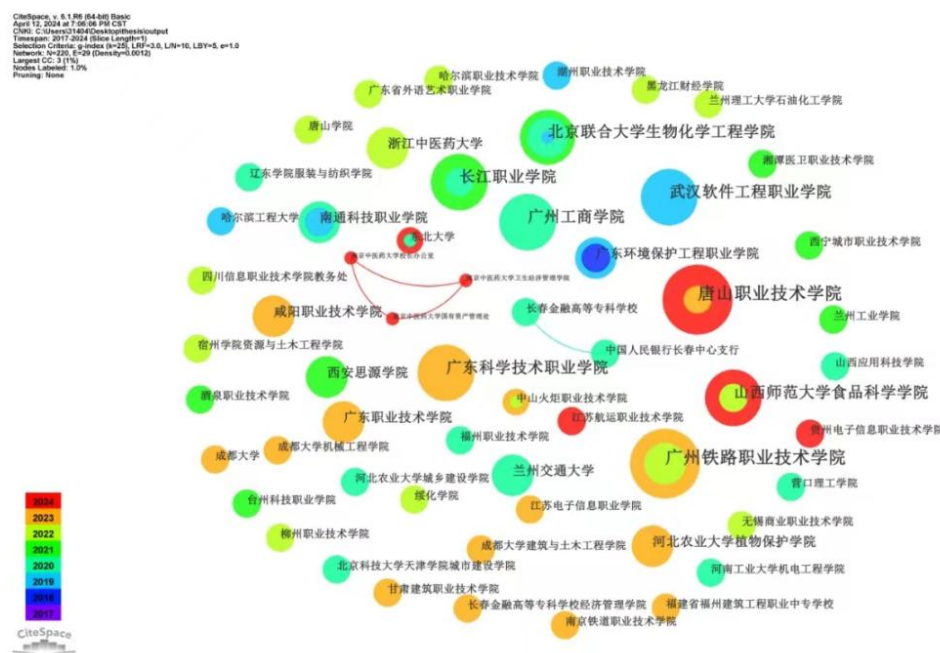


Figure 3. Co-occurrence map of research institutions

4. Hot topics and evolution trends

4.1. Hot topics

The depth of keywords can directly show the hot topics involved in the article field. By using CiteSpace software to analyze the keywords of “integration of specialization and innovation,” the larger the central value, the more critical the node [9]. This results in the co-occurrence of keywords in the past 10 years (Figure 4).

The time slice was set to 1, and 346 keywords were obtained. The co-frequency appeared more than several times, and the map density was 0.881, indicating that the research hotspots were relatively concentrated in the past decade. High-frequency keywords include “Integration of specialty and innovation” (611 times), “Innovation and entrepreneurship” (155 times), “Personnel training” (105 times), “Higher vocational colleges” (97 times), etc., which reflects the current research focus of curriculum design in higher vocational colleges [10].

The analysis of the keyword co-occurrence map (Figure 4) shows that vocational colleges are the core area of the research on the integration of specialty and innovation. In 2015, the State Council proposed that vocational colleges are an important foundation for innovative talents, and promote the “full-time cultivation and integration” education to improve the quality of employment and school running [11]. Keywords with citation bursts are shown in Figure 5.

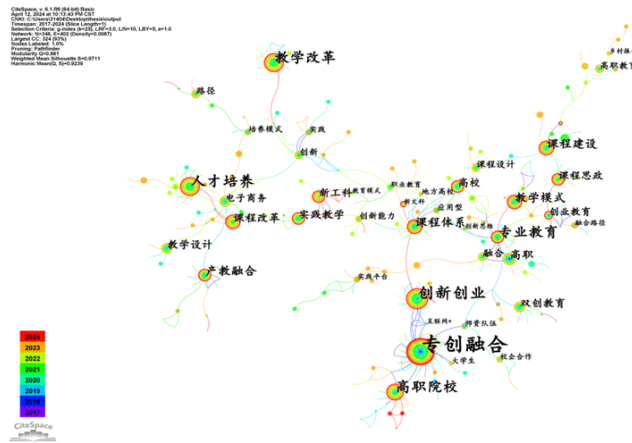


Figure 4. Keyword co-occurrence map

Top 28 Keywords with the Strongest Citation Bursts

| Keywords | Year | Strength | Begin | End | 2017 - 2024 |
|----------|------|----------|-------|------|-------------|
| 全过程 | 2017 | 0.91 | 2017 | 2020 | |
| 师资队伍 | 2018 | 2.3 | 2018 | 2020 | |
| 创业教育 | 2018 | 1.82 | 2018 | 2019 | |
| 创新 | 2018 | 0.95 | 2018 | 2019 | |
| 双创教育 | 2019 | 1.87 | 2019 | 2020 | |
| 专业课程 | 2019 | 1.2 | 2019 | 2020 | |
| 创业导师 | 2019 | 0.95 | 2019 | 2020 | |
| 创新方法 | 2019 | 0.95 | 2019 | 2020 | |
| 电子商务 | 2019 | 0.63 | 2019 | 2020 | |
| 实践 | 2018 | 1.18 | 2020 | 2021 | |
| 职业教育 | 2020 | 1.15 | 2020 | 2021 | |
| 培养模式 | 2019 | 0.85 | 2020 | 2021 | |
| 众筹 | 2020 | 0.72 | 2020 | 2021 | |
| 创业大赛 | 2017 | 0.39 | 2020 | 2021 | |
| 改革 | 2021 | 1.43 | 2021 | 2022 | |
| 教育改革 | 2021 | 1.43 | 2021 | 2022 | |
| 财务管理 | 2021 | 1.14 | 2021 | 2022 | |
| 教育模式 | 2021 | 1.02 | 2021 | 2022 | |
| 职业院校 | 2017 | 0.73 | 2021 | 2022 | |
| 协同育人 | 2021 | 0.57 | 2021 | 2022 | |
| 会展专业 | 2021 | 0.57 | 2021 | 2022 | |
| 双创能力 | 2021 | 0.57 | 2021 | 2022 | |
| 人工智能 | 2022 | 0.89 | 2022 | 2024 | |
| 设计思维 | 2022 | 0.71 | 2022 | 2024 | |
| 体系实践 | 2022 | 0.36 | 2022 | 2024 | |
| 互联网 | 2022 | 0.36 | 2022 | 2024 | |
| 体育 | 2022 | 0.36 | 2022 | 2024 | |
| 共生理论 | 2022 | 0.36 | 2022 | 2024 | |

Figure 5. Highlights of keywords

4.2. Evolution trend

Based on the CiteSpace analysis method, this paper traces the research trends from 2014 to 2024, and is divided into three stages: starting from 2017 to 2018, focusing on the construction of teachers and the ontology research of innovation and entrepreneurship education, and completing the foundation of domain cognition; Expanding (2019–2021) research hotspots to entrepreneurship and innovation education, entrepreneurship tutors and e-commerce innovation, higher vocational colleges promote practical education through entrepreneurship competitions and school-enterprise cooperation; The development (2022–2024) has turned to the integration of emerging engineering/liberal arts, systematic thinking and artificial intelligence, emphasizing the innovation of interdisciplinary practice paths, and the characteristics of specialization and timeliness of research, forming the

evolution trend of deep symbiosis between vocational education and digital technology.

5. Conclusion

Based on 1,020 articles from CNKI, this study used CiteSpace to conduct a visual analysis of the research on the integration of specialization and innovation from 2014 to 2024, reveals the research hotspots and evolution trends, and draws the following conclusions:

First, the number of published papers can be divided into two stages: 2017–2018 is the embryonic stage, the research is few, and has not yet formed a hot spot; 2019–2024 is the development stage, the research is growing rapidly, and the number of published papers is accelerating.

Second, from the perspective of high-yield institutions, seven institutions such as Tangshan Vocational and Technical College and Guangzhou Railway Vocational and Technical College have made the greatest contributions. However, they have not yet formed influential authors or scientific research teams, and there is less inter-institutional cooperation; academic links are weak, and exchanges need to be strengthened to improve the quality of research.

Third, from the perspective of the core author group, the research strength is scattered, most of them are independent research, and there is less cooperation between scholars.

Fourthly, from the analysis of keyword co-occurrence and timeline, the research topics focus on “Integration of specialization and innovation,” “Innovation and entrepreneurship,” “Talent training,” “Curriculum system,” etc. The research stage is divided into start-up (2017–2018), expansion (2019–2021), and development (2022–2024). In recent years, research has gradually focused on the micro level and emphasized practicality, which may be further deepened in the context of the Internet and artificial intelligence in the future.

Disclosure statement

The authors declare no conflict of interest.

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Proof of a New Circle Method of Goldbach's Conjecture

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Abstract: In this paper, a novel circle method is introduced which, compared to previous approaches, eliminates the need to explicitly estimate the prime-variable triangle sum on the residual interval ^[1]. By employing the Fourier series to express the summation formula, we estimate the triangle sum on the residual interval. At the same time, the concept of the intersection set is introduced. Using this concept, we recalculate the estimated values on both the main and residual intervals, thereby forming a new circle method. This new approach focuses on proving that the main value of the solution count is equivalent to its value on the main interval.

Keywords: New circle method; Exception module; Real zero distribution; Asymptotic formula of solution number

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Let N be a sufficiently large even number, N_3, P, M_1, a_1, b_2 be positive integer, m_{01} be natural number. Assume that the following basic relationship holds

$$\begin{aligned} a_1 > 3b_2, b_2 \geq 3, \tau_0 = e^{\frac{6(\log N)^2}{12}}, \tau_1 = \log^{a_1} N, D_0 = 2[\tau_0 \tau_1], \\ P = \sum_{m=0}^{M_0} P_m, N_3 < P_0 \leq 2N_3, (N_3)^{\frac{1}{2^m}} \left((D_0)^{\frac{\sum_{j=0}^{m-1} \frac{3}{2^j} + 1}{2}} \right) < P_m \leq 2(N_3)^{\frac{1}{2^m}} \left((D_0)^{\frac{\sum_{j=0}^{m-1} \frac{3}{2^j} + 1}{2}} \right) \\ N_3 = \left\lfloor \frac{N}{(\tau_0 \tau_1)^2} \right\rfloor, M_0 = \left\lfloor \frac{\log \left(\log \frac{N_3}{(D_0)^6} \right)}{\log 2} \right\rfloor, M_1 = \left\lfloor \frac{\tau_0 \tau_1}{\log^{b_2} N} \right\rfloor, M_1 < m_{01} \leq 2M_1 \\ E(dP) = \frac{1}{dPD_0}, 1 \leq d \leq D_0 \end{aligned}$$

(1)

For each value $y \in \left[-\frac{1}{\tau}, 1 - \frac{1}{\tau} \right)$ could write as

$$y = \frac{a}{q} + z, (a, q) = 1, 1 \leq q \leq \tau, |z| \leq \frac{1}{q\tau}$$

Where

$$\tau = \frac{N}{(\tau_0 \tau_1)^{2.8}}$$

Definite $I_1(\tau_0)$ be the main interval, if $y \in I_1(\tau_0)$, then

$$y = \frac{a}{q} + z, 0 \leq a < q, (a, q) = 1, 1 \leq q < Q_1, |z| \leq \frac{1}{q(\tau_0 \tau_1) \tau}$$

Where

$$Q_1 = e(D_0)^6, \quad q(\tau_0 \tau_1) = \begin{cases} q, & q < \tau_0 \tau_1 \\ \tau_0 \tau_1, & q \geq \tau_0 \tau_1 \end{cases}$$

The remaining interval interval is

$$I_2(\tau_0) = \left[-\frac{1}{\tau}, 1 - \frac{1}{\tau} \right] \setminus I_1(\tau_0)$$

For each value α in the interval, the prime variable function can be expressed as:

$$S(\alpha) = \sum_{p=N_2}^N e^{2i\pi \alpha p}$$

Where

$$N_2 = \frac{N}{\log^{2b_2} N}$$

Prime variable equation $p_1 + p_2 = N$ decompose on the $I_1(\tau_0)$. Formula (3)~(12) proof can be see chapter 11 of reference 4. We have

$$DI(N) = \sum_{q \leq Q_1} \sum_{\substack{a=1 \\ (a,q)=1}}^q \int_{-\frac{1}{q(\tau_0 \tau_1) \tau}}^{\frac{a}{q} + \frac{1}{q(\tau_0 \tau_1) \tau}} S^2(\alpha) e(-N\alpha) d\alpha = \sum_{j=1}^6 D_{1j}(N) \quad (2)$$

where

$$D_{1,1}(N) = \sum_{q \leq Q_1} \frac{\mu^2(q)}{\phi^2(q)} C_q(-N) \int_{-\frac{1}{q(\tau_0 \tau_1) \tau}}^{\frac{1}{q(\tau_0 \tau_1) \tau}} T^2(z) e(-Nz) dz, \quad (3)$$

$$T(z) = \sum_{n=N_2}^N \frac{e^{2\pi i n z}}{\log n}$$

$$D_{1,2}(N) = 2 \sum_{q \leq Q_1} \frac{\mu(q)}{\phi^2(q)} \sum_{\chi_q} \tau\left(\bar{\chi}\right) G_{\chi}(-N) \int_{-\frac{1}{q(\tau_0 \tau_1) \tau}}^{\frac{1}{q(\tau_0 \tau_1) \tau}} T(z) W(z, \chi) e(-Nz) dz, \quad (4)$$

$$W(z, \chi) = \sum_{p=N_2}^N \chi(p) e^{2\pi i p z}$$

$$D_{1,3}(N) = \sum_{q \leq Q_1} \frac{1}{\phi^2(q)} \sum_{\chi_q} \tau\left(\bar{\chi}\right) \tau\left(\bar{\chi}'\right) G_{\chi \chi'}(-N) \int_{-\frac{1}{q(\tau_0 \tau_1) \tau}}^{\frac{1}{q(\tau_0 \tau_1) \tau}} W(z, \chi) W(z, \chi') e(-Nz) dz \quad (5)$$

$$D_{1,4}(N) = \sum_{\substack{q \leq Q_1 \\ q_0 | q}} \frac{C_q(-N)}{\phi^2(q)} \tau^2\left(\chi_q^0 \bar{\chi}\right) \int_{-\frac{1}{q(\tau_0 \tau_1) \tau}}^{\frac{1}{q(\tau_0 \tau_1) \tau}} \left(\tilde{T}(z)\right)^2 e(-Nz) dz, \quad (6)$$

$$\tilde{T}(z) = \sum_{n=N_2}^N n^{\beta_0-1} \frac{e^{2\pi i n z}}{\log n}$$

$$D_{15}(N) = 2 \sum_{\substack{q \leq Q_1 \\ q_0 | q}} \frac{\mu(q)}{\phi^2(q)} \sum_{\chi_q} \tau(\chi_q^0 \tilde{\chi}) G_{\chi_q^0 \tilde{\chi}}(-N) \int_{-\frac{1}{q(\tau_0 \tau_1) \tau}}^{\frac{1}{q(\tau_0 \tau_1) \tau}} T(z) \tilde{T}(z) e(-Nz) dz \quad (7)$$

$$D_{16}(N) = 2 \sum_{\substack{q \leq Q_1 \\ q_0 | q}} \frac{\tau(\chi_q^0 \tilde{\chi})}{\phi^2(q)} \sum_{\chi_q} G_{\chi_q \tilde{\chi}}(-N) \int_{-\frac{1}{q(\tau_0 \tau_1) \tau}}^{\frac{1}{q(\tau_0 \tau_1) \tau}} \tilde{T}(z) W(z, \chi) e(-Nz) dz \quad (8)$$

Estimation of $D_{1j}(N)$, $j = 2, 3, 6$

$$|D_{1j}(N)| \leq 64 \frac{\sqrt{N}}{\log N} \frac{N}{\phi(N)} W + O\left(\frac{N}{(Q_1)^{10}}\right) \quad j = 2, 6 \quad (9)$$

$$|D_{13}(N)| \leq 64 \frac{1}{\log N} \frac{N}{\phi(N)} W^2 + O\left(\frac{N}{(Q_1)^{10}}\right) \quad (10)$$

$$W = \sum_{d \leq Q_1} \sum_{\chi_d} \left(\int_{-\frac{1}{q(\tau_0 \tau_1) \tau}}^{\frac{1}{q(\tau_0 \tau_1) \tau}} \left| \sum_{n=N_2}^N \sum_{|\operatorname{Im} \rho| \leq Q_1^{20}} n^{\rho-1} \frac{e^{2\pi i n z}}{\log n} \right|^2 dz \right)^{\frac{1}{2}} \\ \ll \frac{\sqrt{N}}{e^{\frac{c_{10} \log N}{\log Q_1}}} \quad (11)$$

Formula proof can be see reference 4, chapter 4 theorem 2 and chapter 10 lemma 11 take $T = (Q_1)^{20}$ and c_9 be a constant in the lemma 11 and let $c_{10} = \vartheta c_9$, $0.97 \leq \vartheta \leq 0.99$. In this paper, mathematical symbols inherit this literature..

It can be obtained by formula (6)

$$D_{1,4}(N) = \tilde{\chi}(-1) \frac{q_0 C_{q_0}(-N)}{\phi^2(q_0)} \sum_{\substack{k \leq \frac{Q_1^2}{q_0}}} \tilde{\chi}^2(k) \frac{\mu^2(k) C_k(-N)}{\phi^2(k)} \int_{-\frac{1}{q(\tau_0 \tau_1) \tau}}^{\frac{1}{q(\tau_0 \tau_1) \tau}} \left(\tilde{T}(z) \right)^2 e(-Nz) dz \quad (12)$$

Lemma 1.

Let $\alpha = \frac{a}{q} + \frac{\theta}{q^2}$, $(a, q) = 1$, $q \geq 1$, $|\theta| \leq 1$, then for arbitrarily β , $U > 0$, and integer $N_1 \geq 1$, we have

$$\sum_{n=1}^{N_1} \min\left(U, \frac{1}{\langle \alpha n + \beta \rangle}\right) \leq 6 \left(\frac{N_1}{q} + 1\right) (U + q \log q)$$

Proof see chapter 5 lemma 6 of reference 3.

Lemma.2 Let $\tau \geq 1$, α be a real number, P be a positive integer, $P_1 | P$. Then exist coprime integers a and qP_1 , $1 \leq q \leq \tau$, makes

$$\left| \alpha - \frac{a}{qP_1} \right| \leq \frac{1}{qP\tau}$$

Proof. Without loss of generality, it can be assumed that $0 \leq \alpha < 1$, conside $\{\alpha Pm\}$, $m = 0, 1, \dots, [\tau]$.

You must find two integers $m_1 > m_2$, makes

$$(\{\alpha Pm_1\} - \{\alpha Pm_2\}) \leq \frac{1}{\tau}, \text{ namely } |\alpha q_1 - b_1| \leq \frac{1}{\tau},$$

where $0 < (m_1 - m_2)P = q_1 \leq \tau P$, $b_1 = [\alpha P m_1] - [\alpha P m_2]$. This is the conclusion of exiting lemma.

According to equation (2), it can be assumed that

$$\begin{aligned} J_0(N) &= \int_0^1 S^2(\alpha) e^{-2i\pi\alpha N} d\alpha \quad \text{and} \quad J_0(N, I_1(\tau_0)) = D1(N) = \int_{I_1(\tau_0)} S^2(\alpha) e^{-2i\pi\alpha N} d\alpha \\ J_0(N, m_{01}dP) &= \int_0^1 S^2(\alpha) e^{-2i\pi\alpha(N-m_{01}dP)} d\alpha \end{aligned} \quad (13)$$

Theorem 1(New Circle Method).

Given the parameters same as above (1)~(13). then

$$J_0(N) = J_0(N, I_1(\tau_0)) + O\left(\frac{N}{\sqrt{\tau_0 \tau_1}}\right)$$

In order to prove the theorem 1, we need to proof lemma 3.

Define the following related functions

$$\begin{aligned} Pl(x) &= \sum_{n=1}^{\infty} \frac{\sin(2n\pi x)}{n\pi}, \frac{1}{2} + [x] - x = Pl(x), x \neq 0, \pm 1, \pm 2, \dots, \quad \text{Euler function} \\ F(P, m_{01}, N) &= \sum_{d=1}^{D_0} \sum_{n=0}^{dP-1} \int_{-E(dP)}^{E(dP)} S^2\left(\frac{u}{dP} + z\right) e^{-2i\pi\left(\frac{u}{dP} + z\right)(N-m_{01}dP)} dz \\ F(Pl(Py), m_{01}, N) &= \sum_{d=1}^{D_0} \int_0^1 \{Pl(dPy - dPE(dP)) - Pl(dPy + dPE(dP))\} S^2(y) e^{-2i\pi(N-m_{01}dP)y} dy \end{aligned} \quad (14)$$

and following sets

$$\begin{aligned} I_3(dP) &\equiv \frac{x}{dP} + z, x = 0, \dots, dP-1, -E(dP) \leq z \leq E(dP) \\ U(P) &\equiv \bigcup_{d=1}^{D_0} [-E(dP), 1-E(dP)] \end{aligned}$$

Then by lemma 2,

$$\sum_{d=1}^{D_0} I_3(dP) \supseteq U$$

Quote the following symbols

$$S_1 \oplus = \sum_{m_{01}=M_1+1}^{2M_1} \sum_{N_3 < P_0 \leq 2N_3} \prod_{m=1}^{M_0} \sum_{\substack{(N_3)_{2^m} \left((D_0)_{\sum_{j=0}^{m-1} \frac{3}{2^j} + \frac{1}{2}} \right) < P_m \leq 2(N_3)_{2^m} \left((D_0)_{\sum_{j=0}^{m-1} \frac{3}{2^j} + \frac{1}{2}} \right)}} \frac{1}{N_3 \prod_{m=1}^{M_0} (N_3)_{2^m} \left((D_0)_{\sum_{j=0}^{m-1} \frac{3}{2^j} + \frac{1}{2}} \right)} M_1,$$

Thus

$$S_1 \oplus F(P, m_{01}, N) = S_1 \oplus F11(((d_P P)_y, m_{01}, N) U(P)) + S_1 \oplus F2((P, m_{01}, N))$$

Where

$$F11(((d_P P)_y, m_{01}, N) U(P)) = \int_{U(P)} S^2(y) e^{-2i\pi(N-m_{01}(d_P P)_y)} dy, \quad y = \frac{x}{dP} + z, \quad |z| \leq \frac{1}{dPD_0}, \quad 0 < d \leq D_0$$

$F2((P, m_{01}, N))$

$$\begin{aligned} &= \left(\sum_{d=2}^{\frac{D_0}{2}} \sum_{j=1}^d + \sum_{d=\frac{D_0+1}{2}}^{\frac{D_0}{2}} \sum_{j=2d-D_0}^d \right) \sum_{t=0}^{P-1} \left\{ \int_{E(dP)-DIS(j,d)}^{E(dP)} S^2\left(\frac{a(d,j)}{dP} + \frac{t}{P} + z\right) e^{-2i\pi\left(\frac{a(d,j)}{d} + \frac{t}{P} + z\right)(N-m_{01}dP)} dz + \right. \\ &\quad \left. \int_{-E((D_0-d+j)P)}^{E((D_0-d+j)P)-DIS(j,d)} S^2\left(\frac{b(d,j)}{(D_0-d+j)P} + \frac{t}{P} + z\right) e^{-2i\pi\left(\frac{b(d,j)}{(D_0-d+j)} + \frac{t}{P} + z\right)(N-m_{01}(D_0-d+j)P)} dz \right\} \\ &\quad + \left\{ \int_{-E(dP)}^{-(E(dP)-DIS(j,d))} S^2\left(-\frac{a(d,j)}{dP} + \frac{t}{P} + z\right) e^{-2i\pi\left(-\frac{a(d,j)}{d} + \frac{t}{P} + z\right)(N-m_{01}dP)} dz + \right. \\ &\quad \left. \int_{E((D_0-d+j)P)-DIS(j,d)}^{E((D_0-d+j)P)} S^2\left(-\frac{b(d,j)}{(D_0-d+j)P} + \frac{t}{P} + z\right) e^{-2i\pi\left(-\frac{b(d,j)}{(D_0-d+j)} + \frac{t}{P} + z\right)(N-m_{01}(D_0-d+j)P)} dz \right\} \Bigg\} \\ &\quad , \quad a(d, j) \nmid D_0 - d + j - b(d, j)d = -1, \quad a(d, j) < d, \quad b(d, j) < (D_0 - d + j), \\ &\quad DIS(j, d) = \frac{j}{2d(D_0 - d + j)D_0P} \end{aligned}$$

(15)

Correspondingly ,there are

$$F2((Pl(Py), m_{01}, N))$$

$$= \left(\sum_{d=2}^{\frac{D_0}{2}} \sum_{j=1}^d + \sum_{d=\frac{D_0}{2}+1}^{D_0} \sum_{j=2d-D_0}^d \right) \left\{ \int_0^1 \left\{ Pl \left(Py - \frac{a(d,j)}{d} - PE(dP) \right) - Pl \left(Py - \frac{a(d,j)}{d} - P(E(dP) - DIS(j,d)) \right) \right\} S^2(y) e^{-2i\pi(N-m_{01}dP)y} dy \right. \\ + \int_0^1 \left\{ Pl \left(Py - \frac{b(d,j)}{(D_0-d+j)} + P(E((D_0-d+j)P) - DIS(j,d)) \right) - Pl \left(Py - \frac{b(d,j)}{(D_0-d+j)} + PE((D_0-d+j)P) \right) \right\} S^2(y) e^{-2i\pi(N-m_{01}(D_0-d+j)P)y} dy \left. \right\} \\ + \left(\sum_{d=2}^{\frac{D_0}{2}} \sum_{j=1}^d + \sum_{d=\frac{D_0}{2}+1}^{D_0} \sum_{j=2d-D_0}^d \right) \left\{ \int_0^1 \left\{ Pl \left(Py + \frac{a(d,j)}{d} + P(E(dP) - DIS(j,d)) \right) - Pl \left(Py + \frac{a(d,j)}{d} + PE(dP) \right) \right\} S^2(y) e^{-2i\pi(N-m_{01}dP)y} dy \right. \\ + \int_0^1 \left\{ Pl \left(Py + \frac{b(d,j)}{(D_0-d+j)} - PE((D_0-d+j)P) \right) - Pl \left(Py + \frac{b(d,j)}{(D_0-d+j)} - P(E((D_0-d+j)P) - DIS(j,d)) \right) \right\} S^2(y) e^{-2i\pi(N-m_{01}(D_0-d+j)P)y} dy \left. \right\}$$

(16)

then we have

Lemma 3. Given the parameters in (1), (14),(15),(16) .Let

$$S_1 \oplus C_0(\tau_0) = S_1 \oplus \sum_{d=1}^{D_0} \frac{e^{2\pi i m_{01} d P E(dP)} - e^{-2\pi i m_{01} d P E(dP)}}{2\pi i m_{01}} \\ S_1 \oplus C_1(\tau_0) = 2 \left(\sum_{d=2}^{\frac{D_0}{2}} \sum_{(d, (D_0-d+j))=1}^d + \sum_{d=\frac{D_0}{2}+1}^{D_0} \sum_{j=2d-D_0}^d \right) \left(\frac{j}{d(D_0-d+j)D_0} + O\left(\frac{1}{\log^{b_2} N}\right) \right)$$

Then

$$S_1 \oplus (C_0(\tau_0) - C_1(\tau_0))(J_0(N) - J_0(N, I_1(\tau_0))) \\ = S_1 \oplus F1(((d_P P)_y, m_{01}, N), U(P) \cap I_2(\tau_0)) + O\left(\frac{N}{\sqrt{\tau_0 \tau_1}}\right)$$

Proof. With Euler summation formula we have

$$F((P, m_{01}, N)) = \sum_{d=1}^{D_0} \frac{2}{D_0} J(N, m_{01} d P) - \sum_{d=1}^{D_0} \int_{-E(dP)}^{E(dP)} \int_0^1 \left[S^2\left(\frac{t}{dP} + z\right) e^{-2\pi i \left(\frac{t}{dP} + z\right)(N-m_{01}dP)} \right] Pl(t) dt dz \\ = \sum_{d=1}^{D_0} \frac{2}{D_0} J(N, m_{01} d P) - \sum_{d=1}^{D_0} \int_0^1 \left\{ Pl(dPy - dPE(dP)) - Pl(dPy + dPE(dP)) \right\} S^2(y) e^{-2i\pi(N-m_{01}dP)y} dy \\ = \sum_{d=1}^{D_0} \frac{2}{D_0} J(N, m_{01} d P) - F(Pl(Py), m_{01}, N)$$

(17)

Replace the Euler function with following function

$$Pl(x, m_{01}) = \frac{1}{\pi} \left\{ \sum_{\substack{n=1 \\ n \neq m_{01}}}^{\infty} \frac{\sin(2n\pi x)}{n} + \frac{e^{2\pi i m_{01} x}}{2im_{01}} \right\}$$

in (17),thus could get the coefficient $C_0(\tau_0)$.we have

$$F(Pl(Py), m_{01}, N) = -C_0(\tau_0) J_0(N) + F(Pl(Py, m_{01}), m_{01}, N)$$

(18)

Next we change $\int_0^1 \Rightarrow \int_{\frac{1}{\tau}}^{\frac{1}{\tau}-1}$ in $S_1 \oplus F(Pl(Py, m_{01}), m_{01}, N)$, Write

$$Pl(x, m_{01}) = \bar{Pl}(x, m_{01}) + \sum_{\substack{n=1 \\ n > \tau^3}}^{\infty} ()'$$

integration by parts and by Schwarz inequality, $\sum_{n > \tau^{\frac{2}{3}}}^{\infty}$ in (18) is

$$\ll \tau_0 \tau_1 \frac{1}{N_3 \tau^{\frac{2}{3}}} \frac{N^2}{\log N} \ll \sqrt{N}$$

Thus

$$\begin{aligned} & F(P_1(P_y, m_{01}), m_{01}, N) \\ &= \sum_{d=1}^{D_0} \int_{-\frac{1}{\tau}}^{1-\frac{1}{\tau}} \left\{ \bar{P}_1(dPy - dPE(dP), m_{01}) - \bar{P}_1(dPy + dPE(dP), m_{01}) \right\} S^2(y) e^{-2i\pi(N-m_{01}dP)y} dy + O(\sqrt{N}) \\ &= F\left(\left(\bar{P}_1(P_y, m_{01}), m_{01}, N\right), I_1(\tau_0)\right) + F\left(\left(\bar{P}_1(P_y, m_{01}), m_{01}, N\right), I_2(\tau_0)\right) + O(\sqrt{N}) \end{aligned} \quad (19)$$

On the set $I_2(\tau_0)$, we are listed in the following formula:

$$\frac{1}{M_1 N_3 \prod_{m=1}^{M_0} (N_3)^{\frac{1}{2^m}} \left((D_0)^{\sum_{j=0}^{m-1} \frac{3}{2^j} + \frac{1}{2}} \right)} \sum_{n=1}^{\tau^{\frac{2}{3}}} \sum_{n \neq m_{01}}^{2M_1} \prod_{m=1}^{M_0} \sum_{(N_3)^{\frac{1}{2^m}} \left((D_0)^{\sum_{j=0}^{m-1} \frac{3}{2^j} + \frac{1}{2}} \right) < P_m \leq 2(N_3)^{\frac{1}{2^m}} \left((D_0)^{\sum_{j=0}^{m-1} \frac{3}{2^j} + \frac{1}{2}} \right)} \sum_{N_3 < P_0 \leq 2N_3} \sum_{d=1}^{D_0} e^{-2i\pi(n-m_{01})dP \left(\frac{a}{q} + \frac{\theta}{q^2} \right)} \frac{\sin(2n\pi dPE(dP))}{2i\pi}, \quad P = \sum_{m=0}^{M_0} P_m$$

If $(n-m_{01})d < (D_0)^4$, sum P_0 , then fixd n sum $(n-m_{01})d$, by lemma 1. this gives

$$\begin{aligned} & S_1 \oplus F\left(\left(\bar{P}_1(P_y, m_{01}), m_{01}, N\right), I_2(\tau_0)\right) \\ & \ll \frac{(D_0)^6 \log \tau}{N_3 M_1} \left(\left(\frac{(D_0)^4}{q} + 1 \right) q \log q \right) \int_{I_2(\tau_0)} |S^2(y)| dy \\ & \ll \frac{N}{\tau_0 \tau_1} \end{aligned} \quad (20)$$

If $(n-m_{01})d \geq (D_0)^4$, first sum P_0 , then fixed m_{01} , d , sum $(n-m_{01})d$ by lemma 1(logarithmic divide N into segments $\ll \log \tau$), thus also gives

$$\begin{aligned} & S_1 \oplus F\left(\left(\bar{P}_1(P_y, m_{01}), m_{01}, N\right), I_2(\tau_0)\right) \\ & \ll \frac{D_0}{N_3} \sum_{j=\left[\frac{3 \log D_0}{\log 2}\right]}^{\log \tau} \frac{1}{2^j} \left(\left(\frac{2^{j+1} + 2M_1 |D_0|}{q} + 1 \right) (N_3 + q \log q) \right) \int_{I_2(\tau_0)} |S^2(y)| dy \\ & \ll \frac{N}{\tau_0 \tau_1} \end{aligned} \quad (21)$$

It easy to see

$$\begin{aligned} & S_1 \oplus \sum_{d=1}^{D_0} \int_{I_1(\tau_0)} \left\{ \bar{P}_1(dPy - dPE(dP), m_{01}) - \bar{P}_1(dPy + dPE(dP), m_{01}) \right\} S^2(y) e^{-2i\pi(N-m_{01}dP)y} dy \\ &= S_1 \oplus \sum_{d=1}^{D_0} \int_{I_1(\tau_0)} \left\{ P_1(dPy - dPE(dP)) - P_1(dPy + dPE(dP)) \right\} S^2(y) e^{-2i\pi(N-m_{01}dP)y} dy \\ & \quad + S_1 \oplus C_0(\tau_0) \int_{I_1(\tau_0)} S^2(y) e^{-2i\pi N y} dy + O(\sqrt{N}) \end{aligned} \quad (22)$$

We use same method to calculate the function $F_2((P, m_{01}, N))$, we have

$$\begin{aligned}
 S_1 \oplus F2((P, m_{01}, N)) &= S_1 \oplus C_1(\tau_0)(J_0(N) - J_0(N, I_1(\tau_0))) + \\
 &+ S_1 \oplus \left(\sum_{d=2}^{\frac{D_0}{2}} \sum_{\substack{j=1 \\ (d, (D_0-d+j))=1}}^d + \sum_{d=\frac{D_0}{2}+1}^{D_0} \sum_{j=2d-D_0}^d \right) \left(\frac{j}{d(D_0-d+j)D_0} \right) \{J_0(N, dm_{01}P) + J_0(N, (D_0-d+j)m_{01}P)\} \\
 &- S_1 \oplus F2((P_1(P_y), m_{01}, N), I_1(\tau_0)) + O\left(\frac{N}{\sqrt{\tau_0 \tau_1}}\right)
 \end{aligned} \tag{23}$$

We noticed that the functions on the set are all functions with period of 1, thus

$$\begin{aligned}
 S_1 \oplus F((P_1(P_y), m_{01}, N), I_1(\tau_0)) &= S_1 \oplus F((P, m_{01}, N), I_1^*(\tau_0)) + S_1 \oplus \sum_{d=1}^{\frac{D_0}{2}} \frac{2}{D_0} J_0(N, m_{01}dP, I_1(\tau_0)) \\
 , \quad I_1^*(\tau_0) &= \begin{cases} I_1(\tau_0) & 1 < q < Q_1, y = \frac{a}{q} + z \in I_1(\tau_0) \\ a = 0 \text{ or } 1 & q = 1 \end{cases} \\
 S_1 \oplus F2((P_1(P_y), m_{01}, N), I_1(\tau_0)) &= S_1 \oplus F2((P, m_{01}, N), I_1^*(\tau_0)) \\
 &+ S_1 \oplus \left(\sum_{d=2}^{\frac{D_0}{2}} \sum_{\substack{j=1 \\ (d, (D_0-d+j))=1}}^d + \sum_{d=\frac{D_0}{2}+1}^{D_0} \sum_{j=2d-D_0}^d \right) \left(\frac{j}{d(D_0-d+j)D_0} \right) \{J_0(N, dm_{01}P, I_1(\tau_0)) + J_0(N, (D_0-d+j)m_{01}P, I_1(\tau_0))\}
 \end{aligned}$$

And

$$S_1 \oplus F1((d_P P)_y, m_{01}, N, U(P) \setminus I_2(\tau_0)) + S_1 \oplus F2((P, m_{01}, N), I_1^*(\tau_0)) = S_1 \oplus F((P, m_{01}, N), I_1^*(\tau_0)) \tag{24}$$

It easy to know

$$S_1 \oplus \sum_{d=1}^{\frac{D_0}{2}} \frac{2}{D_0} J_0(N, m_{01}dP, I_2(\tau_0)) < \frac{N}{M_1}, \quad \text{etc.} \tag{25}$$

By (15)~(25) the lemma 3 thus proved.

Theorem 1 proof. Let

$$\begin{aligned}
 y &= \frac{a}{q} + z_1 \in I_2(\tau_0), \\
 S_1 \oplus &= \frac{1}{N_3 M_1 \prod_{m=1}^{M_0} (N_3)^{\frac{1}{2^m}} \left((D_0)^{\sum_{j=0}^{m-1} \frac{3}{2^j} + \frac{1}{2}} \right)} \sum_{m_0=1}^{2M_1} \prod_{m=1}^{M_0} \sum_{(N_3)^{\frac{1}{2^m}} \left((D_0)^{\sum_{j=0}^{m-1} \frac{3}{2^j} + \frac{1}{2}} \right) < P_m \leq 2(N_3)^{\frac{1}{2^m}} \left((D_0)^{\sum_{j=0}^{m-1} \frac{3}{2^j} + \frac{1}{2}} \right)} \sum_{N_3 < P_0 \leq 2N_3} \quad \text{if } \sqrt{N_3} (D_0)^{\frac{1}{2}} < q \leq \tau, \\
 S_1 \oplus &= \frac{1}{N_3 M_1 \prod_{m=1}^{M_0} (N_3)^{\frac{1}{2^m}} \left((D_0)^{\sum_{j=0}^{m-1} \frac{3}{2^j} + \frac{1}{2}} \right)} \sum_{m_0=1}^{2M_1} \sum_{N_3 < P_0 \leq 2N_3} \prod_{a=1}^{M_0} \sum_{(N_3)^{\frac{1}{2^a}} \left((D_0)^{\sum_{j=0}^{a-1} \frac{3}{2^j} + \frac{1}{2}} \right) < P_a \leq 2(N_3)^{\frac{1}{2^a}} \left((D_0)^{\sum_{j=0}^{a-1} \frac{3}{2^j} + \frac{1}{2}} \right)} \sum_{(N_3)^{\frac{1}{2^m}} \left((D_0)^{\sum_{j=0}^{m-1} \frac{3}{2^j} + \frac{1}{2}} \right) < P_m \leq 2(N_3)^{\frac{1}{2^m}} \left((D_0)^{\sum_{j=0}^{m-1} \frac{3}{2^j} + \frac{1}{2}} \right)} \\
 &\text{if } (N_3)^{\frac{1}{2^{m+1}}} \left((D_0)^{\sum_{j=0}^m \frac{3}{2^j}} \right) < q \leq (N_3)^{\frac{1}{2^m}} \left((D_0)^{\sum_{j=0}^{m-1} \frac{3}{2^j}} \right) \\
 \text{If } (N_3)^{\frac{1}{2^{m+1}}} \left((D_0)^{\sum_{j=0}^m \frac{3}{2^j}} \right) &< q \leq (N_3)^{\frac{1}{2^m}} \left((D_0)^{\sum_{j=0}^{m-1} \frac{3}{2^j}} \right), \text{ let } q^{(m)} = q \text{ and}
 \end{aligned}$$

$$P^{(m)} = P^{(m)}(P_0, \dots, P_{m-1}, P_{m+1}, \dots, P_{M_0}) = \sum_{\substack{a=1 \\ a \neq m}}^{M_0} P_a + P_m, \quad (N_3)^{\frac{1}{2^m}} \left((D_0)^{\sum_{j=0}^{m-1} \frac{3}{2^j} + \frac{1}{2}} \right) < P_m \leq 2(N_3)^{\frac{1}{2^m}} \left((D_0)^{\sum_{j=0}^{m-1} \frac{3}{2^j} + \frac{1}{2}} \right)$$

For by lemma 2, let set $I_2(\tau_0)$ contract with the following sets

$$y = \frac{a}{q^{(m)}} + z_1 \in I_2(\tau_0), \quad \frac{a}{q^{(m)}} + z_1 = \frac{x}{d_{P^{(m)}} P^{(m)}} + z, \quad 1 \leq d_{P^{(m)}} \leq D_0, \quad |z| \leq \frac{1}{d_{P^{(m)}} P^{(m)} D_0} \tag{A}$$

Assume the equation $\frac{ad}{r} P^{(m)} - \frac{q^{(m)}}{r} x = 1$, $r = (d, q^{(m)})$ has solution (P_{0d}, x_0) , the condition of interval intersection (A) is given from the following equation

$$adP^{(m)} - xq^{(m)} = lr, r = (d, q^{(m)}) \quad l \leq \frac{2q}{rD_0},$$

Thus gives

$$P_d^{(m)} = lP_{0d} + t \frac{q^{(m)}}{r}, \frac{\left((N_3)^{\frac{1}{2^m}} \left((D_0)^{\sum_{j=0}^{m-1} \frac{3}{2^j} + \frac{1}{2}} \right) + P^{(m)} - P_m - lP_{0d} \right) r}{q} < t \leq \frac{\left(2(N_3)^{\frac{1}{2^m}} \left((D_0)^{\sum_{j=0}^{m-1} \frac{3}{2^j} + \frac{1}{2}} \right) + P^{(m)} - P_m - lP_{0d} \right) r}{q}, \left(P_{0d}, \frac{q^{(m)}}{r} \right) = 1, 1 \leq d \leq D_0, 1 \leq l \leq \frac{2q^{(m)}}{rD_0}$$

,if $dP_d^{(m)} \equiv d_1 P_{d_1}^{(m)} (q^{(m)})$, then $d \left(l_1 P_{0d} + t_1 \frac{q^{(m)}}{r} \right) \equiv d_1 \left(l_2 P_{0d_1} + t_2 \frac{q^{(m)}}{r} \right) (q^{(m)})$, that is $adl_1 P_{0d} \equiv ad_1 l_2 P_{0d_1} (q^{(m)})$, for

$adP_{0d} \equiv r (q^{(m)})$, $ad_1 P_{0d_1} \equiv r_1 (q^{(m)})$, thus gives $rl_1 \equiv r_1 l_2 (q^{(m)})$, if $r = r_1$ $l_1 = l_2$, then

$$P_d^{(m)} P_{0d_1} - P_{d_1}^{(m)} P_{0d} = (t_1 P_{0d} - t_2 P_{0d_1}) \frac{q^{(m)}}{r}$$

For must exist $N_3 < P_{0d}, P_{0d_1} < 3N_3$ satisfy (A), because the number of different prime factor of

P_{0d_1} great than $\sqrt{D_0}$ is less than $\sqrt{\log N}$, for $\left(P_{0d}, \frac{q^{(m)}}{r} \right) = \left(P_{0d_1}, \frac{q^{(m)}}{r} \right) = 1$, thus must exist $0 \leq i \leq \lfloor \sqrt{\log N} \rfloor$, $P'_{0d} = P_{0d} + (t_0 + i) \frac{q^{(m)}}{r}$

makes $(P'_{0d}, P_{0d_1}) = r_3 \leq \sqrt{D_0}$, thus equation $P_d^{(m)} P_{0d_1} - P_{d_1}^{(m)} P'_{0d} = (t_1 P'_{0d} - t_2 P_{0d_1}) \frac{q^{(m)}}{r}$, only have

$$\prec \prec \sqrt{D_0} \left(\frac{r(N_3)^{\frac{1}{2^m}} \left((D_0)^{\sum_{j=0}^{m-1} \frac{3}{2^j} + \frac{1}{2}} \right)^2}{q^{(m)}} \right)$$

values $P_d^{(m)}, P_{d_1}^{(m)}$. If $r \neq r_1$, $rl_1 = r_1 l_2$, then $(l_1, l_2) \geq \frac{\sqrt{q^{(m)}}}{D_0}$, $l_1, l_2 > \sqrt{q^{(m)}}$. Thus by lemma 1 we have

$$S_1 \oplus FI((d_P P)_y, m_{01}, N, U(P) \cap I_2(\tau_0))$$

$$\begin{aligned} & \prec \prec \max_{y, m} \frac{1}{(N_3)^{\frac{1}{2^m}} \left((D_0)^{\sum_{j=0}^{m-1} \frac{3}{2^j} + \frac{1}{2}} \right) M_1} \left(\frac{(N_3)^{\frac{1}{2^m}} \left((D_0)^{\sum_{j=0}^{m-1} \frac{3}{2^j} + \frac{1}{2}} \right)}{q^{(m)}} + 1 \right) \sum_{1 \leq l \leq q^{(m)}} \left| \sum_{m_{01} > M_1} e^{2\pi i m_{01} l y} \right| \int_{I_2(\tau_0)} |S^2(y)| dy + O\left(\frac{N}{D_0} \right) + O\left(\frac{(D_0)^2 N}{\sqrt{Q_1}} \right) + O\left(\frac{M_1 N_3 D_0 N}{Q_1 \tau} \right) \\ & \prec \prec \max_m \frac{1}{(N_3)^{\frac{1}{2^m}} \left((D_0)^{\sum_{j=0}^{m-1} \frac{3}{2^j} + \frac{1}{2}} \right) M_1} \left(\frac{(N_3)^{\frac{1}{2^m}} \left((D_0)^{\sum_{j=0}^{m-1} \frac{3}{2^j} + \frac{1}{2}} \right)}{q^{(m)}} + 1 \right) \sum_{1 \leq l \leq q^{(m)}} \min \left[M_1, \frac{1}{\left\langle \frac{a}{q^{(m)}} + \frac{\theta}{q^{(m)} \tau} \right\rangle l} \right] \int_{I_2(\tau_0)} |S^2(y)| dy + O\left(\frac{N}{D_0} \right) \\ & \prec \prec \frac{N}{M_1} \end{aligned}$$

(26)

Next we calculate the value of the coefficient

$$\begin{aligned} S_1 \oplus (C_0(\tau_0) - C_1(\tau_0)) &= 2 - 2 \left(\sum_{d=2}^{\frac{D_0}{2}} \sum_{(d, (D_0-d+j))=1}^d + \sum_{d=\frac{D_0}{2}+1}^{\frac{D_0}{2}} \sum_{j=2, d-D_0}^d \right) \frac{j}{d(D_0-d+j)D_0} + O\left(\frac{1}{\log^{b_2} N} \right) \\ &\geq 2 - 2 \sum_{d=2}^{\frac{D_0}{2}} \left(\frac{1}{dD_0} (d - (D_0-d)(\log D_0 - \log((D_0-d+1)))) \right) + \sum_{d=\frac{D_0}{2}+1}^{\frac{D_0}{2}} \left(\frac{1}{dD_0} ((D_0-d) - (D_0-d)(\log D_0 - \log d)) \right) + O\left(\frac{1}{\log^{b_2} N} \right) \\ &= 2 - 2 \left\{ \sum_{n=1}^{\infty} \left(\frac{1}{n} - \frac{1}{n+1} \right) \left(\frac{1}{n+1} \right) \left(\frac{1}{2} \right)^{n+1} + \frac{1}{2} \log 2 - \frac{1}{2} (\log 2)^2 \right\} + O\left(\frac{1}{\log^{b_2} N} \right) \\ &= 1.718 + O\left(\frac{1}{\log^{b_2} N} \right) \end{aligned}$$

(27)

By (26), (27) and lemma 3, theorem 1 thus proved.

Note, the theorem 1 also holds for if let $N = N + 3 - p_i$, $2 < p_i \leq N + 3$ be prime number. The theorem of three prime numbers tells us that $\tau < N$.

In order to prove theorem 2, lemma 4 and lemma 5 is proved first.

Lemma 4. Let

$$Q_i = e^{a_0'(\log N)^{\frac{7}{12}}}, \quad a_0' = \frac{6}{5}, \quad 0 \leq i \leq M_0, \quad M_0 = \left\lceil (\log a_0)^{-1} \log \left(\frac{2(\log N)^{\frac{5}{12}}}{(\log \log N)} \right) \right\rceil$$

N be a sufficiently large integer, c_1 be a arbitrary positive number, then

$$\sum_{Q_0 \leq q \leq Q_{M_0}} \left| \frac{\mu^2(q)}{\Phi^2(q)} C_q(-N) \right| \ll \frac{1}{(Q_0)^{\frac{1}{7} - \varepsilon_2}}$$

Where $\varepsilon_1, \varepsilon_2$ is a sufficiently small positive number.

Proof. We have

$$\begin{aligned} \sum_{Q_0 \leq q \leq Q_{i+1}} \left| \frac{\mu^2(q)}{\Phi^2(q)} C_q(-N) \right| &= \sum_{d|N} \Phi(d) \sum_{\substack{Q_0 \leq q \leq Q_{i+1} \\ (q, N) = d}} \frac{\mu^2(q)}{\Phi^2(q)} \\ &\ll (\log \log Q)^2 \sum_{d|N} \frac{\mu^2(d)}{\Phi(d)} \sum_{Q_0 \leq d \leq Q_{i+1}} \frac{1}{d^2} \\ &\ll (Q_i)^{-1} (\log \log Q)^2 \sum_{\substack{d|N \\ d < Q_{i+1}}} \frac{\mu^2(d)d}{\Phi(d)} \end{aligned}$$

Let $\nu_1(N)$ be the numbers of different prime factors of N , $\nu_1([Q_{i+1}]) = \min(\max_{q \leq Q_{i+1}} \nu_1(q), \nu_1(N))$, then

$$\sum_{\substack{d|N \\ d < Q_{i+1}}} \frac{\mu^2(d)d}{\Phi(d)} \ll (\log \log N) (1 + C_1^{\nu_1(N)} + \dots + C_{\nu_1([Q_{i+1}])}^{\nu_1(N)}) \ll (\log N) C_{\nu([Q_{i+1}])}^{\nu(N)},$$

$$\nu_1(N) \leq \nu(N) = \left\lceil \frac{4 \log N}{(\log \log N)} \right\rceil \quad \text{and} \quad \nu_1([Q_{i+1}]) \leq \nu([Q_{i+1}]) = \left\lceil \frac{a_0^{i+1+\varepsilon} c_1 (\log N)^{\frac{13}{24}}}{\log(a_0^{i+1} c_1 (\log N)^{\frac{13}{24}})} \right\rceil$$

Hence

$$\begin{aligned} \sum_{\substack{d|N \\ d < Q_{i+1}}} \frac{\mu^2(d)d}{\Phi(d)} &\ll (\log N) \prod_{j=0}^{\left\lceil \frac{a_0^{i+1+\varepsilon} (\log N)^{\frac{7}{12}}}{\log(a_0^{i+1} (\log N)^{\frac{7}{12}})} \right\rceil - 1} \left(\frac{4 \log N}{(\log \log N)} \right) \prod_{j=0}^{\left\lceil \frac{a_0^{i+1+\varepsilon} (\log N)^{\frac{7}{12}}}{\log(a_0^{i+1} (\log N)^{\frac{7}{12}})} \right\rceil - 1} \left(\frac{a_0^{i+1+\varepsilon} (\log N)^{\frac{7}{12}}}{\log(a_0^{i+1} (\log N)^{\frac{7}{12}})} \right) \left(1 - \frac{j}{\frac{a_0^{i+1+\varepsilon} (\log N)^{\frac{7}{12}}}{\log(a_0^{i+1} (\log N)^{\frac{7}{12}})}} \right) \\ &\ll \log N e^{\frac{a_0^{i+1+\varepsilon} (\log N)^{\frac{7}{12}}}{\log(a_0^{i+1} (\log N)^{\frac{7}{12}})} \left(\frac{5}{12} (\log \log N) + \log \frac{4}{a_0^{i+1}} \right) - \frac{a_0^{2+2i} (\log N)^{\frac{1}{6}}}{8 \log^2(a_0^{i+1} (\log N)^{\frac{7}{12}})} \log \log N} e^{-\frac{a_0^{i+1+\varepsilon} (\log N)^{\frac{7}{12}}}{\log(a_0^{i+1} (\log N)^{\frac{7}{12}})}} \ll e^{\frac{5}{7} a_0^{i+1+\varepsilon} (\log N)^{\frac{7}{12}}} = (Q_i)^{\frac{6}{7} + \varepsilon_1} \end{aligned}$$

Thus

$$\sum_{Q_0 \leq q \leq Q_{M_0}} \left| \frac{\mu^2(q)}{\Phi^2(q)} C_q(-N) \right| \ll \sum_{0 \leq i \leq M_0} \frac{1}{(Q_i)^{\frac{1}{7} - \varepsilon_1}} \ll \frac{1}{(Q_0)^{\frac{1}{7} - \varepsilon_2}}$$

This proves the lemma 4.

Lemma 5. Given the parameters in lemma 3, Let

$$\begin{aligned} S_2 \oplus FG((P_I(p_Y), m_{01}, N), I_1(\tau_0)) &= S_2 \oplus \tau_0 \tau_1 \int_{I_1(\tau_0)} \{P_I(P_Y + PE_1(2P)) - P_I(P_Y + PE_1(P))\} S^2(y) e^{-2i\pi(N - m_{01}P)} dz \\ &= S_2 \oplus FG((P, m_{01}, N), I_1(\tau_0)) + \frac{1}{4} S_2 \oplus J_0(N, m_{01}P, I_1(\tau_0)) \quad , \quad E_1(P) = \frac{1}{2\tau_0 \tau_1 P} \end{aligned}$$

Then

$$S_2 \oplus FG((Pl(py), m_{01}, N), I_9(P, \tau_0)) = S_2 \oplus \frac{1}{4} J_0(N, m_{01}P, I_1(\tau_0)) + S_2 \oplus \tau_0 \tau_1 \int_{I_3(\tau_0)} s^2(y) e^{-2i\pi(N-m_{01}P)y} dy + \Omega D_{1,4}(N, \tau_0) + O\left(\frac{N}{e^{\frac{c_{10} \log N}{\log Q_1}}}\right) + O\left(\frac{N}{(\tau_0 \tau_1)^8}\right)$$

Where

$$S_2 \oplus = \sum_{m_{01}=M_1+1}^{2M_1} \sum_{P=N_1+1}^{2N_1} \frac{1}{M_1 N_3} \left| \sum_{\substack{\tau_0 \tau_1 < k \leq \frac{Q_1}{\tau_0} \\ q_0}} \chi^2(k) \frac{\mu^2(k) \mathcal{C}_k(-N)}{\phi^2(k)} \frac{1}{q(\tau_0 \tau_1)^{\tau}} \int_1^{\frac{1}{q(\tau_0 \tau_1)^{\tau}}} \left(\tilde{T}(z) \right)^2 e(-Nz) dz \right|$$

$$\tilde{I}_3(\tau_0) \equiv \frac{a}{q} + z \in I_1(\tau_0), \quad -E_1(P) \leq z \leq -E_1(2P)$$

Proof. Let $I_3(p) \equiv \frac{x}{P} + z, x=0, \dots, P-1, -E_1(P) \leq z \leq -E_1(2P)$, we analyse the value on the $I_3(p) \cap I_1(\tau_0)$,

If $\frac{a}{q} \neq \frac{x}{P}$ let $I_4(\tau_0) = I_3(\tau_0) \cap I_5$ in which $I_5 \in I_1(\tau_0) : q < \tau_0 \tau_1, |z| \leq \frac{1}{2qP}$. For $\left| \frac{a}{q} - \frac{x}{P} \right| = \frac{|P-qx|}{qP} \geq \frac{1}{2qP} + E_1(P)$, hence $I_4(\tau_0) = \emptyset$ (null set), let $I_6 = I_1(\tau_0) \setminus I_5$ and $I_{6,A}(\tau_0) \in I_6$ in which $q < \tau_0 \tau_1, \frac{1}{2qP} < |z| \leq \frac{1}{q(\tau_0 \tau_1)^{\tau}}$, For here

$$y \in I_{6,A}(\tau_0) \cap I_3(\tau_0), \quad y = \frac{h_1}{P_1} + z, \text{ where}$$

$$P_1 \geq \frac{1}{q} \left(\frac{1}{q(\tau_0 \tau_1)^{\tau}} + \frac{1}{2\tau_0 \tau_1 P} \right)^{-1} > \frac{\tau}{Q_1},$$

Sum m_{01} by Abel transform then sum P by Lemma 1,(3)~(12) gives

$$S_1 \oplus FG((Pl(py), m_{01}, N), I_{6,A}(\tau_0))$$

$$< \frac{\tau_0 \tau_1}{M_1 N_3} \sum_P \min \left(M_1, \frac{1}{\left\langle \frac{h_1}{P_1} * P \right\rangle} \right) \int_{I_{6,A}(\tau_0)} |S^2(y)| dy$$

$$< (\log N)^{b_2+2} \int_{I_{6,A}(\tau_0)} |S^2(y)| dy$$

$$< \log^{b_2+2} N \left(\frac{\tau_0 \tau_1 N_3}{\log N} + \frac{N}{e^{\frac{c_{10} \log N}{\log(\tau_0 \tau_1)}}} \right)$$

$$< \frac{N}{\tau_0} + \frac{N}{e^{\frac{c_{10} \log N}{\log(\tau_0 \tau_1)}}}$$
(28)

2). IF $\frac{a}{q} = \frac{x}{P}$, use $\tilde{I}_3(\tau_0)$ to represent this set.

3). $q \nmid P$, define set $I_8(\tau_0) \in I_1(\tau_0), \tau_0 \tau_1 \leq q < Q_1, I_9(P, \tau_0) = I_3(\tau_0) \cap I_8(\tau_0)$. we analysis the value

on it. Let $r = (q, P_0P)$, then $\frac{a}{q} - \frac{x}{P} = \frac{aP-xq}{qP} = \frac{n_{01}r}{qP}$, this gives the number of intersection interval, namely for

fixed q and P , the numbers of the pairs (a, x) of equation

$$aP - xq = n_{01}r, \quad (n_{01}, q) = 1, \quad n_{01} \leq \frac{I(q, P)}{r},$$

and the condition of interval intersection is given

$$I(q, P) < 2 \left(\frac{qP}{q(\tau_0 \tau_1)^{\tau}} + \frac{q}{2\tau_0 \tau_1} \right) \quad (29)$$

For $\left(\frac{q}{r}, \frac{P}{r} \right) = 1$, the equation $\frac{P}{r}y - \frac{q}{r}x = 1$ has solution (y_0, x_0) . Hence the equation $Pa - qx = r$, (a, x) just

has solution $\left(y_0 + t \frac{q}{r}, x_0 + t \frac{P}{r} \right), t=0, 1, \dots, r-1$, but here

$\left(\frac{q}{r}, r\right)=1$, there exists $t_i, 0 < i \leq \varphi(r)$ makes $\left(y_0 + t_i \frac{q}{r}, r\right)=1$, thus the complete intersecting set could defined as following

$$\frac{a_i^{(1)}}{q} \pm \frac{r}{qP(k,l)} \pm z, \dots, \frac{a_i^{(\varphi(r))}}{q} \pm \frac{r}{qP(k,l)} + z, \dots, \frac{n_{01}a_i^{(i)}}{q} \pm \frac{n_{01}r}{qP(k,l)} + z, \dots, \frac{n_{01}a_i^{(\varphi(r))}}{q} \pm \frac{n_{01}r}{qP(k,l)} + z, \dots, \frac{R(k,l)a_i^{(1)}}{q} \pm \frac{R(k,l)r}{qP(k,l)} + z, \dots, \frac{R(k,l)a_i^{(\varphi(r))}}{q} \pm \frac{R(k,l)r}{qP(k,l)} + z$$

Where

$$1 \leq n_{01} \leq R(k,l) \leq \frac{l(q, P(k,l))}{r}, (n_{01}, q) = 1, P(k,l) = kq + rl, l < \frac{q}{r}, \left(l, \frac{q}{r}\right) = 1, -E(P) \leq z \leq -E(2P),$$

$P(k,l)a_i^t - qx = r \Rightarrow a_i^{(i)}l \equiv 1 \pmod{q}$, $\{n_{01}a_i^{(i)}\}, t \leq \varphi(r), l \leq \varphi\left(\frac{q}{r}\right)$ just go through the reduced residual of module q .

(30)

The series expansion will be the following form, note $a_i(i) * (rl) \equiv r \pmod{q}$,

$$e^{2\pi i m_{01}(kq+rl)\left(\frac{n_{01}a_i^{(i)}}{q} + z\right)} = e^{2\pi i(m_{01}rl)\left(\frac{n_{01}a_i^{(i)}}{q}\right)} e^{2\pi i m_{01}kqz} (1 + 2\pi i m_{01}rlz + \dots) = e^{2\pi i\left(\frac{m_{01}n_{01}r}{q}\right)} e^{2\pi i m_{01}kqz} + O\left(\frac{M_1 Q_1}{\tau_0 \tau_1 \tau}\right)$$

(31)

Finally by (29)~(31), we have the value on $I_9(P, \tau_0)$

$$S_2 \oplus FG((P, m_{01}, N), I_9(P, \tau_0)) \leq \frac{\tau_0 \tau_1}{N_3 M_1} \sum_{\tau_0 \tau_1 \leq q < Q_1} \sum_{r|q} \sum_{k=0}^{\left[\frac{N_3}{q}\right]-1} \sum_{\substack{1 \leq n \leq l(q, P(k,l)) \\ M_1 < m_{01} \leq 2M_1}} e^{2\pi i\left(\frac{m_{01}n_{01}r}{q} + 2\pi i m_{01}(N_3 + kq)z\right)} \int_{\frac{1}{q(\tau_0 \tau_1) \tau}}^{\frac{1}{q(\tau_0 \tau_1) \tau}} \sum_{t \leq \varphi(r)} \sum_{l \leq \varphi\left(\frac{q}{r}\right)} S^2\left(\frac{n_{01}a_i^{(i)}}{q} + z\right) e^{-2\pi i\left(\frac{n_{01}a_i^{(i)}}{q} + z\right)N} dz + \frac{M_1 Q_1}{N_3 \tau} \sum_{\tau_0 \tau_1 \leq q < Q_1} \sum_{k=0}^{\left[\frac{N_3}{q}\right]-1} \sum_{1 \leq n \leq l(q, P(k,l))} d(n) \sum_{\substack{a=1 \\ (a,q)=1}}^q \int_{\frac{1}{q(\tau_0 \tau_1) \tau}}^{\frac{1}{q(\tau_0 \tau_1) \tau}} S^2\left(\frac{a}{q} + z\right) dz$$

(3)~(12) and lemma 4 gives the value

$$S_2 \oplus FG((P, m_{01}, N), I_9(P, \tau_0)) = S_2 \oplus \tau_0 \tau_1 \int_{\tilde{I}_3(\tau_0)} s^2(y) e^{-2i\pi(N-m_{01}P)y} dy + \Omega D_{1,4}(N, \tau_0) + O\left(\frac{N}{(\tau_0 \tau_1)^{\frac{1}{7}-\varepsilon_2}}\right) + O\left(\frac{N \log^2 N}{e^{\frac{c_{10} \log N}{\log Q_1}}}\right)$$

(32)

By (28), (32), the proof of lemma 5 is thus completed.

Let q_0 be a exception module (chapter 10 lemma 7 of reference 4)

Theorem 2. (Real Zero Distribution of Exception Module)

Let A_1 be a sufficiently large positive number, $\log^{A_1} N < q_0 \leq Q_1$, $\tilde{\chi}$ be a real primary feature module

q_0, β_0 be a real zero of $L(s, \chi)$, $\chi \pmod{q} \chi \Leftrightarrow \tilde{\chi} \quad q_0 | q$. when N is fully large then

$$\beta_0 \leq \max\left(1 - \frac{\log q_0}{25 \log N}, 1 - \frac{c_{10}}{21 \log Q_1}\right)$$

Where c_{10} be a constant in (11).

proof. Corresponding to lemma 3 and lemma 5, Redefine the following parameters

$$\tau_1 = \min\left((q_0)^{\frac{1}{12}}, e^{\frac{c_{10} \log N}{10 \log Q_1}}\right), \tau_0 = q_0(\tau_1)^8, N_3 = \left[\frac{N}{(Q_1)^3}\right] S_1^* \oplus = \sum_{\substack{M_{01} = m_{01} + \dots + m_{0r} \\ M_1 + 1 < m_{01} \leq 2M_1}} \sum_{N_3 < P \leq 2N_3} \frac{1}{N_3(M_1)^t}, t = \left[\frac{\log N}{\log \log N}\right]$$

Define an N^* related q_0 instead of N , as we know $q_0 = 2^a p_1 \dots p_s$, $a = 0, 2, 3$, we define

$$N^* = 2^{n_{03}} p_1 \dots p_s, \quad n_{03} = \left\lceil \frac{1}{\log 2} \log \left(\frac{N}{p_1 \dots p_s} \right) \right\rceil + 1$$

hence $N^* = 2^{\theta} N$, $0 < \theta \leq 1$ and $q_0 \mid N^*$

Let E_{q_0} be a set, if $y \in E_{q_0}$, then

$$y = \frac{a}{q} + z, 0 \leq a < q, (a, q) = 1, q_0 \leq q < Q_1, q_0 \mid q, |z| \leq \frac{1}{q(\tau_0 \tau_1) \tau}, \tau = 10N_3$$

Consider following equation

$$\begin{aligned} S_1^* \oplus \sum_{n=1}^2 F^* \left(\left((P_1(P_y), M_{0r}), N^* \right), E_{q_0} \right) \\ = S_1^* \oplus \sum_{n=1}^2 F^* \left(\left((P_1(P_y), M_{0r}), N^* \right), E_{q_0} \right) + S_1 \oplus C_0^*(\tau_0) \sum_{\substack{q_0 < q \leq Q_1 \\ q_0 \mid q}} \sum_{\substack{a=1 \\ (a, q)=1}}^q \int_{\frac{1}{q(\tau_0 \tau_1) \tau}}^{\frac{1}{q(\tau_0 \tau_1) \tau}} S^2 \left(\frac{a}{q} + z \right) e^{-2i\pi \left(\frac{a}{q} + z \right) N^*} dz \end{aligned}$$

Where

$$\begin{aligned} S_1^* \oplus F^* \left(\left((P_1(P_y), M_{0r}), N^* \right), E_{q_0} \right) &= S_1^* \oplus \tau_0 \tau_1 \int_{E_{q_0}} \{ P_1(P_y + PE_1(2P)) - P_1(P_y + PE_1(P)) \} S^2(y) e^{-2i\pi (N^* - M_{0r}) P} dy \\ S_1^* \oplus C_0^*(\tau_0) &= S_1^* \oplus \tau_0 \tau_1 \frac{e^{-2i\pi M_{0r} PE_1(2P)} - e^{-2i\pi M_{0r} PE_1(P)}}{2\pi i M_{0r}} \end{aligned}$$

(33)

First let

$$\begin{aligned} P_1(x, M_{0r}) &= P_3(x, M_{0r}) + \sum_{\substack{n=2 \\ n > \tau_1^2}}^{\infty} () \\ S_1 \oplus F^* \left(\left((P_1(P_y, M_{0r}), M_{0r}), N^* \right), E_{q_0} \right) \\ &= \frac{\tau_0 \tau_1}{N_3(M_1)} \sum_{\substack{M_1 < m_{0r} \leq M_1+1 \\ M_{0r} = \sum_{i=1}^s m_{0r_i}}} \left\{ \sum_{n=1}^2 \sum_{\substack{P=N_3+1 \\ P \neq M_{0r}}}^{2N_1} e^{-2i\pi (n - M_{0r}) P \left(\frac{a}{q} + \frac{\theta}{q^2} \right)} \frac{\sin(n\pi PE_1(2P)) e^{-3i\pi PE_1(2P)}}{2n\pi} + \sum_{n=1}^2 \sum_{P=N_3+1}^{2N_1} e^{-2i\pi (n + M_{0r}) P \left(\frac{a}{q} + \frac{\theta}{q^2} \right)} \frac{\sin(n\pi PE_1(2P)) e^{3i\pi PE_1(2P)}}{2n\pi} \right\} + O(\sqrt{N}) \end{aligned}$$

We calculate first one, sum P , this gives unprotected assume $q \mid (n - M_{0r})$, $n = M_{0r} + kq$, if $n \leq \frac{q}{\tau_1}$ then

$q < M_1 \log N$, by lemma 1,

$$\begin{aligned} S_1^* \oplus F^* \left(\left((P_1(P_y, M_{0r}), M_{0r}), N^* \right), E_{q_0} \right) \\ &\ll \frac{q}{N_3 M_1 \tau_1} \left(\frac{M_1}{q} + 1 \right) \left(N_3 + q \log q' \right) \frac{N}{\log N} \\ &\ll \frac{N}{(q_0)^{1/2}} + \frac{N}{e^{\frac{c_{10} \log N}{10 \log Q_1}}} \end{aligned}$$

(34)

If $n > \frac{q}{\tau_1}$, $n = M_{0r} + kq$, then if $q \mid P$, thus

$$\begin{aligned} S_1^* \oplus F^* \left(\left((P_1(P_y, M_{0r}), M_{0r}), N^* \right), E_{q_0} \right) \\ &\ll \frac{\tau_0 \tau_1}{q} \sum_{\substack{n=kq+M_{0r} > \frac{q}{\tau_1}}} \frac{1}{|kq + M_{0r}|} \frac{N}{\log N} \\ &\ll \frac{(\tau_1)^{1/2} N}{q} \ll \frac{N}{(q_0)^{1/2}} \end{aligned}$$

(35)

if $q \nmid P$, $q \leq \frac{M_1}{\log N}$, sum M_{0r} , then sum P by lemma 1, we have

$$S_1^* \oplus F^* \left(\left((P_1(P_y, M_{0r}), M_{0r}), N^* \right), E_{q_0} \right)$$

$$\begin{aligned} & \ll \frac{\tau_0 \tau_1 \log \tau}{N_3 (M_1)^{\gamma}} \left(\frac{N_3}{q} + 1 \right) \left(\frac{5}{4} q \right)^t \frac{N}{\log N} \\ & \ll \sqrt{N} \end{aligned} \quad (36)$$

Otherwise $q > \frac{M_1}{\log N}$, $n = M_{0t} + kq \geq \frac{q}{\tau_1}$, (3)~(12) gives

$$\begin{aligned} & S_1^* \oplus F^* \left(\left((P(y, M_{0t}))_b, M_{0t}, N^* \right)_b E_{q_0} \right) \\ & \ll S_1^* \oplus \tau_0 \tau_1 \sum_{\substack{k \\ \left[\frac{q}{\tau_1} \right] \leq n(k) \leq \tau^{-1}}} \frac{1}{|kq + M_{0t}|} \sum_{\substack{M_{0t} < q \leq Q_1 \\ \log N}} \frac{1}{q_0 k q} \int_{\frac{1}{q(\tau_0 \tau_1)^{\gamma}}}^{\frac{1}{q(\tau_0 \tau_1)^{\gamma}}} \sum_{a=1}^q S^2 \left(\frac{a}{q} + z \right) e^{-2i\pi \left(\frac{a}{q} + z \right) (N^* - M_{0t} Pz)} dz \\ & \ll \tau_0 (\tau_1)^3 \frac{\log N}{M_1} \left\{ \sum_{\substack{M_{0t} < q \leq Q_1 \\ \log N}} \left| \frac{\mu^2(q) C_q(-N^*)}{\phi^2(q)} \int_{\frac{1}{q(\tau_0 \tau_1)^{\gamma}}}^{\frac{1}{q(\tau_0 \tau_1)^{\gamma}}} \left(\tilde{T}(z) \right)^2 e(-N^* z) dz \right| \right. \\ & \quad \left. + \sum_{\substack{M_{0t} < k \leq Q_1 \\ q_0 \log N}} \left| \tilde{\chi}^2(k) \frac{\mu^2(k) C_k(-N^*)}{\phi^2(k)} \int_{\frac{1}{q(\tau_0 \tau_1)^{\gamma}}}^{\frac{1}{q(\tau_0 \tau_1)^{\gamma}}} \left(\tilde{T}(z) \right)^2 e(-N^* z) dz \right| \right\} + O \left(\frac{N \log^2 N}{e^{\frac{7c_{10} \log N}{10 \log Q_1}}} \right) \end{aligned}$$

If $\tau_1 = (q_0)^{\frac{1}{12}}$, for $2^{\nu_1(N^*)} \leq 2^{\nu_1(q_0)+1} \ll (q_0)^{e_1}$, then

$$\begin{aligned} & S_1^* \oplus F^* \left(\left((P(y, M_{0t}))_b, M_{0t}, N^* \right)_b E_{q_0} \right) \\ & \ll \frac{N}{\sqrt{q_0}} + \frac{N}{e^{\frac{7c_{10} \log N}{10 \log Q_1}}} \end{aligned} \quad (37)$$

If $\tau_1 = e^{\frac{c_{10} \log N}{10 \log Q_1}}$, we use the same proof method as lemma 4, could obtained

$$\begin{aligned} & S_1^* \oplus F^* \left(\left((P(y, M_{0t}))_b, M_{0t}, N^* \right)_b E_{q_0} \right) \\ & \ll (\log^{b_1+2} N)^{\frac{2c_{10} \log N}{10 \log Q_1}} \sum_{\substack{M_{0t} < k \leq Q_1 \\ e^{\frac{c_{10} \log N}{10 \log Q_1}} < k \leq Q_1}} \left| \tilde{\chi}^2(k) \frac{\mu^2(k) C_k(-N^*)}{\phi^2(k)} \int_{\frac{1}{q(\tau_0 \tau_1)^{\gamma}}}^{\frac{1}{q(\tau_0 \tau_1)^{\gamma}}} \left(\tilde{T}(z) \right)^2 e(-N^* z) dz \right| + \frac{N}{e^{\frac{c_6 \log N}{10 \log Q_1}}} \\ & \ll \frac{N}{e^{\frac{c_{10} \log N}{5 \log Q_1}}} + \frac{N}{e^{\frac{7c_{10} \log N}{10 \log Q_1}}} \end{aligned} \quad (38)$$

On the other hand, by lemma 5, first we have

$$\begin{aligned} & S_1^* \oplus J_0(N, M_{0t}, P', E_{q_0}) = \frac{1}{N_3 (M_1)^{\gamma}} \sum_{N_3 < P \leq 2N_3} \sum_{\substack{M_{0t} < \sum_{i=1}^{\tau_1} m_{0i} \\ M_1 < m_{0t} \leq M_1}} \sum_{\substack{q_0 < q \leq Q_1 \\ q_0 k q}} \sum_{a=1}^q \int_{\frac{1}{q(\tau_0 \tau_1)^{\gamma}}}^{\frac{1}{q(\tau_0 \tau_1)^{\gamma}}} S^2 \left(\frac{a}{q} + z \right) e^{-2i\pi \left(\frac{a}{q} + z \right) (N^* - M_{0t} Pz)} dz \\ & \ll \frac{N}{q_0} \end{aligned} \quad (39)$$

Secondly,

$$\begin{aligned} & S_1^* \oplus F^* \left(\left(P, M_{0t}, N^* \right), \tilde{I}_3(\tau_0) \cap E_{q_0} \right) \\ & = \tau_0 \tau_1 \frac{1}{N_3 (M_1)^{\gamma}} \sum_{N_3 < P \leq 2N_3} \sum_{\substack{M_{0t} < \sum_{i=1}^{\tau_1} m_{0i} \\ M_1 < m_{0t} \leq M_1}} \sum_{\substack{M_{0t} < \sum_{i=1}^{\tau_1} m_{0i} \\ M_1 < m_{0t} \leq M_1}} \sum_{\substack{q_0 < q \leq Q_1 \\ q_0 | q - q | P}} \frac{1}{q} \sum_{\substack{a=1 \\ -E_1(2P)}}^q \int_{\frac{1}{q(\tau_0 \tau_1)^{\gamma}}}^{\frac{1}{q(\tau_0 \tau_1)^{\gamma}}} S^2 \left(\frac{a}{q} + z \right) e^{-2i\pi \left(\frac{a}{q} + z \right) (N^* - M_{0t} Pz)} dz \\ & \ll (\tau_1)^9 \left(\tau_0 \tau_1 N_3 + \frac{N}{e^{\frac{c_{10} \log N}{\log Q_1}}} \right) \\ & \ll \left(\frac{N}{Q_1} + \frac{N}{e^{\frac{c_{10} \log N}{10 \log Q_1}}} \right) \end{aligned} \quad (40)$$

Because according to the conditions of the hypothesis set,

$$\frac{a}{q} + z \cap I_3(P) = \Phi, \quad q < \tau_0 \tau_1.$$

Thus by lemma 5,(39),(40),same as (37),(38),we have

$$\begin{aligned} S_1^* \oplus F^* \left((Pl(P_Y), M_{01}, N^*), E_{q_0} \right) \\ \ll \log N \left| \sum_{\substack{\tau_0 \tau_1 \leq k \leq \frac{Q_1}{q_0} \\ q_0 | k}} \tilde{\chi}^2(k) \frac{\mu^2(k) C_k(-N^*)}{\phi^2(k)} \int_{\frac{1}{q(\tau_0 \tau_1) \tau}}^{\frac{1}{q(\tau_0 \tau_1) \tau}} \left(\tilde{T}(z) \right)^2 e(-N^* z) dz \right| + O\left(\frac{N}{q_0} \right) + O\left(\frac{N \log^2 N}{e^{\frac{c_{10} \log N}{10 \log Q_1}}} \right) \\ \ll O\left(\frac{N}{(q_0)^{\frac{2}{3}}} \right) + O\left(\frac{N \log^2 N}{e^{\frac{2c_{10} \log N}{5 \log Q_1}}} \right) \end{aligned}$$

(41)

Finally by (33)~(41), (3)~(12) could obtain

$$\begin{aligned} \sum_{\substack{q_0 \leq q \leq Q_0 \\ q_0 | q}} \frac{\mu^2(q)}{\phi^2(q)} C_q(-N^*) \int_{\frac{1}{q(\tau_0 \tau_1) \tau}}^{\frac{1}{q(\tau_0 \tau_1) \tau}} \left(\sum_{N_2 \leq n \leq N^*} \frac{e^{2\pi i n z}}{\log n} \right)^2 e^{-2\pi i n z} dz \\ + \tilde{\chi}(-1) \frac{q_0}{\phi(q_0)} \sum_{\substack{0 < k \leq \frac{Q_0}{q_0} \\ q_0 | k}} \tilde{\chi}^2(k) \frac{\mu^2(k)}{\phi^2(k)} C_k(-N^*) \int_{\frac{1}{q(\tau_0 \tau_1) \tau}}^{\frac{1}{q(\tau_0 \tau_1) \tau}} \left(\sum_{N_2 \leq n \leq N^*} \frac{n^{\beta_0 - 1} e^{2\pi i n z}}{\log n} \right)^2 e^{-2\pi i n z} dz \\ = O\left(\frac{N^*}{(q_0)^{\frac{1}{12}}} \right) + O\left(\frac{N^*}{e^{\frac{c_{10} \log N^*}{10 \log Q_0}}} \right) \end{aligned}$$

That is

$$\frac{(N^*)^{2\beta_0 - 1}}{\log^2 N^*} < \mu^2(q_0) \frac{N^*}{\phi(q_0) \log^2 N^*} + O\left(\frac{N^*}{(q_0)^{\frac{1}{12}}} \right) + O\left(\frac{N^*}{e^{\frac{c_{10} \log N^*}{10 \log Q_1}}} \right)$$

Namely

$$\beta_0 \leq \max \left(1 - \frac{\log q_0}{25 \log N}, 1 - \frac{c_{10}}{21 \log Q_1} \right)$$

Theorem 2 thus proved.

Theorem 3. (Asymptotic Formula of Solution Number)

Let $D(N)$ be the number of solutions of $p_1 + p_2 = N$, where p_1, p_2 be prime numbers, N be a even integer, when N is fully large

$$D(N) = \Theta(N) \frac{N}{\log^2 N} + O\left(\frac{N \log \log N}{\log^3 N} \right)$$

where

$$\Theta(N) = \prod_{p \nmid N} \left(1 - \frac{1}{(p-1)^2} \right) \prod_{p|N} \left(1 + \frac{1}{(p-1)} \right),$$

proof. By the Schwarz inequality, $N_2 = \frac{N}{\log^{2b_2} N}$, thus

$$D(N) = J_0(N) + O\left(\frac{N}{\log^{b_2+1} N} \right)$$

Theorem 1 thus gives

$$D(N) = \sum_{q \leq Q_1} \sum_{\substack{a=1 \\ (a,q)=1}}^{q_2} \int_{\frac{a}{q} - \frac{1}{q(\tau_0 \tau_1) \tau}}^{\frac{a}{q} + \frac{1}{q(\tau_0 \tau_1) \tau}} S^2(\alpha) e(-N\alpha) d\alpha + O\left((\log^{2b_2} N) \Omega_{D_{1,4}}(N, \tau_0) \right) + O\left(\frac{N}{\log^3 N} \right)$$

By lemma 4, $2^{\nu(N)} \leq 2^{\frac{2 \log N}{\log \log N}}$, (3)~(12) easy to show

$$D_{1,1}(N) = \Theta(N) \frac{N}{\log^2 N} + O\left(\frac{N \log \log N}{\log^3 N}\right)$$

In (4)~(12) still need to care $D_{14}(N), D_{15}(N)$, when $q_0 \leq \log^{A_1} N$, with the Siegel's theorem $\beta_0 \leq 1 - \frac{c(\varepsilon)}{\log^{\varepsilon A_1} N}$, take ε makes $\varepsilon A_1 < \frac{1}{10}$. if $\log^{A_1} N < q_0 \leq Q_1$ using theorem 2. thus prove theorem 3.

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The Value Implications, Realistic Dilemmas, and Practical Dimensions of Zigong Lantern Culture in Early Childhood Aesthetic Education

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Abstract: As a national intangible cultural heritage, Zigong colored lanterns play a significant role in cultural inheritance and local economic development due to their long historical context. The integration of Zigong lantern culture into children's aesthetic education can enrich the content and form of aesthetic education, promote local culture, and build cultural self-confidence; it can also cultivate aesthetic taste and promote children's personality development. Through the research, it is found that the teachers' inner motivation and the depth of cultural integration are insufficient in the process of the integration of Zigong lantern culture into children's aesthetic education. The external capacity of the garden society is not enough, and the real predicament of aesthetic education resources needs to be explored. In order to improve these conditions, the education process of understanding beauty to enlighten children's cognition, experiencing beauty to enhance children's experience and sensibility, appreciating beauty to cultivate children's appreciation, and creating beauty to activate children's creativity is proposed to promote the development of children's aesthetic education.

Keywords: Zigong colored lanterns; Zigong lantern culture; Children's aesthetic education; Practical dimension

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1. Development of Zigong lantern culture

1.1. Connotation of Zigong lantern culture

Since the Tang and Song Dynasties, Zigong colored lanterns have gradually formed the custom of burning lanterns in the New Year and decorating lanterns before and after the Lantern Festival. Its source is closely connected with the Jingyan civilization of Zigong. Then, relying on Zigong Lantern Fair to develop and grow, and integrating the customs of lantern fair in Sichuan, especially in adjacent areas, Zigong colored lantern culture has gradually evolved into a unique Zigong colored lantern culture ^[1]. Its prosperity is mainly inseparable from the inheritance of the lantern production process, the accurate grasp of the emerging art of the times, and the creative use of new technologies, so

that the lantern is more intelligent, vivid, and interactive, and enhances the audience's appreciation experience and cultural identity. Zigong colored lanterns not only carry forward the traditional beautiful meaning, but also integrate the elements of the times and the power of science and technology. The formed Zigong colored lantern culture is not only the spiritual sustenance for people to pray for happiness and peace, but also a bright pearl in the excellent traditional culture of China.

1.2. Characteristics of Zigong lantern culture

Zigong lantern culture involves creating scenery with lamps and conveying text with scenery. Each colorful lamp is like a miniature stage, which cleverly constructs a vivid story scene with lights, bringing visitors into a world full of fantasy and imagination. In the process of appreciating colored lanterns, people can not only appreciate the unique charm of Zigong colored lantern art, but also deeply feel the broad and profound Chinese culture. These lamp sets are based on historical stories, myths and legends, and vivid representations of folk customs, exquisite workmanship, and art models. "The production of colored lanterns is an extremely complex and intelligent process, which begins with on-site inspection and personalized design based on the characteristics of the terrain, aiming to finally present a stunning and large-scale three-dimensional mountain and sea of lanterns" [2]. It not only involves the clever use of silk, bamboo, porcelain, and other traditional natural materials, but also good at turning waste materials such as glass bottles, waste glass spoons, straw and other waste into treasure, combined with modern scientific and technological means, to create both traditional and modern, and complex and fine structure, smooth lines, rich color art works.

1.3. Realistic significance of Zigong lantern culture

Zigong lantern culture enhances cultural confidence and promotes international exchanges and cooperation. "Zigong Lanterns have been loved by many foreign friends since they went abroad in 1990. For example, at the Yue Hwa Garden Light Show in Singapore, Zigong Lanterns were presented with the 'first lantern in the world' banner by the then President of Singapore, Wee Kim Wee" [2]. In 2006, the Chinese Lantern Festival opened in the Amusement Palace of Ontario, Toronto, Canada, and attracted many local residents to watch it with its unique lighting sets and ingenious craftsmanship [2]. This kind of cross-cultural communication not only enhances China's international image and influence, but also contributes an indispensable force to the construction of a strong cultural country, driving local economic prosperity, innovation tourism industry development. Only in 2023, "during the lantern fair, the 18 A-level tourist attractions in Zigong City received a total of 1.0564 million tourists, an increase of 46.55%, and achieved ticket revenue of 54.3 million yuan, a significant year-on-year growth [3]. With the continuous promotion of Zigong lantern culture, more and more domestic and foreign tourists begin to pay attention to and understand Zigong, which opens up new space for the economic development of Zigong.

2. Value implication of integrating Zigong lantern culture into children's aesthetic education

2.1. Carrying forward local culture and building strong cultural confidence

As a national intangible cultural heritage project of traditional skills, Zigong colored lanterns are material forms with

both cultural and economic attributes. The production process mainly includes art design, lofting, manual binding, three-dimensional modeling, color separation pasting, etc. The main types of colored lanterns are tie-dye, paper cutting, bamboo weaving, etc. However, the low economic returns and the downturn in the lantern market have led many young people to give up learning lamp-making skills, which has caused difficulties in the inheritance of Zigong's traditional lantern-making skills. In 2021, the General Office of the CPC Central Committee and The General Office of the State Council issued the *Opinions on Further Strengthening the Protection of Intangible Cultural Heritage*, which clearly pointed out that the dissemination and popularization of intangible cultural heritage should be strengthened, and the content of intangible cultural heritage should be integrated throughout national education [4,5]. The colorful lantern culture of Zigong is integrated into the aesthetic education of children in a vivid and interesting form, and the innovation is carried out to adapt to the curriculum mode of the kindergarten stage, which is conducive to enriching the aesthetic education resources of the kindergarten. Taking it as the carrier, carrying out educational activities is conducive to stimulating children's aesthetic ability and imagination, and improving children's self-confidence and identity of traditional culture.

2.2. Cultivating aesthetic taste and promoting personality development

In 1795, Schiller, a German writer and thinker, first proposed "moral education, intellectual education, physical education, and aesthetic education" as the goals of school education [6]. In 1912, Mr. Cai Yuanpei, in his *Opinions on Educational Policies*, advocated that education be divided into five aspects: military national education, materialistic education, civic moral education, world outlook education, and aesthetic education, aiming at cultivating the sound personality of republican citizens [7]. In 2015, The General Office of the State Council issued *Opinions on Comprehensively Strengthening and Improving Aesthetic Education in Schools*, which clearly pointed out that the function of aesthetic education in schools should be strengthened, Chinese aesthetic education resources should be fully tapped, and Chinese excellent traditional culture inheritance and development and art classic education should be given priority [8]. As an important part of preschool education, aesthetic education aims to cultivate children's aesthetic concept and initial ability to appreciate art. From the design of the lantern sample to the fixing of the finished product, from the appreciation of the lantern art works to the children's mutual evaluation of the homemade lantern works, each operation step helps the children's imagination, fine muscle movements, and aesthetic development, and then continuously develop their personal abilities in practice and exploration [9].

3. Dilemma of integrating Zigong lantern culture into children's aesthetic education

3.1. Teachers' lack of inner motivation and depth of cultural integration

Teachers are the guides, supporters, helpers, and evaluators in the development of aesthetic education teaching activities, so they need to clarify the value of activities, set the goal, control the dynamic of activities, and evaluate the effect of activities [10]. Through investigation and practice, it is found that the effect of aesthetic education activities related to colored lanterns in kindergartens is poor. The reason is that teachers themselves have different cognition of Zigong colored lantern culture. They equate aesthetic education activities with "art handicraft" activities and require children to mechanically complete "colored lantern artworks" according to teachers' demonstration actions, ignoring the exploration and cultural nature of aesthetic education. This obviously violates the initial intention of the fusion activity, narrates the cultural implication, and fails to give full play to the value of the aesthetic education activity with

Zigong lantern culture as the carrier.

3.2. Poor external capacity of garden society and unexplored resources of aesthetic education

As an important source of kindergarten curriculum, regional cultural resources should take their cultural essence, integrate educational concepts, carry out innovative and interesting education and teaching activities for all children, optimize the class environment of the kindergarten, and create the kindergarten's characteristic curriculum in exploration and practice^[10]. For example, the kindergarten nature curriculum created with the theme of "rapeseed flower," the kindergarten characteristic curriculum developed with the theme of "Salt Dragon Lantern food," the kindergarten-based curriculum with the theme of "Yanjing culture," and the children's research activities carried out with the "journey of exploring the lamp." Through the investigation, it is found that most kindergartens carry out teaching activities, create themed environment, organize research activities, and so on when carrying forward Zigong lantern culture, and there is room for further exploration of the connotation of its culture and the development of local resources. The content of the characteristic courses between the parks is much the same; the practical and valuable goals need to be sublimated, and the logic and coherence between the themes fail to form a complete curriculum or activity system.

4. Improving quality and increasing efficiency: The practical dimension of integrating Zigong lantern culture in children's aesthetic education

4.1. Understanding beauty: Enlightening children's cognition

The rich colors, unique shapes, and profound culture of Zigong colored lanterns provide an excellent window for children to recognize beauty. For example, the theme teaching activities of "History and Legend of Zigong Colored Lanterns" are carried out to guide children to understand the deep heritage of Zigong colored lantern culture by telling the origin, development process, and related folklore and stories of colored lanterns. Organizing visits to the Zigong lantern exhibition or lantern fair allows children to observe the details of the lantern up close, feel the exquisite and complex production process of the lantern, and further experience the charm of Zigong lantern culture; carry out the language education activities of "Those things in making colored lanterns," invite the designers and craftsmen of Zigong colored lanterns to the garden to explain the production process and inspiration sources of colored lanterns for children, so as to increase children's understanding of Zigong colored lantern culture. This process not only opens the door for children to understand Zigong lantern culture, but also gradually builds their initial cognition of the entire Chinese aesthetic system and stimulates their strong interest in traditional culture and desire to explore.

4.2. Experiencing beauty: Enhancing children's experience

When carrying out various activities with the theme of "self-tribute colored lights," children can not only improve their aesthetic ability, but also gradually cultivate patience and carefulness, stimulate imagination, and guide children to feel the cultural charm behind the colored lights in the process of appreciating and personally making colored lights. This

process, in essence, is a process for children to “experience beauty” in an all-round way. For example, by organizing visits to the Zigong Lantern Museum or exhibitions, children can witness a variety of colorful lantern works. These lanterns not only have different shapes, but also integrate traditional crafts and modern design elements, showing a high artistic value. Teachers guide children to use environmentally friendly materials, such as waste cardboard boxes, colored paper, LED lights, etc., to give full play to creativity, personally design and make their own colored lights. In this process, children not only exercise their hands-on ability and spatial imagination, but more importantly, experience the fun and sense of achievement of creation in practice.

4.3. Feeling the beauty: Enhancing children’s sensibility

Feeling beauty is an important way for children to know the world and enrich their emotions and imagination. The Guide to Learning and Development for Children Aged 3–6 also makes it clear: “Young children feel and understand things differently from adults, and they express their knowledge and emotions differently from adults” ^[11]. On this basis, when designing the theme of “Zigong Colored Lantern Culture” aesthetic education activities, diversified strategies should also be adopted to adapt to children’s diverse senses and expressions. First, the activity should pay attention to experience, encourage children through direct observation, touch, and personally participate in the production of lights and other links, all-round, multi-angle contact with the art of lights, so as to deepen their unique understanding and feelings of beauty. Second, teaching activities should pay attention to the development of children’s empathy, using storytelling, role playing, and other forms to pass on the cultural significance and emotional value behind the lights to children. Third, teachers should continue to pay attention to children’s behavior in the learning process, and through observation, recording, and analysis, understand the growth trajectory and individual differences of each child in the perception side.

4.4. Appreciating beauty: Cultivating children’s appreciation

Carrying out various activities with the theme of “Zigong Lantern Culture” is not only the process of guiding children to appreciate beauty, but also an effective way to cultivate children’s appreciation. First, the Zigong lantern culture can be organically combined with the creation of the kindergarten environment to create a learning space full of an artistic atmosphere. In the corridor, wall, ceiling, and other areas of the kindergarten, hang or place a variety of Zigong lantern works or children’s homemade lantern handicrafts, so that children can contact the lantern culture at any time in daily activities, so as to realize the infiltration of aesthetic education. The second is the organic combination of Zigong lantern culture and kindergarten education activities, through a series of carefully designed activities, to guide children to deeply understand and appreciate the beauty of colored lanterns. For example, carry out activities such as lantern theme painting and hand-making, and encourage children to express their understanding and feelings of the beauty of colorful lanterns in their own way. These activities not only enrich children’s learning content, but also promote their aesthetic ability and creativity ^[12]. The third is to integrate the Zigong lantern culture into the daily life and festival celebrations of kindergartens, so that children can experience and appreciate the beauty of colorful lanterns in a broader context. Children can not only gain pleasure and satisfaction in the process of appreciating beauty, but also cultivate children’s appreciation, so as to enhance their understanding and feeling of beauty.

4.5. Creating beauty: Activating children's creativity

Creating beauty is not only an important part of children's aesthetic education, but also a key link to cultivating their innovative thinking and personality expression. Taking "Big Class Art Activity—Creative Lights" as an example, before the activity starts, it is necessary to prepare enough materials for children to make lights, such as paper, cloth, light pieces, etc., and the corresponding production tools, such as scissors, glue, brushes, etc., to ensure that they have enough space to play the imagination. At the same time, it is necessary to consider children's existing knowledge and experience of Zigong colored lanterns, clarify the core objectives of the activity, and cut into different dimensions of Zigong colored lantern culture, such as color use, modeling design, etc., in order to cultivate children's observation, practical ability, and creativity. Giving children sufficient imagination space, teachers inspire children to freely use their imagination to create, and invite children to share their creative ideas, in order to promote the development of their language expression ability. In the process of "creating beauty" activities, children not only experience the sense of achievement brought by the production of colored lights, but also deepen their understanding of the culture of colored lanterns and promote the development of their creativity.

5. Conclusion

Through the integration of Zigong lantern culture into the practice of children's aesthetic education, it not only enriches the content and form of aesthetic education, but also stimulates children's cognition, experience, feeling, appreciation, and creativity of beauty. Sowing in the hearts of children is like the germination of the flower of art, and the innovative practice of children's aesthetic education provides fertile soil and sufficient sunshine and rain for this seed. Therefore, it is necessary to continue to deepen the research on the traditional culture represented by Zigong lantern culture, explore more effective inheritance and innovation ways, and let the traditional culture bloom more brilliantly in early childhood education.

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Review and Reflection on the Research Approach of Ethnic Relations in the New Era

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Abstract: Since the reform and opening up, the study of ethnic relations has gradually formed a system. The study of ethnic relations from a multidisciplinary perspective has gained more depth and breadth, with a stronger combination of theoretical frameworks and empirical research, and increasingly diversified research methods. In the new era, research on ethnic relations should continue to deepen the theoretical and practical study of new ethnic relations with Chinese characteristics, achieve a more balanced approach to studying ethnic relations at different levels, and urgently strengthen comparative studies of various types of ethnic relations.

Keywords: Ethnic relations; New ethnic relations; New era

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1. Introduction

After the reform and opening up, China entered a new period of development, accelerating the pace of modernization, rapidly improving the levels of industrialization, informatization, and urbanization, and significantly improving the quality of life for people of all ethnic groups. With the eradication of absolute poverty in China and facing the new era and situation, Chinese ethnic relations have once again entered a new historical period. This article takes the study of ethnic relations in China as the object of review, focusing on summarizing the research achievements of domestic academic circles since the reform and opening up in terms of the connotation of ethnic relations, the evolution of ethnic relations, the influencing factors and early warning mechanisms of ethnic relations, and ethnic relations theories. It explores the gains and losses of existing ethnic relations research and the path for future research.

2. Connotation of ethnic relations

The understanding of ethnic relations varies from era to era, and these differences constitute the rich connotation of ethnic relations. Overall, the academic community has explored the connotation of ethnic relations mainly from aspects such as essential characteristics, manifestations, and functional roles.

Jin believed that ethnic content is the key to constituting ethnic relations ^[1]. To determine the extension and connotation of ethnic relations, Liao and Qin believed it is necessary to examine the elements that may produce ethnic relations in inter-ethnic exchanges ^[2]. Zhang and Zhong emphasized that the core issues of ethnic relations are ethnic interests, ethnic rights, and ethnic development ^[3]. Yuan believed that mutual benefit and symbiosis between ethnic groups are the foundation of ethnic relations ^[4]. Ethnicity is the nature that distinguishes ethnic relations from other social relations, and interest is the driving force for the occurrence and development of ethnic relations. In terms of manifestations, Xu pointed out that ethnic relations are manifested as peaceful, conflicting, or coexisting relations within and between ethnic groups ^[5]. In terms of function, Li believed that ethnic relations transmit or exchange “energy” between ethnic groups, promoting the ordering and integration of multi-ethnic societies ^[6]. In the process of ethnic relations evolution, Liu believed that ethnic relations have their own development laws under the influence of various internal and external factors ^[7]. Based on the above scholars’ discussions, ethnic relations arise from the inherent drive for survival and development, characterized by ethnicity and interest, and have the function of promoting the orderly development of inter-ethnic relations, with groups as the basic form of expression.

3. Evolutionary forms of ethnic relations

Ethnic relations are a dynamically developing process. Bai believed that the mainstream of ethnic relations development is the co-creation of history, joint efforts, mutual dependence, and mutual support among multiple ethnic groups, jointly pushing forward the development of Chinese history ^[8]. Yang thought that long-term contact, close interaction, mutual dependence, and common development are the mainstream of ethnic relations in Chinese history ^[9]. Chen pointed out that when discussing ethnic relations in history, it is important to value the contributions made by ethnic minorities to the creation of a unified multi-ethnic country in China ^[10]. From a dialectical perspective, China’s ethnic relations contain contradictions within the trend of harmonious development ^[11]. As China’s ancestors evolved from barbarism to civilization, they experienced three stages of development: antagonistic ethnic relations, closed ethnic relations, and open ethnic relations ^[12]. In the study of ethnic relations, Fei’s theory of the “diverse yet unified pattern of the Chinese nation” has had the greatest influence ^[13]. With the changes and development of social history, the nature of ethnic relations in China has undergone fundamental changes. The ethnic relations of oppression and exploitation have become history, and a new type of ethnic relation featuring equality, unity, mutual assistance, and harmony has become the mainstream. After the founding of the country, the exchanges between various ethnic groups have continued to deepen, and the feelings of mutual understanding, respect, and identity have further strengthened ^[14]. Historically, the general trend of ethnic relations in China has been to value harmony and coexistence in diversity, with various ethnic groups united and helping each other to create Chinese history.

4. Influencing factors and early warning mechanisms of ethnic relations

Research on the influencing factors and early warning mechanisms of ethnic relations can timely guide ethnic relations onto a healthy development path. In the period of social transformation, due to various reasons, there are disparities in the economic and social development of various ethnic groups, and conflicts and collisions can easily arise from differences in interactions ^[15]. The mobility of ethnic populations has had a positive impact on the formation of a “diverse yet unified” Chinese culture ^[16]. However, factors such as high population mobility, strong ethnic and religious consciousness, and poor ability to actively adapt to cities have also had a negative impact on urban ethnic relations ^[17].

Constructing a scientific, reasonable, and feasible early warning mechanism for ethnic relations has become the focus of current research. Yang explored the functional orientation, construction principles, and basic structure of the early warning mechanism for ethnic relations ^[18]. Zheng and Zhang believed that the monitoring and evaluation of ethnic relations should be gradually analyzed and summarized from both macro and micro perspectives, and an indicator system for evaluating ethnic relations should be extracted ^[19]. Yan *et al.* thought that the early warning system for ethnic relations includes organizational structure, division of responsibilities, operational processes, supervision and implementation, and a safeguard system ^[20]. For the complex urban ethnic relations and their potential risks during the economic and social transformation period, Zhang proposed regulatory countermeasures and a monitoring and early warning mechanism for urban ethnic relations during the economic transformation period ^[21]. The research on the early warning system for ethnic relations is of great significance, and currently, domestic research in this area is still in its infancy.

5. Multidisciplinary exploration of ethnic relations theory

Significant efforts have been made by Jin’s team and the “Heilongjiang Ethnic Publications” in researching and elaborating on the theory of ethnic relations with Chinese characteristics. In 2003, the “Heilongjiang Ethnic Publications” consecutively published 14 papers by Jin and others, providing a systematic and comprehensive exposition of the theory of socialist ethnic relations. Scholars have introduced the concept of “inter-embedding” and proposed the construction of an “ethnically inter-embedded community” to address how to build ideal ethnic relations in society (community) ^[22]. The cultural aspect serves as a crucial link for the existence and functioning of such communities, facilitating the diverse coexistence and mutual integration of various ethnic cultures through long-term cultural exchanges ^[23]. The construction of an “ethnically inter-embedded society” involves creating social structural connections that maintain social solidarity. Different ethnic groups are brought together through these structural connections, as well as connections based on shared interests and social participation, fostering an organic unity ^[24]. From a psychological perspective, ethnic interactions are inherently linked to motivational factors. This process encompasses the psychological motivations underlying ethnic interactions, including the cognitive, emotional, volitional, and behavioral dimensions. Establishing an awareness of ethnic equality stands out as a particularly significant aspect of these interactions ^[25]. In the context of ecology, some scholars argue that “ethnic symbiosis reflects a complementary relationship in ethnic interactions. The emergence and development of this relationship can evolve the ethnic symbiosis system towards a more vital direction” ^[26]. The integration of symbiotic complementarity theory with sociological theories provides valuable insights for constructing an ideal model of

“symbiotic complementarity” in ethnic relations in scattered and mixed areas.

6. Reflection and prospects

Academic research on ethnic relations has achieved fruitful results. Firstly, the study of ethnic relations has gradually formed a system. Secondly, from the perspectives of multiple disciplines such as ethnology, sociology, history, political science, psychology, and ecology, new breakthroughs have been made in the depth and breadth of research on ethnic relations. Thirdly, the combination of theoretical research and empirical research on ethnic relations has been further strengthened. Fourthly, the use of qualitative and quantitative methods in the study of ethnic relations has gradually increased, but further advancements in broader and deeper directions are needed based on existing research results.

Firstly, it is necessary to continue strengthening the research and interpretation of the theory of ethnic relations with Chinese characteristics, focusing on the study of empirical facts of ethnic relations in a specific time and space. Research should be based on national conditions and facts, constantly enriching its theoretical connotation in the dynamically changing ethnic relations.

Secondly, a more balanced approach is needed in the hierarchical study of ethnic relations. China's ethnic relations can be divided into three levels. For the convenience of expression, the relations between ethnic groups can be called primary; the relations between ethnic minorities and the Han nationality can be called intermediate; the relations between all ethnic groups and the Chinese nation can be called advanced. Primary ethnic relations are the foundation, intermediate ethnic relations are the core, and advanced ethnic relations are the goal. Among existing studies, high-level ethnic relations represented by “pluralistic integration” have achieved significant research results; intermediate-level ethnic relations research results are second; primary ethnic relations research still has much room for improvement, and empirical research can still make a significant contribution.

Thirdly, the comparative study of ethnic relations urgently needs to be strengthened. The holistic study of China's ethnic relations, on the one hand, requires comparing the similarities and differences between the three levels of ethnic relations and studying the interactive relationships among them. On the other hand, it also necessitates comparing various ethnic relations within each level, discovering the similarities and differences in the formation reasons, influencing factors, interaction modes, and identity consciousness of different types of ethnic relations through comparison, and identifying their unique and common features.

Fourthly, the study of ethnic relations should be based on the new era. After decades of development, China has become the world's second-largest economy. With the comprehensive eradication of absolute poverty, China has embarked on its second centenary goal, and the Chinese nation has begun to move towards becoming stronger. In this context, the living standards of all ethnic groups have been greatly improved, the scope and frequency of exchanges and interactions among ethnic groups have gradually increased, and ethnic relations have developed positively overall. However, the new era brings new situations and problems, such as how to overcome the contradictions arising from the widening economic gap among ethnic groups, how to achieve symbiotic complementarity of ethnic cultures within Chinese culture, how to anticipate and resolve ethnic conflicts in new situations, and how to unite the consciousness of various ethnic groups under the consciousness of the Chinese nation community. Facing these new situations and problems, researchers should adopt new ideas and methods, base their work on current social realities, seek truth from facts, and deeply explore the path of healthy development for socialist ethnic relations with Chinese

characteristics.

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Innovation in Chemistry Culture Teaching Based on the “Four-Point Breakthrough” Paradigm: A Case Study of “Chemical Knowledge in Yi Embroidery”

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Abstract: With the deepening reform of basic education curricula, cultivating students’ core competencies in chemistry teaching has become a hot topic in the field of education. This paper adopts the “Four-Point Breakthrough” teaching paradigm as its theoretical framework and integrates the intangible cultural heritage resources of Yi embroidery to explore new pathways for fostering core competencies in chemistry. By constructing a progressive teaching chain of “innate interest-accompanying interest-derivative interest,” the study combines chemical knowledge with ethnic cultural resources, forming an ecological classroom model of “contextual stimulation-knowledge modeling-transfer and application.” The results show that this teaching model effectively stimulates students’ learning interest, enhances their scientific inquiry skills and cultural identity, and provides an innovative practical example for chemistry teaching in ethnic regions.

Keywords: Four-Point Breakthrough paradigm; Chemistry culture teaching; Yi embroidery; Core competencies; Scientific inquiry ability

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1. Introduction

1.1. Curriculum reform background and teaching challenges

The current reform of basic education curricula is oriented toward core competencies, aiming to implement the concept of “disciplinary education.” However, the following contradictions persist in chemistry teaching practices.

First, there is a misalignment between curriculum concepts and learning motivation. Students’ interest in chemistry often stems from the novelty of experimental phenomena, but it tends to decline as abstract concepts are introduced. In ethnic regions, students’ limited awareness of the social application value of chemical knowledge, due

to insufficient connections between textbook content and local culture, affects the sustainability of their learning motivation.

Second, the transformation of teaching methods faces structural resistance. Some classrooms still rely on one-way knowledge transmission, especially in areas with limited experimental resources. Teachers, constrained by objective conditions, struggle to implement inquiry-based teaching activities, which weakens the cultivation of students' scientific inquiry skills.

Third, the educational value of the discipline has not been fully realized. Current curricula inadequately explore the chemical wisdom embedded in traditional culture, making it difficult for students in ethnic regions to develop cultural identity during knowledge construction, thereby hindering the synergistic development of scientific spirit and humanistic literacy.

1.2. Proposal of the “Four-Point Breakthrough” teaching paradigm

To address these issues, Professor Zou Hongtao's research team at Qiannan Normal University for Nationalities proposed the “Four-Point Breakthrough” teaching paradigm. This paradigm emphasizes breakthroughs in interest points, starting points, key and difficult points, and goal achievement points, ensuring that interest permeates the entire classroom and constructing a complete teaching system. The paradigm highlights the functions of “stimulating interest, nurturing aspirations, and fostering habits” by activating innate interest, maintaining accompanying interest, and elevating derivative interest, thereby helping students develop lasting learning motivation and enthusiasm^[1].

2. Core concepts

2.1. “Four-Point Breakthrough” teaching paradigm

The core of the “Four-Point Breakthrough” teaching paradigm is to “unlock” interest, emphasizing that interest is a fusion of cognition and emotion. It establishes strategies for activating innate interest through breakthroughs in starting points, maintaining accompanying interest through breakthroughs in key and difficult points, and elevating derivative interest through breakthroughs in goal achievement points (Table 1). This forms an endless chain of interest that runs through the entire teaching process, creating an ecological classroom where “interest arises as the lesson begins, deepens as it progresses, and lingers after it concludes”^[2].

Table 1. “Four-Point Breakthrough” teaching paradigm

| Four-point | Breakthrough |
|------------------------------------|---|
| Key point of interest | By creating scenarios and employing problem-driven approaches, students' learning interest is stimulated, and their innate curiosity is activated |
| Starting point of teaching | Building upon students' prior knowledge and experiences, we design authentic, life-relevant instructional scenarios to facilitate meaningful connections between new and existing knowledge |
| Key and difficult knowledge points | Through experimental inquiry and problem-chain-driven approaches, we break through key teaching difficulties, enabling students to develop a profound understanding of core concepts |
| Target achievement point | Through knowledge transfer and extended application, we achieve teaching objectives while cultivating students' core competencies and comprehensive skills |

2.2. “Chemical Knowledge in Yi Embroidery”

“Chemical Knowledge in Yi Embroidery” refers to the integration of chemical principles in Yi traditional embroidery with modern chemistry teaching, uncovering its scientific and cultural value. Specific aspects include:

Extraction of plant dyes and chemical reactions: involving redox reactions, pigment separation, and other chemical principles [3].

Chemical properties of embroidery threads: for example, the durability and corrosion resistance of hemp fibers [4].

Chemical aesthetics in pattern design: for example, the symmetry and stability of chemical structures, and the relationship between color combinations and chemical reactions [5].

Modern improvements to traditional techniques: for example, using modern chemical technology to enhance the environmental friendliness of dyes and preservation methods for embroidered works.

2.3. Progressive teaching chain of “innate interest-accompanying interest-derivative interest”

Innate interest: Students’ natural curiosity about new things, stimulated through real-life contexts and cognitive conflicts [6].

Accompanying interest: Interest gradually formed during the learning process, maintained through activity-based teaching and problem chains.

Derivative interest: Transformed into deep-seated learning motivation and innovative thinking through knowledge transfer and extended applications.

3. Teaching design for “Chemical Knowledge in Yi Embroidery”

3.1. Analysis of teaching resources

Analysis of chemical elements in Yi embroidery culture: As an important part of Yi traditional culture, Yi embroidery contains rich chemical knowledge.

Extraction of plant dyes involves redox reactions. Students can explore color changes and chemical compositions of different plant dyes through experiments.

The selection of embroidery thread materials relates to fiber chemistry, such as the durability and corrosion resistance of hemp fibers. Students can compare the chemical properties of different fibers through experiments.

Symmetry in pattern design reflects the aesthetic value of chemical structures. Students can observe and analyze the symmetry of patterns to understand the stability and beauty of chemical structures [7].

Educational transformation of regional cultural resources: Yi embroidery resources provide vivid practical scenarios for chemistry teaching. By transforming the chemical principles of intangible cultural heritage into educational content, students can understand the practical application of chemical knowledge in real contexts, enhancing the fun and meaningfulness of learning. For example:

Dye extraction experiments: Students can extract plant dyes by hand to understand the principles of redox reactions [8].

Comparative experiments on eco-friendly dyes: By comparing natural plant dyes with modern chemical dyes, students can explore the relationship between chemical technology and environmental protection.

3.2. Setting teaching objectives

Knowledge and skills: Students can identify chemical substances and their properties in Yi embroidery production, and understand chemical principles in traditional techniques (e.g., dye extraction and preservation, fiber durability).

Process and methods: Through contextual teaching and experimental inquiry, students can connect chemical knowledge with life practices and use observation, reasoning, and modeling to analyze scientific phenomena in an ethnic culture.

Emotional attitudes and values: It aims to cultivate students' sense of identity and pride in ethnic culture, help them appreciate the aesthetic value of the integration of science and humanities, and strengthen cultural confidence [9].

3.3. Teaching case design

Case 1: Extraction of plant dyes and redox reactions ^[10], as presented in **Table 2**.

Table 2. Case 1

| | |
|-----------------------|---|
| Situational lead-in | <p>Students visit the Yi embroidery street, where they can observe the material differences between traditional fabrics and modern cotton textiles. Pose the driving question: "Why can traditional hemp fabric remain intact for centuries without decaying?" This real-world scenario effectively sparks students' curiosity and desire for inquiry</p> <p>Experimental design: Students work in groups to extract natural dyes from plants, specifically using indigo plants to produce blue dye.</p> <p>Experimental procedure:</p> |
| Knowledge modeling | <ol style="list-style-type: none"> 1. Crush the leaves of the indigo plant and mix them with an appropriate amount of water and lime (as an alkaline catalyst). 2. After allowing the mixture to sit for a period of time, filter it to obtain the blue dye solution. 3. Soak white cotton fabric in the dye solution and observe the color change. |
| Principle explanation | <p>Through experimental observations, the teacher explains the principles of redox reactions, illustrating the reduction process of indigo dye under alkaline conditions</p> |
| Transfer application | <ol style="list-style-type: none"> 1. Environmental comparison: Compare the eco-friendliness of natural plant dyes versus modern synthetic dyes, examining how chemical technologies can be applied for environmental protection. 2. Extension task: Design an eco-friendly textile dyeing product. Students are required to integrate experimental findings, propose innovative solutions to enhance the environmental sustainability of traditional dyeing methods |

Case 2: Chemical properties of embroidery threads, as presented in **Table 3**.

Table 3. Case 2

| | |
|-----------------------|---|
| Situational lead-in | <p>Display embroidery threads of different materials (e.g., linen fiber, cotton fiber, silk fiber), and pose the question: “Why is linen fiber predominantly chosen for Yi embroidery?” Through tactile observation and visual comparison, stimulate students’ curiosity</p> <p>1. Experimental design:</p> <p>Students work in groups to conduct durability tests on different embroidery thread materials.</p> |
| Knowledge modeling | <p>2. Experimental procedure:</p> <p>Take segments of linen fiber, cotton fiber, and silk fiber, and measure their initial length.</p> <p>Soak the segments separately in:</p> <p>Acidic solution (e.g., acetic acid)</p> <p>Alkaline solution (e.g., sodium carbonate solution)</p> <p>Neutral solution (control group)</p> <p>for 24 hours.</p> <p>Remove the threads, measure their length changes, and observe fiber breakage conditions.</p> |
| Principle explanation | <p>Based on experimental data, the teacher explains the chemical stability of different fibers under acidic and alkaline conditions, demonstrating linen fiber’s superior durability and corrosion resistance</p> |
| Transfer application | <p>1. Practical application:</p> <p>Explore how modern chemical technologies can be utilized to enhance embroidery thread materials, improving their durability and colorfastness.</p> <p>2. Extension task:</p> <p>Design a contemporary embroidery product that incorporates Yi ethnic motifs. Students are required to:</p> <p>Draw upon experimental findings</p> <p>Propose innovative solutions to optimize thread material performance</p> |

Case 3: Chemical aesthetics in pattern design, as presented in **Table 4**.

Table 4. Case 3

| | |
|-----------------------|---|
| Situational lead-in | <p>Display traditional patterns from Yi embroidery and pose the question: “Why do these patterns appear so symmetrical and aesthetically pleasing?” Through observation and discussion, stimulate students’ curiosity and engagement</p> |
| Knowledge modeling | <p>Observation & analysis: Students work in groups to examine the symmetry and color composition of Yi embroidery patterns, documenting their findings</p> |
| Principle explanation | <p>Teacher's explanation:</p> <p>The instructor explains the relationship between chemical structure symmetry and molecular stability, while connecting these principles to color theory in design (e.g., how complementary colors create visual contrast due to their underlying chemical properties).</p> |
| Transfer application | <p>Design task: Students are required to work in groups to design a modern pattern that integrates Yi embroidery elements, with the requirement to reflect the principles of chemical aesthetics.</p> <p>Presentation and evaluation: Each group will present their design outcomes, and both teachers and students will jointly evaluate their scientific validity and aesthetic appeal.</p> |

4. Implementation path of the “Four-Point Breakthrough” teaching paradigm

4.1. Activating innate interest: Contextual introduction strategies

Creating real-life contexts ^[11]:

Students visit Yi embroidery streets, observe the material differences between traditional and modern cotton fabrics, and pose driving questions such as, “Why can traditional hemp cloth remain intact for centuries?” This stimulates students’ curiosity and desire to explore.

Stimulating cognitive conflicts:

Presenting comparative experiments between modern chemical dyes and natural plant dyes, asking, “Which dyeing method is more environmentally friendly?” Use cognitive conflicts to prompt deep reflection on the application of chemical knowledge.

4.2. Maintaining accompanying interest: Knowledge modeling process

Activity-based teaching strategies:

Designing a “dye extraction” experiment to explore the chemical composition of plant dyes. Through hands-on operations, students observe color changes and understand the principles of redox reactions ^[12].

Problem-chain-driven strategies:

Using “hearth culture” as a starting point to construct a problem chain: “How does fire change the color of ores? → What is the principle of oxidation reactions? → How are Yi embroidery pigments preserved?” Guide students to delve deeper into inquiry through interconnected questions.

4.3. Elevating derivative interest: Transfer and application design

Knowledge transfer strategies:

Guiding students to apply chemical anti-moth principles to design preservation solutions for Yi embroidery, exploring how modern chemical technology can improve traditional embroidery techniques.

Extended learning design:

Assigning project-based tasks, such as “Design an eco-friendly dyeing and weaving product incorporating Yi embroidery elements,” encouraging students to combine chemical knowledge with cultural creativity to foster innovative thinking and practical skills.

5. Teaching effects and reflection

5.1. Analysis of student learning performance

Observation of interest sustainability:

Through quantitative analysis of classroom participation and tracking of post-class extended learning behaviors, it was found that students’ participation in contextual teaching significantly increased, and their independent inquiry behaviors after class noticeably rose. This indicates that the “Four-Point Breakthrough” paradigm effectively sustains students’ learning interest ^[12].

Assessment of core competency development:

Students showed significant improvement in scientific inquiry skills, cultural understanding, and value

identification. For example, they demonstrated strong scientific thinking in experimental design and data analysis, and exhibited profound cultural identity when discussing the cultural value of Yi embroidery.

5.2. Discussion on the applicability of the teaching paradigm

Educational transformation efficiency of ethnic cultural resources:

Yi embroidery resources provide abundant materials for chemistry teaching. Through contextualized, problem-based, and project-based teaching designs, deep educational transformation of cultural resources is achieved [13].

Potential for cross-disciplinary application of the “Four-Point Breakthrough” paradigm:

The paradigm emphasizes the activation, maintenance, and elevation of interest, demonstrating strong universality. By adjusting contextual creation and problem design, it can be applied to teaching practices in other disciplines such as physics and biology.

6. Conclusion and outlook

6.1. Summarizing the innovative value of “Yi Embroidery Chemistry” teaching practice

This study integrates Yi embroidery cultural resources with chemistry teaching through the “Four-Point Breakthrough” teaching paradigm, constructing an ecological classroom model of “contextual stimulation-knowledge modeling-transfer and application.” It effectively enhances students’ learning interest and core competencies.

6.2. Proposing recommendations for promoting the “Four-Point Breakthrough” paradigm in ethnic regions

It is recommended that schools in ethnic regions systematically organize local cultural resources, develop teaching cases that integrate disciplinary knowledge, and promote the “Four-Point Breakthrough” paradigm through teacher training and teaching seminars to improve regional teaching quality [14].

6.3. Future directions for research on the integration of science and humanities in education

Future research could further explore educational models that integrate science and humanities, develop more interdisciplinary teaching resources, and provide theoretical support and practical guidance for cultivating well-rounded talents.

Disclosure statement

The author declares no conflict of interest.

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Research on the Tourism Image Perception of Sanya Scenic Spots based on Big Data Text Mining

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Abstract: The online travel evaluations of tourists about Sanya scenic spots were collected through Python crawler technology. Then, ROSTCM6.0 software was used to perform text analysis on the collected online travel evaluations. The high-frequency words, word units, and visual cloud maps of the network semantics of online travel evaluations were analyzed and sorted out. Finally, from the data processing results, it was concluded that the three dimensions of the perception of the tourism image of Sanya scenic spots are the company service dimension, the team atmosphere dimension, and the natural scenery dimension. From the unique perspective of group tourists, the tourists' perception of the tourism image of Sanya scenic spots was analyzed, and then the tourists' perception characteristics of the electronic word-of-mouth (e-WOM) of Sanya scenic spots were studied and analyzed. The research results provide reference significance for tourists' travel to Sanya scenic spots, and at the same time provide data support for the decision-making of tourism companies.

Keywords: Big data text mining; Electronic word-of-mouth (e-WOM); Group tourists; Tourism image perception

Online publication: March 26, 2025

1. Introduction

With the progress of the times and the development of technology, electronic word-of-mouth (e-WOM) formed by online tourist comments plays a crucial role in customers' tourism decision-making [1]. In the era of big data and information technology, new technologies such as 5G and artificial intelligence have brought convenience to tourists' travel experiences [2]. The emergence of various multimedia software applications has provided a platform for tourists to share their stories and travel experiences [3]. With the widespread use of smartphones, more and more people enjoy posting their travel insights on various social media platforms, forming a type of e-WOM [4]. Since the end of the pandemic in 2023, the tourism industry has rapidly recovered. According to the "2023 Cultural and Tourism

Development Statistics Bulletin of the Ministry of Culture and Tourism of the People's Republic of China" issued by the Ministry of Culture and Tourism, the number of domestic tourist trips in 2023 reached 4.89 billion, an increase of 93.3% compared to 2022 ^[5]. This article mainly analyzes tourists' perceptions of the tourism image of Sanya scenic spots from the unique perspective of group tourists, thereby investigating the characteristics of their e-WOM perceptions of Sanya tourism.

2. Literature review

2.1. Electronic word-of-mouth

The concept of e-WOM originated from the term "online word-of-mouth." With the continuous development of electronic technology and the progress of digitization, the term e-WOM emerged, giving rise to research on the network semantics of online customer electronic word-of-mouth ^[6]. In the tourism industry, e-WOM largely consists of tourists' personal experiences and travel stories, playing a crucial role in shaping the image of tourism destinations. Most tourists prepare travel guides beforehand, relying primarily on user-generated online travelogues and UGC (user-generated content) to gather various information about their intended destinations. This information encompasses multiple aspects such as local cuisine, scenic spots, travel itineraries, and hotel details along the route. UGC not only assists tourists in planning their trips but also provides valuable insights for destination managers to identify areas for improvement and development ^[7]. Tourist e-WOM mainly consists of spontaneous personal insights and evaluations generated by tourists after their travels. It plays a decisive role in shaping the image of tourism destinations. For instance, the rising popularity of Harbin's cultural tourism and the booming situation of Zibo's barbecue are positive impacts of online e-WOM on the promotion of tourism destinations. Therefore, tourist e-WOM holds significant importance in shaping the image of tourism destinations and influencing tourists' personal decision-making processes.

2.2. Tourism image perception

The concept of tourism destination image was initially introduced by scholar JD Hunt and quickly became a focal point of research in various disciplines such as tourism studies and psychology ^[8]. Tourism image perception refers to the overall personal evaluation of a destination by tourists based on their experiences during their visit. It encompasses multiple aspects, including food, accommodation, transportation, shopping, entertainment, and more. Tourists' perception of a destination's image is influenced by various factors such as the cultural significance of the destination, natural scenic beauty, and online reviews from other tourists ^[9].

Research methods for studying tourism destination image perception have gradually diversified, with a wide range of quantitative and qualitative analysis techniques emerging. These include quantitative methods like survey questionnaires and IPA analysis, as well as qualitative methods such as text analysis, content analysis, and grounded theory ^[10]. These methodologies provide decision-makers and managers with valuable data-driven insights and theoretical support to assess the image perception of tourism destinations. This article primarily utilizes big data text analysis and network semantic visualization techniques to analyze and study the online reviews of group tourists regarding their experiences at Sanya tourist attractions. The aim is to explore the perception structure of group tourists towards the tourism image of Sanya.

3. Research design and methodology

3.1. Sample selection and processing

This article primarily employs Python web scraping technology to extract online tourism evaluation data from group tourists regarding Sanya's attractions from the Ctrip website and app. Through this data collection process, a total of 12,763 pieces of raw network data were obtained.

3.2. Research methods and processes

As shown in **Figure 1**, the article mainly uses two major research methods: data collection and data analysis to analyze and study the image perception of Sanya scenic spots. Firstly, data scraping of online customer reviews was performed using Python software. Then, data preprocessing was carried out by importing the scraped raw data into an Excel spreadsheet. Through data preprocessing, meaningless adverbs, modal particles, etc., in the raw data were deleted, and similar adverbs were merged. Finally, after rigorous screening, 12,000 valid reviews were obtained. Through ROSTCM6.0 research and analysis of high-frequency words and word clouds, three dimensions of group tourists' image perception of Sanya scenic spots were obtained.

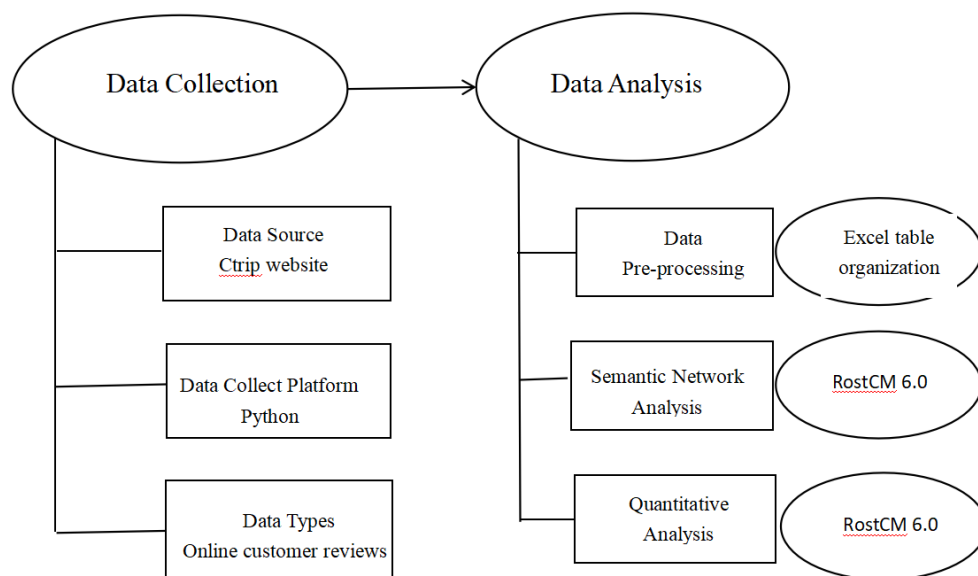


Figure 1. Flowchart of the research process

4. Research analysis

4.1. Analysis of high-frequency words in tourists' online reviews

Based on the analysis of high-frequency words in Table 1, group tourists' perception of the image of Sanya scenic spots is mainly manifested in three dimensions. These three dimensions are named the company service dimension, group atmosphere dimension, and natural scenery dimension.

Table 1. High-frequency words in group tourists' online reviews (top 50)

| Serial number | High-frequency word | Word frequency | Serial number | High-frequency word | Word frequency |
|---------------|---------------------|----------------|---------------|---------------------|----------------|
| 1 | Guide | 9,061 | 26 | experience | 641 |
| 2 | journey | 3,548 | 27 | child | 628 |
| 3 | Sanya | 3,380 | 28 | care | 616 |
| 4 | arrange | 3,160 | 29 | intimate | 594 |
| 5 | Serve | 2,671 | 30 | shopping | 576 |
| 6 | hotel | 2,629 | 31 | first | 560 |
| 7 | satisfy | 2,435 | 32 | serious | 549 |
| 8 | explain | 2,400 | 33 | manner | 516 |
| 9 | happy | 2,090 | 34 | play | 510 |
| 10 | enthusiasm | 2,001 | 35 | funny | 506 |
| 11 | travel | 1,767 | 36 | mangroves | 476 |
| 12 | Hainan | 1,305 | 37 | worth | 469 |
| 13 | travel | 1,303 | 38 | elder | 466 |
| 14 | grateful | 1,294 | 39 | weather | 462 |
| 15 | Play | 1,282 | 40 | free | 423 |
| 16 | time | 1,264 | 41 | environment | 422 |
| 17 | Attractions | 1,207 | 42 | reviews | 417 |
| 18 | thoughtful | 1,167 | 43 | Knowledge | 398 |
| 19 | Reasonable | 1,049 | 44 | beauty | 363 |
| 20 | joy | 845 | 45 | parents | 357 |
| 21 | humor | 808 | 46 | scenery | 355 |
| 22 | family | 785 | 47 | room | 339 |
| 23 | patience | 771 | 48 | pretty | 329 |
| 24 | landscape | 658 | 49 | Consumption | 320 |
| 25 | careful | 651 | 50 | seafood | 292 |

From the high-frequency words in Table 1, it can be seen that “tour guide” ranks first with a frequency of 9,061 times, indicating that “tour guide” is crucial for tourism companies. Secondly, “arrangement” ranks fourth with a frequency of 3,160 times, and “time” ranks 16th with a frequency of 1,264 times. These high-frequency words suggest that group tour companies need to make relevant schedule arrangements and travel route planning ahead of time, such as “two days and one night” or “three days and two nights” schedules. These high-frequency words reflect that tourists value the scheduled arrangement and travel route planning.

It can also be seen from the high-frequency words in Table 1 that tourists attach great importance to the group atmosphere. Among them, “satisfied” ranks seventh with a frequency of 2,435 times, “enthusiastic” ranks tenth with a frequency of 2,001 times, “happy” ranks 20th with a frequency of 845 times, “humorous” ranks 21st with a frequency of 808 times, and “witty” ranks 35th with a frequency of 506 times. The appearance of these high-frequency words indicates that group tour tourists value the atmosphere very much. A good group atmosphere can make tourists relax and enhance their stickiness. The word cloud derived from high-frequency words is presented

in Figure 2 below.



Figure 2. Word cloud of high-frequency words in online reviews of Sanya scenic spots

4.2. Social network semantics

Social network semantics is a visual representation of tourists' online review texts, where the connections between words reflect their mutual relationships [11]. The words "tour guide," "Sanya," "happy," "arrangement," and "service" are closely connected to other words, indicating their strong centrality and prominence in the network semantics. As shown in Figure 3 below, the social network semantic analysis diagram of group tourists' online reviews of Sanya scenic spots visualizes the tourists' online text reviews.

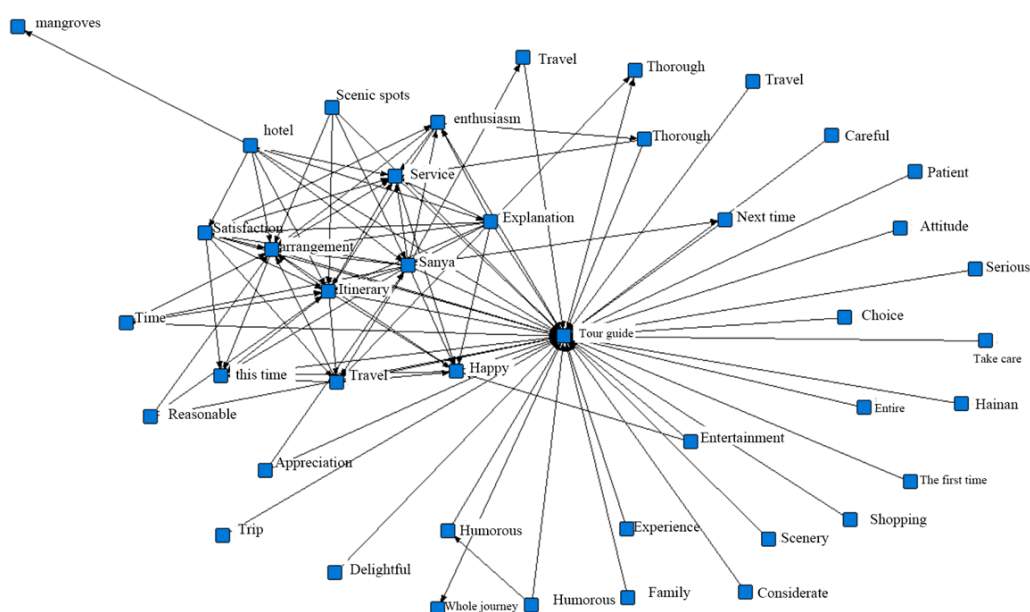


Figure 3. Semantic analysis diagram of online reviews social network for tourists

5. Results and discussion

5.1. Results

Through the visualization of high-frequency words, word clouds, and social network analysis diagrams of online tourist reviews, three dimensions of group tourists' cognitive image of Sanya scenic areas can be identified. These three dimensions are named the company service dimension, group atmosphere dimension, and natural scenery

dimension.

In the cognition of the company service dimension, it can be seen from the high-frequency words “tour guide,” “thoughtful,” and “careful” that group tourists value the service quality of tourism companies very much. It can also be seen from Figure 3, the semantic analysis diagram of the online review social network for group tourists, that the words “tour guide” and “arrangement” have strong centrality and are closely connected with other words. At the same time, the high-frequency words “elderly” and “children” appear in Table 1, indicating that family group tours and parent-child group tours are important components of group tours. Therefore, tourism companies should make advance preparations for service systems and training for special groups, with a “people-oriented” approach that takes care of tourists’ emotional value and experience. For group tours of special groups, tourism companies need to be equipped with relevant doctors to accompany them, so that tourists have positive evaluations of the company’s service dimension.

In the cognition of the group atmosphere dimension, it can be seen from Figure 2, the high-frequency word cloud diagram of online reviews for Sanya scenic areas, that words such as “happy,” “enthusiastic,” and “satisfied” are related to the group atmosphere dimension. Therefore, it can be seen that the group atmosphere is also a critical part for group tour tourists. A relaxed and pleasant group atmosphere during the trip plays a significant role in enhancing tourists’ satisfaction, increasing their intention to revisit, and enhancing their loyalty.

In the cognition of the natural scenery dimension, it can be seen from high-frequency words such as “scenic spots,” “scenery,” and “mangroves” that natural scenery is an indispensable part of the tourist experience. Appreciating the natural scenery of the tourist destination has a significant impact on tourists’ mood and perception of the destination. It can be seen from Figure 3 that “Sanya” and “scenic spots” have strong centrality and are closely connected with other words.

5.2. Discussion

This article mainly collects tourism evaluation data of group tourists on the Ctrip travel website through Python web scraping software, from the unique perspective of group tourists. It uses the text analysis software ROST-CM6.0 to study the tourism image perception of Sanya scenic spots through two aspects: word frequency and network semantic visualization.

Through analysis and research, three dimensions of group tourists’ cognitive image of Sanya scenic spots are identified, namely the company service dimension, group atmosphere dimension, and natural scenery dimension. Firstly, from the analysis of high-frequency words, word clouds, and network semantics, it is found that the word “tour guide” appears most frequently in group tour companies. Therefore, training for tour guides is very important and should be prioritized. Among them, “explanation” and “culture” also appear frequently. Therefore, the training of tour guides should not only focus on service etiquette but also strengthen their cultural knowledge of tourist destinations and enhance their ability to explain tourist destinations.

Secondly, the appearance of high-frequency words such as “elderly” and “children” indicates that there are more and more tours for the elderly, families, and parent-child groups. Therefore, tourism companies need to be equipped with relevant medical staff ahead of time, so that they can solve any physical problems that may arise for the elderly or children during the trip. This can provide a sense of security for group tourists and increase user loyalty.

Finally, the group atmosphere of group tourists is also particularly important. As mentioned in the three

dimensions of cognitive image, the group atmosphere can increase the bond between group members. A pleasant, humorous, and relaxed group is more conducive to experiencing and appreciating natural scenery. It can leave a good impression and enhance tourists' loyalty.

5.3. Research limitations

Firstly, the article only adopts online tourism evaluation data from group tourists to the Sanya scenic area, and the data collected is relatively homogeneous. Future research can increase the diversity of data channels, such as offline questionnaire surveys and destination interview studies.

Secondly, the analysis and verification methods used in the article are limited to big data text analysis and network semantic visualization. Future analyses can utilize relevant software such as SPSS to add confirmatory factor analysis, making the overall analysis more scientific, reasonable, and complete. This will enable a more comprehensive understanding of group tourists' perception of the tourism image of Sanya scenic areas.

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Analysis of Differences in College Students' Learning Effects between Online and Offline Teaching Modes

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Abstract: With the development of information technology, online teaching is becoming increasingly popular in college students' education, which forms a diversified teaching system together with offline teaching. This paper analyzes the learning effect of college students in the mode of online and offline teaching, from the aspects of learning investment, time, concentration, participation, and knowledge mastery. By using the method of comparative research, the author puts forward a perfect method, aiming at improving the initial effect of college students' learning and solving some problems in the learning effect caused by the single teaching mode.

Keywords: College students; Learning effect; Online; Offline; Differences

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1. Introduction

Relying on the rapid development of the Internet, online teaching breaks the boundaries of time and space and provides a new way for college students to learn. After years of precipitation, the offline teaching mode, with its unique advantages of face-to-face interaction, still occupies an important position in education. The in-depth exploration of the differences in college students' learning effects under the online and offline teaching modes is helpful for educators to accurately grasp the teaching direction and provide strong support for improving the teaching system and teaching quality.

2. Multi-dimensional differences in college students' learning effects

2.1. Differences in learning engagement

In the online learning environment, there is no strong learning atmosphere in the traditional classroom. Students do

not focus on the lecture together and actively interact, which is difficult to stimulate students' learning enthusiasm and competitive consciousness. Online learning mainly relies on students to arrange their own learning time and progress, and lacks real-time supervision and management by teachers. Some students are prone to procrastination, laziness, and other behaviors, resulting in insufficient learning input. While watching online courses, some students frequently switch pages to check social information, play games, etc., and are unable to fully devote themselves to their studies.

In the offline classroom environment, students learn together in the same space, and each other's focused attitude and positive performance will form an invisible pressure and motivation, prompting students to be more engaged. Teachers can timely pay attention to students' learning status through eye contact, classroom questions, and other ways, remind and supervise students who are not paying attention, and improve students' learning engagement. In the classroom discussion, students actively participate and have a collision of ideas, which enables them to understand and master knowledge more deeply, and their learning involvement is significantly higher than that of online learning.

2.2. Differences in learning time

Online learning time has a strong flexibility; students can choose their study time according to their own life and study arrangements, which is very convenient for some students with special circumstances or personal habits. Students who often stay up late can study at night when they are full of energy and schedule other activities during the day. However, this kind of flexibility also easily leads to the fragmentation of learning time. Students may use spare time, such as recess and lunch break, to study, and each study time is short, which is difficult to form a systematic learning process and is not conducive to in-depth understanding and mastery of knowledge. Due to the lack of clear time limits and regular learning arrangements, some students may have insufficient learning time, and the total time may be less than that of offline learning.

The time for offline learning is fixed and focused, usually arranged according to the school schedule, with a clear class time and recess time each day. This arrangement is in line with the learning habits and biological clocks of most students, and can help students establish a stable learning rhythm and ensure sufficient learning time. Students attend classes on time every day and have a proper rest time in the middle of each class, which is conducive to students maintaining a good learning state and improving learning efficiency. Moreover, fixed learning time is also convenient for teachers to carry out teaching management and organize teaching activities.

2.3. Differences in learning concentration

When learning online, students face many distractions. In the family environment, there may be interference such as family activities and TV sounds, which can easily distract students. In the online world, social media, online games, and short videos are full of various temptations, and students are easily affected by these factors in the learning process, resulting in a decline in learning concentration ^[1]. Network problems are also an important factor affecting the concentration of learning. Network instability, stutters, network interruptions, and other situations will interrupt students' learning ideas, affect the coherence and fluency of learning, and make it difficult for students to maintain a high degree of concentration. When some students watch live online courses, the sound and picture are not synchronized due to the network delay, and they need to constantly adjust and wait, which affects their learning

concentration and experience.

The offline learning environment is relatively quiet, and the school's classrooms, libraries, and other places have a good learning atmosphere, which can reduce external interference. In class, teachers can directly manage students' learning behaviors and timely stop unfocused behaviors such as talking to each other and using mobile phones to ensure that students can focus on learning content. Face-to-face teaching enables students to feel the teaching charm and knowledge attraction of teachers more intuitively, which helps to improve students' learning concentration. In the experimental class, students focus on the experimental operation, observe the experimental phenomenon, and deeply understand the experimental principles and knowledge under the guidance of the teacher, with a high concentration on learning.

2.4. Differences in learning engagement

The interactive ways of online learning are relatively limited, mainly through bullet screen, message, even chat, and other ways of interaction, which are not as good as offline learning in real-time and cannot achieve positive interactive effects. Some students may be worried about network problems, embarrassed to speak, and other reasons, and have low enthusiasm to participate in interaction, resulting in low participation in learning [2]. Group cooperation in online learning is difficult, communication between members is inconvenient, and it is difficult to carry out effective collaboration and communication, which affects students' sense of participation. In some online discussions, students simply express their views, lack in-depth discussion and communication, and fail to give full play to the advantages of interactive learning.

In offline learning, there are frequent interactions between teachers and students and between classmates. In class, students can raise their hands at any time to ask questions and have face-to-face communication with teachers. In group discussions, students sit together and are able to fully express their ideas, listen to the opinions of others, and solve problems together. This rich and diverse interactive way can stimulate students' learning interest and enthusiasm, and improve students' learning participation. In the classroom debate activities, students actively participate and express their opinions. Through fierce debate with opponents and close cooperation with teammates, they not only deepen their understanding of knowledge but also improve their communication skills and teamwork ability.

2.5. Differences in knowledge mastery

Due to the lack of face-to-face interaction and timely feedback in online learning, students may encounter difficulties in the process of understanding knowledge and cannot get timely guidance and help from teachers, resulting in deviations in understanding. Although online teaching platforms usually provide functions such as course playback to facilitate students' review, students may lack systematic and targeted review, do not know the key points and difficulties, and the review effect is poor [3]. When learning some abstract concepts and theories, students may not be able to fully understand them through online courses, and they do not communicate with teachers in time, resulting in a poor grasp of knowledge.

In offline learning, teachers can adjust teaching methods and progress in time according to students' responses and questions in class to help students better grasp knowledge [4]. In the review stage, teachers will systematically sort out knowledge points, emphasize key points and difficulties, provide students with targeted review guidance, and

help students build a complete knowledge system and improve knowledge mastery. In the review class, teachers help students consolidate what they have learned and deepen their understanding and memory of knowledge by explaining typical examples and having students summarize knowledge.

3. Strategies to improve college students' learning effects

3.1. Constructing a mixed teaching mode

The blended teaching mode organically integrates the advantages of online and offline teaching to maximize the teaching effect. In terms of time allocation, teachers can upload pre-made teaching videos on online teaching platforms such as Superstar Learning Pass, which cover the basic concepts, principles, and other basic knowledge of the course, and set corresponding online tests, so that students can check their mastery in time after learning. In class, students are divided into groups to carry out in-depth discussions on difficult problems in online learning. Representatives from each group are elected to make speeches, and teachers make comments and summaries. In this way, students' thinking can be stimulated and their learning participation can be improved. In terms of content arrangement, the content with strong theory and fixed knowledge points is suitable for online teaching. Students can watch the teaching video repeatedly to deepen their understanding of the knowledge. For the practical content such as experiment class and course design, which requires on-site demonstration and guidance, offline teaching mode should be adopted so that students can master the skills in actual operation [5].

3.2. Improving students' autonomous learning ability

Teachers can guide students to make scientific and reasonable learning plans, arrange daily learning time and tasks reasonably, make weekly learning plans according to the class schedule, reasonably allocate tasks such as preview, review, homework, and reading relevant materials to daily time, and strictly follow the plan. Teachers can also encourage students to develop the habit of regular summary and reflection, summarize their learning situation every week, analyze their problems and shortcomings in the learning process, and timely adjust learning methods and strategies. Students set clear learning goals and incentive mechanisms to motivate themselves, break big goals into small goals, and give themselves a small reward for completing each small goal. Students participate in study groups, supervise each other with classmates, create a good learning atmosphere, and improve their self-discipline.

3.3. Optimizing the allocation of teaching resources

Schools and teachers can collect and sort out all kinds of high-quality online teaching resources, combine the actual teaching situation of schools and teachers' teaching experience, develop teaching resources with the characteristics of the school, integrate these online and offline resources, and establish a unified teaching resource library, which is convenient for students to obtain and use at any time. When explaining abstract theoretical knowledge, online animation demonstration, virtual simulation experiment, and other resources can be selected to help students better understand and master the knowledge. In the practice of teaching, we can make full use of the school's laboratory, practice base, and other offline resources, so that students can improve their ability in practical operations. For students with strong learning ability, we can provide some advanced academic research reports, relevant materials of

discipline competitions, and other expanded learning resources to meet their learning needs. For students with learning difficulties, we can provide some basic knowledge explanation videos, tutoring materials, etc., to help them fill the knowledge gaps and improve their academic performance.

4. Conclusion

Through the above analysis, it can be seen that although online teaching has high flexibility, it is often insufficient in learning engagement, concentration, and participation, and the effect of knowledge mastery is easily affected by the lack of interaction. With good classroom atmosphere, real-time supervision, and frequent interaction of teachers, offline teaching has outstanding performance in learning commitment, concentration, and knowledge mastery, but it is not flexible in time arrangement. Constructing a mixed teaching mode, improving students' autonomous learning ability, and optimizing the allocation of teaching resources can narrow the gap between them to a certain extent and improve the overall learning effect.

Disclosure statement

The author declares no conflict of interest.

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Mirror of Art: The Evolution of Humanism Before Modern Western Society

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Abstract: This study examines how artistic production and ideological change are related in pre-modern Western social formations. It analyzes the characteristics of art in various historical periods to show how art practices shape mainstream ideologies within specific social structures. The focus is on the symbolic codes of ancient artworks and their cultural contexts and how these relate to shifts in ideological paradigms. The paper uses art history, conceptual history, social anthropology, and philosophical hermeneutics to build a theoretical framework for analyzing art and ideology, emphasizing art's role as a material carrier of social consciousness in recording history and promoting conceptual innovation.

Keywords: Ideological transformation; Pre-modern Western society; Sociology of art; Conceptual history research

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1. The interweaving of art and humanism

1.1. Art as a carrier of humanism

Art is closely related to historical events. Ancient art reflects society and thoughts. Archaeological discoveries show that artworks reveal social structures and daily life. Primitive art practices usually had utilitarian purposes. For example, cave paintings and painted pottery patterns demonstrated human needs for survival resources. The frog-shaped and fish-shaped patterns embodied primitive reproductive worship. These totem symbols were related to the fertility worship in matriarchal societies, reflecting the ancestors' thoughts on the continuation of the population. The decorative patterns of reproductive worship on pottery indicated that primitive art transcended pragmatism and constructed a spiritual expression system.

1.2. The reflection of humanism in Western art history

Ancient Egyptian civilization is an important source of the development of Western art. Its art forms, including

pyramids, temple reliefs, and tomb art, embody the dual characteristics of eternity and stylized expression. The creation strictly follows sacred geometry and religious norms. The Giza Pyramid Complex and the Sphinx showcase the eternity of pharaonic power and the anthropomorphic characteristics of Egyptian art, embodying strict geometric proportions and symbolic meanings. The Abu Simbel Temple Complex combines political and religious functions. The seated statue of Ramses II strengthens the divinity of the ruler through stylized modeling, reflecting the pursuit of eternal order in ancient Egyptian society. The figures follow specific visual norms.

2. Art and philosophical thoughts in the classical period

2.1. The rise of ancient Greek art and humanism

During the ancient Greek city-state period, art practices and philosophical thoughts formed an intertextual relationship. Plato's "Theory of Ideas" proposed in "The Republic" profoundly influenced the concept of art creation. He believed that the essence of beauty lies in mathematical proportional relationships rather than surface imitation^[1-5]. This rationalist aesthetic orientation gave birth to the three major orders of Greek classical architecture: the robust and simple Doric order, the elegant and refined Ionic order, and the magnificent and elaborate Corinthian order, which together constructed the basic paradigm of Western architectural aesthetics.

The Parthenon, a model of the Doric order, with the application of the entasis curve of its columns and the slightly convex base molding, not only reflects the ancient Greeks' profound understanding of visual correction techniques, but also its design and construction techniques, such as the use of marble and fine carving techniques, make it the pinnacle of ancient Greek architectural art. This creative approach that combines mathematical precision and aesthetic perception symbolizes a significant leap from empirical accumulation to theoretical deepening in art practice.

The artistic shift in the Hellenistic period reflected the changes in social trends of thought. With the disintegration of the Alexandrian Empire, the ideological collisions between the Epicurean and Stoic schools gave rise to new artistic themes. Sculpture works such as "The Dying Gaul" broke through the classical idealist paradigm. Through the portrayal of dramatic postures and pained expressions, they deeply reflected the social unrest and spiritual crisis in the Hellenistic world.

2.2. Roman art and the symbol of power

The art system in the Roman Empire period exhibited distinct political representation functions. Monumental buildings such as the Column of Trajan constructed a visual chronicle of imperial power through continuous scenes of spiral narrative reliefs. This creative model that integrates artistic narration and national humanism marked the development and maturity of the pragmatic characteristics of Roman art.

In the field of architecture, the Romans innovatively combined the Greek order system with arch technology, developing a composite style with imperial grandeur^[6]. The concrete dome structure (with a diameter of 43.3 meters) of the Pantheon not only represents a breakthrough in engineering technology, but its perfect spherical space is also endowed with the symbolic meaning of "cosmic order". This design concept that unifies material construction and spiritual symbolism has become the most prominent paradigm feature of Roman art^[1-5,7,8].

The proposition "Art is the mirror of civilization" put forward by Seneca in "On Benefits" is fully confirmed in the Pompeii murals. The Fourth Style murals combine architectural perspective with mythological narration. Their

visual expression not only inherits the classical charm of Hellenism but also creates a unique Roman decorative art style system. The evolution process of this art form is essentially a material manifestation of the construction of cultural identity in the Roman Empire.

3. Christian art

3.1. The rise and spread of Christian art

The paradigm transformation of Christian art marked an important turning point in the history of Western visual culture. From the promulgation of the Edict of Milan in 313 AD to Christianity becoming the state religion of Rome in 392 AD, religious art completed the transformation from underground catacomb symbols to imperial official art (**Figure 1**). This transformation not only meant a fundamental reshaping of the image expression system but also, at a deeper level, reflected the profound changes in the humanistic spirit of late Roman society. Symbolic images such as ichthys and Agnus Dei in early Christian art were essentially the products of visually encoding Neoplatonic philosophy and New Testament doctrines. The function of such images transformed from being mere aesthetic carriers to media for spreading religious doctrines, thus constructing a unique iconographic theology framework for Christianity.



Figure 1. Milan Cathedral.

The evolution of basilica-style churches demonstrates the architectural transformation of Christian art. Early churches, such as St. Peter's Basilica, enhanced the drama of religious ceremonies through a longitudinal spatial sequence. It features a rectangular plan, a nave-aisle structure, a semicircular apse, and a symbolic lighting system. The Basilica of San Vitale in Ravenna showcases a composite structure of a centralized and cruciform plan. Its octagonal layout and dome structure embody the early characteristics of Byzantine architecture, and the interior mosaic art reflects the golden age of Byzantine art.

During the Roman Republic period, art practices showed a realist tendency, which was closely related to the Roman social tradition of ancestor worship [9–13]. Portrait sculptures like “The Roman with the Busts of His Ancestors” precisely replicated facial features through the wax-mold technique, forming the verism style. Works

such as “The Baker and His Wife” in Pompeii demonstrated secular characteristics. In contrast to the idealized modeling of the Hellenistic period, they reflect the expansion of the social function of Roman art in the education of civic virtues.

During the Roman Empire period, art theory was influenced by the Stoic school and cosmopolitan trends. The Ara Pacis, through relief narration, portrayed the emperor as the defender of cosmic order, echoing Seneca’s concept of “citizen of the world.” Heidegger criticized Roman humanism, believing that it simplified the concept of human nature into a tool for political governance.

3.2. Religious doctrines and social order in medieval art

Medieval art, based on the Bible and canon law, formed an iconographic theology system. Chartres Cathedral showcases the grandeur and refinement of 12th-century art. Its architectural elements symbolize the Virgin Mary and transform the cosmology of scholastic philosophy into a perceptible space. This practice combines Aristotle’s theory of formal cause and Pseudo-Dionysius’s negative theology. The theory of Hugh of Saint Victor provided the basis for the symbolic system of stained-glass windows.

The evolution of the basilica form demonstrates the spatial politics of Christian architecture. The spatial sequence of the Old St. Peter’s Basilica, including the atrium, nave, transept, and apse, is an important symbol of the Catholic Church and can accommodate 50,000 people. This axial space strengthened the collective identity of believers through processional ceremonies. The Basilica of Sant’Apollinare in Ravenna introduced a centralized plan, and its radial spatial structure metaphorically represents Christ as the center of the universe.

The construction system of Romanesque architecture embodies the technical integration of the Carolingian Renaissance. Its typical features include the mechanical balance system of barrel vaults and buttresses, the enclosed space formed by thick walls and small windows, and the image system of lintel reliefs and capital carvings. The floor plan of Cluny III Church reflects the reinterpretation of classical architectural proportions in the early Middle Ages.

The breakthrough of Gothic architecture lies in the integration of structural rationalism and chromatic symbolism. The flying buttress system and rose windows of Chartres Cathedral, through the lead-inlay technique, showcase the Bible narrative, echoing the image education theory of St. Bernard. The vertical rhythm of Milan Cathedral embodies the transformation of Thomist Trinitarianism into architectural proportion language.

The spatial paradigm of Byzantine art is based on Neoplatonic optical theory. The giant dome (with a diameter of 31 meters) of the Hagia Sophia, through the halo effect created by 40 ribbed vaults and circular windows, materializes the “divine darkness” described by Pseudo-Dionysius. This unique architectural language, which skillfully combines geometry and mysticism, further evolved into a more complex Greek cross-plan layout and five-dome structure system in St. Mark’s Basilica in Venice.

4. Art and humanism in the Renaissance

4.1. The revival of classical culture in Renaissance art

The humanistic turn in Renaissance art was based on the revival of classical philology^[13,14]. Botticelli’s “The Birth of Venus” transformed pagan themes into carriers of Christian allegories through the Neoplatonic image program. The

essence of this “classical rebirth” (*rinascità*) was a creative misinterpretation of Cicero’s rhetoric and Vitruvius’s architectural theory by 14th-century intellectuals in Italian city-states. Alberti, in “On Painting,” not only systematically expounded on perspective but also reduced the formal language of painting to geometry, theoretically proposing perspective for the first time. This marked an epistemological revolution in the mathematization of the cosmic order, rather than just the application of Euclidean optics.

4.2. The embodiment of humanism in artworks

Humanistic art practices made breakthroughs in the field of portraiture. Leonardo da Vinci’s “Mona Lisa,” through the *sfumato* technique, created a “gradual fading” effect, giving the figure’s expression psychological depth. This discovery of individuality dialogues with Petrarch’s self-cognition theory expounded in “*Secretum*.” Michelangelo’s “David,” through anatomical accuracy and heroic proportions (head: body = 1: 8), transformed the ideal aesthetic concept of the Hellenistic period into a monument symbolizing civic virtues.

Raphael’s “Madonna in the Chair” marks the secular transformation of Christian images. Its tondo form is derived from the tradition of classical reliefs, and the intimacy shown in the figure modeling is deeply inspired by the image of the Virgin Mary in Dante’s “*La Vita Nuova*”. This way of humanizing the divine is essentially the visual counterpart of the “inner piety” advocated by Erasmus in “*The Handbook of a Christian Knight*”. It is worth noting that Vasari’s narrative system of the Renaissance, constructed in “*Lives of the Most Excellent Painters, Sculptors, and Architects*,” skillfully integrates the theory of artistic progress with the Tuscan dialect literary movement, jointly constructing the humanistic framework of national art.

5. Conclusion

Art creation coexists with the historical context. From Egyptian murals to Renaissance perspective, the evolution of visual forms reflects the transformation of epistemology. Wofflin proposed the dialectical structure of “Zeitgeist-visual form”, and Panofsky revealed the relationship between the symbol system and the worldview. The social function of art reflects the balance between the sacred and the secular. From the pharaoh worship in ancient Egypt to the art market in the Renaissance, the reshaping of the power structure is accompanied by the transformation of functions. Adorno criticized the institutionalization of art, and problems had already emerged in the Medici family’s patronage system.

The evolution of art styles responds to “tradition and innovation.” The Gothic pointed arch is an improvement of the Romanesque round arch and also a metaphor of scholastic philosophy; the classical revival in the Renaissance is the translation of ancient forms into modern discourses. The awakening of media autonomy in modernist theory can be traced back to Giotto’s planar innovation in painting art. This innovation not only influenced the art development in the Renaissance but also provided a theoretical basis for later modernist artists.

Disclosure statement

The author declares no conflict of interest.

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Research on the Construction and Practice of the “Post-Course-Competition-Certificate” Integration Model for the Course “Creation and Commentary of Tour Guide Speeches” in Higher Vocational Colleges under the Background of the World Skills Competition — Taking Ningxia Vocational College of Finance and Economics as an Example

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Abstract: Taking Ningxia Vocational College of Finance and Economics as an example, this paper discusses the significance of the construction and practice of the “Post-Course-Competition-Certificate” integration model for the course “Creation and Commentary of Tour Guide Speeches” under the background of the World Skills Competition. It analyzes the current teaching status and existing problems of this course, elaborates on the ideas and specific practical paths for the construction of the integration model, including integration measures in aspects such as course objectives, teaching contents, teaching methods, and assessment and evaluation. Finally, it summarizes and reflects on the practical effects, aiming to provide useful references for the teaching reform of relevant courses in higher vocational colleges and better cultivate high-quality skilled talents who can adapt to the development needs of the tourism industry.

Keywords: World Skills Competition; Higher vocational colleges; The course “Creation and Commentary of Tour Guide Speeches”; “Post-Course-Competition-Certificate” integration model

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1. Introduction

In the context of the booming development of the tourism industry today, the comprehensive quality requirements for professional tour guide talents are increasing day by day. As an important platform for demonstrating the vocational

skill levels of various countries, the World Skills Competition plays an important leading role in the teaching of relevant professional courses in vocational colleges ^[1]. The course “Creation and Commentary of Tour Guide Speeches” is one of the core courses in tourism majors and is crucial for cultivating students’ tour guide service skills ^[2]. Taking Ningxia Vocational College of Finance and Economics as an example, exploring the construction and practice of the “Post-Course-Competition-Certificate” integration model for this course under the background of the World Skills Competition will help improve the teaching quality of the course and enhance students’ employment competitiveness, which conforms to the practical needs of talent cultivation in the tourism industry.

2. Analysis of the current teaching status and existing problems of the course “Creation and Commentary of Tour Guide Speeches”

2.1. Current teaching status

Currently, in terms of teaching content, the course “Creation and Commentary of Tour Guide Speeches” at Ningxia Vocational College of Finance and Economics covers the teaching of basic knowledge such as the basic structure of guide words, the key points of creating guide words for different types of scenic spots, and explanation techniques. In terms of teaching methods, various forms such as classroom lectures,, and simulated explanations are adopted, aiming to enable students to master relevant theoretical knowledge and be able to carry out certain practical operations. In terms of assessment and evaluation, students’ course learning achievements are mainly evaluated by comprehensively considering usual assignments, classroom performance, and final examination results.

2.2. Main existing problems

2.2.1. Disconnection between the course and post requirements

Although the course content involves relevant knowledge of Creation and Commentary of Tour Guide Speeches, some parts fail to closely combine with the requirements of the current actual posts in the tourism industry for innovation, personalization of guide word creation, and the appeal of explanations. As a result, it is difficult for students to quickly adapt to the actual work scenarios after graduation ^[3].

2.2.2. Insufficient connection with skill competitions

The World Skills Competition and various domestic tour guide-related skill competitions have strict and cutting-edge competition standards and requirements. However, there are deficiencies in aspects such as the integration of competition items into the course teaching and the cultivation of competition skills, and students’ ability and competitiveness to participate in competitions need to be improved.

2.2.3. Insufficient attention to vocational qualification certificates

During the teaching process, the knowledge points and skill points involved in obtaining tour guide vocational qualification certificates have not been fully integrated with the course learning, resulting in students lacking targeted training in obtaining certificates, which affects their future career development.

3. Ideas for the construction of the “Post-Course-Competition-Certificate” integration model

3.1. Oriented by post requirements

Conduct in-depth research on the actual needs of tour guide posts in the tourism industry for Creation and Commentary of Tour Guide Speeches, analyze the knowledge, skills, and qualities required by the posts, and integrate them into the teaching objectives and teaching contents of the course to ensure that what is learned in the course can be directly applied to post work and achieve seamless connection between the course and the posts ^[4].

3.2. Guided by skill competitions

Draw lessons from competition rules, and scoring standards of the World Skills Competition and high-level domestic tour guide skill competitions, optimize the teaching contents and teaching methods of the course, introduce excellent cases and innovative techniques in the competitions into the classroom, cultivate students’ professional skills that meet the requirements of the competition ^[1].

3.3. Based on vocational qualification certificates

Sort out the examination syllabus of tour guide vocational qualification certificates, clarify the core knowledge points and skill points involved in obtaining the certificates, and organically integrate them with the course teaching ^[4], so that students can simultaneously complete the accumulation of knowledge and skills related to certificate examination during the course learning process, improve the certificate acquisition rate, and enhance their employment competitiveness ^[2].

4. Specific practices of the “Post-Course-Competition-Certificate” integration model

4.1. Integration of course objectives

4.1.1. Docking with post ability objectives

Based on the actual work tasks of tour guide posts, determined that students should possess the ability to accurately create guide words, be able to create high-quality guide words according to different tourist groups and different scenic spot features ^[5]. At the same time, they should have vivid and appealing explanation abilities, as well as good adaptability and service awareness. Incorporate these ability cultivation objectives into the overall objectives of the course ^[6].

4.1.2. Integration of competition skill objectives

Referring to the requirements for the tour guide explanation session in the tourism service event of the World Skills Competition ^[1], such as the accuracy, logic, and innovation of the explanation content, the fluency and vividness of language expression, and the appropriate use of body language, set corresponding course skill objectives, so that students can improve themselves according to the competition standards in their daily learning.

4.1.3. Combination with certificate examination objectives

According to the key points of the examination on Creation and Commentary of Tour Guide Speeches in the tour guide vocational qualification certificate examination, such as the standard format of guide words, the scope of scenic spot knowledge covered, and the control of explanation duration, refine the course objectives to ensure that the course learning is in line with the requirements of the certificate examination.

4.2. Integration of teaching contents

4.2.1. Integration of typical post-work tasks

Introduce typical work tasks of tour guide posts, such as guide word creation before receiving a tour group, the implementation of explanations during the tour group process, and responding to tourists' questions. Design corresponding teaching projects. For example, relying on famous local tourist attractions in Ningxia (such as Sand Lake, Zhenbeibu Western Film Studio, etc.), let students master the skills of Creation and Commentary of Tour Guide Speeches in practice.

4.2.2. Introduction of competition cases and standards

Intersperse excellent guide word cases in the World Skills Competition and important domestic tour guide skill competitions in the teaching contents, analyze their creation highlights and explanation techniques. At the same time, interpret the scoring standards of the competitions in detail, so that students can create and explain guide words according to high standards, such as how to highlight cultural connotations in explanations and how to interact with tourists [7].

4.2.3. Integration of certificate examination point knowledge

Sort out the examination points related to Creation and Commentary of Tour Guide Speeches in the tour guide vocational qualification certificate, and integrate these knowledge points into the daily teaching contents. Strengthen students' mastery of the examination points through forms such as special exercises and mock examinations [8].

4.3. Integration of teaching methods

4.3.1. Project-driven teaching method

Driven by actual tour guide work projects, for example, taking on the task of a three-day tour of a tourist group in Ningxia, require students to complete the design of Creation and Commentary of Tour Guide Speeches plans for the entire itinerary in groups, display and conduct mutual evaluations in the classroom, and finally the teacher gives comments. In this way, students can learn by doing and improve their comprehensive abilities.

4.3.2. Simulated competition teaching method

Regularly organize simulated tour guide skill competitions, completely following the procedures and rules of the World Skills Competition or domestic competitions, so that students can become familiar with the competition atmosphere in the simulated competition environment, exercise their competition skills, discover their shortcomings and make timely improvements. At the same time, cultivate students' competitive awareness and team cooperation

spirit.

4.3.3. Online and offline blended teaching method

Utilize online teaching platforms to upload rich course resources, including excellent guide word examples, video explanations of competitions, and tutoring materials for certificate examinations, for students' autonomous learning. In offline classrooms, conduct practical operations, answer questions and have interactive exchanges to improve teaching effects [8].

4.4. Integration of assessment and evaluation

4.4.1. Multi-subject evaluation

Construct a multi-evaluation subject composed of teachers, part-time enterprise teachers, and students. Teachers evaluate from the perspectives of professional knowledge and skills. Part-time enterprise teachers evaluate students' operational standardization and professional qualities according to the actual post standards. Students can understand the differences between themselves and their peers through mutual evaluation, realizing the comprehensiveness of evaluation.

4.4.2. Combination of process and outcome evaluation

Not only pay attention to students' final guide word creation results and explanation performances, but also attach importance to students' participation, team cooperation ability, and learning attitude in the course learning process. Conduct process evaluation through various aspects such as usual assignments, project completion, and classroom performance, and combine it with outcome evaluation, such as final examinations, to more objectively reflect students' learning achievements.

4.4.3. Integration of post, competition, and certificate evaluation elements

Integrate the work requirements of tour guide posts, such as tourists' satisfaction with explanations, into the assessment and evaluation indicators. Refer to the scoring details of skill competitions, such as the accuracy and fluency of explanations. Combine the scoring standards of vocational qualification certificate examinations, such as the content integrity of guide words, to make the assessment and evaluation more targeted and practical [9].

5. Practical effects of the “Post-Course-Competition-Certificate” integration model

5.1. Obvious improvement in students' professional skills

Through participating in the course learning under the integration model, students can create higher-quality guide words that are more characteristic, meet the needs of tourists, and reflect the cultural connotations of scenic spots in terms of guide word creation. In terms of explanation skills, the appeal and attractiveness of explanations have been significantly enhanced. The number of awards won by students in various levels of tour guide skill competitions has increased.

5.2. Increase in students' certificate examination pass rate

Due to the in-depth integration of the course with the tour guide vocational qualification certificate examination, students are more targeted in the preparation process, have a firmer grasp of the knowledge points and skill points of the examination, and the certificate examination pass rate has been significantly improved compared with the past.

5.3. Enhancement of students' employment competitiveness

Students cultivated under the integration model are more in line with the actual needs of tour guide posts in the tourism industry, possess the knowledge, skills, and qualities required by the posts, and have accumulated certain experience and honors in competitions. They are favored by tourism enterprises in the job market, and the employment quality has improved.

5.4. Optimization of course teaching quality

The teaching contents of the course are more abundant and practical, the teaching methods are more flexible and diverse, the assessment and evaluation are more scientific and reasonable, and the overall teaching quality has been significantly improved.

6. Summary

Under the background of the World Skills Competition, the construction and practice of the "Post-Course-Competition-Certificate" integration model for the course "Creation and Commentary of Tour Guide Speeches" at Ningxia Vocational College of Finance and Economics has achieved certain results and has played an active role in improving students' comprehensive skills ^[10]. In the future, the "Post-Course-Competition-Certificate" integration model should be deepened continuously to cultivate more high-quality tourism professionals.

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Research on the Teaching Reform of Cost Accounting Course Based on Big Data and Artificial Intelligence

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Abstract: With the rapid development of big data and artificial intelligence technologies, the traditional teaching mode of cost accounting course is facing many challenges. This paper deeply analyzes the existing problems in the current teaching of cost accounting course, explores the application value of big data and artificial intelligence in cost accounting teaching, and proposes teaching reform strategies for cost accounting course based on these two technologies. The aim is to improve teaching quality and cultivate cost accounting talents who meet the needs of the times.

Keywords: Big Data; Artificial Intelligence; Cost Accounting Course

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1. Introduction

With the advent of the digital economy era, big data and artificial intelligence technologies have deeply penetrated into various fields of social economy. In enterprise operations, these technologies have not only changed the way of data processing and analysis but also reshaped the cost management model of enterprises. Through the rapid processing and intelligent analysis of massive data, enterprises can achieve accurate cost prediction, dynamic monitoring, and optimal decision-making, thereby enhancing their competitiveness. In this context, cost management has become a key link in the digital transformation of enterprises, and the requirements for cost accounting talents have also undergone great changes.

However, the current teaching of cost accounting course in universities still mainly adopts the traditional mode. The teaching content focuses on theoretical knowledge and basic accounting methods, and the teaching methods mostly rely on lectures. There are few practical links, and there is a lack of connection with actual work scenarios ^[1]. Students trained under this teaching mode often find it difficult to meet the needs of digital cost management in enterprises and have obvious deficiencies in data processing, intelligent analysis, and other aspects. Therefore, the contradiction between the traditional teaching mode of cost accounting course and the development needs of the times has become

increasingly prominent, and reform is urgently needed.

This paper aims to explore an effective path to integrate big data and artificial intelligence technologies into the teaching of a cost accounting course. By optimizing the curriculum content, innovating teaching methods, strengthening practical teaching, and other means, it aims to construct a cost accounting course teaching system that meets the needs of the times.

2. Problems existing in the current teaching of cost accounting course

2.1. Lagging teaching content

In terms of content arrangement, the existing cost accounting textbooks still take traditional cost accounting methods and cost analysis and control theories as the core. They mostly focus on basic accounting models such as the job costing method, batch costing method, and process costing method. The introduction of modern cost management methods like activity-based costing is relatively brief, and even in many courses, due to time constraints, the accounting of activity-based costing cannot be covered. The update cycle of textbooks is long, and the innovative applications of big data and artificial intelligence technologies in the field of cost management have not been incorporated in a timely manner.

This lag in content has caused a serious disconnection between the knowledge learned by students and the actual needs of enterprises. When students enter the workplace and face the cost management systems constructed by enterprises based on big data platforms and the work scenarios of using machine learning algorithms for cost analysis, they often feel at a loss and find it difficult to effectively apply the knowledge learned in class to their actual work. The disconnection between the teaching content and the development of the industry not only affects students' professional competitiveness but also restricts the supporting role of cost accounting education in the industry's development.

2.2. Single teaching method

The traditional teaching mode is dominated by teachers' lectures. In class, teachers impart knowledge, and students passively accept it, lacking effective interaction between teachers and students. During the teaching process, teachers mostly adopt the "cramming" teaching method, focusing on the instillation of theoretical knowledge. They demonstrate cost accounting formulas and analysis processes through blackboard writing or slides, and students mechanically record and memorize ^[2,3]. They have very few opportunities to participate in classroom discussions and express their personal opinions, making it difficult to mobilize their learning enthusiasm and resulting in a dull classroom atmosphere.

At the same time, the practical teaching links are seriously insufficient. Many universities do not have corresponding practical courses. Even if there are, they mostly use traditional paper-based simulated account books as the carrier and set up simple cost accounting cases, lacking a deep integration with the actual business scenarios of enterprises. It is difficult for students to experience the cost management workflow in the environment of big data and artificial intelligence ^[4]. This teaching method is difficult to stimulate students' learning interest and initiative. Students cannot fully exercise their practical abilities, such as data processing and intelligent analysis, during the learning process, and it is even more difficult to cultivate innovative thinking. Against the backdrop of the widespread application of intelligent financial systems in enterprises for cost management ^[5], the single teaching method makes it difficult for students to meet the digital and intelligent work requirements, restricting the improvement of students' professional development potential and comprehensive qualities.

2.3. Weak practical teaching links

In the practical teaching process, it still mainly relies on traditional manual simulated account books and basic financial software operations. Manual simulation training is mostly limited to basic accounting processes such as voucher filling, account book registration, and statement preparation. Although it can help students master the basic operation logic of cost accounting, it is seriously disconnected from the real business scenarios of enterprises and is difficult to reflect the application value of big data and artificial intelligence technologies in cost management.

In terms of the application of financial software, most colleges and universities only require students to operate the basic accounting modules and rarely involve high-level financial systems with functions such as data analysis and intelligent decision-making. Even when practical teaching is introduced, it mostly stays at the simple entry and preliminary calculation of cost data, lacking the design of practical links such as data collection, cleaning, and analysis on big data platforms, as well as using artificial intelligence algorithms for cost prediction and optimization decision-making [6]. Under this teaching mode, students cannot get in touch with the big data analysis tools and artificial intelligence models applied by enterprises and have difficulty forming an intuitive understanding of the intelligent cost management workflow. When students enter the workplace and face the cost management systems built by enterprises based on big data and artificial intelligence, due to the lack of relevant practical experience, they are difficult to quickly adapt to the job requirements and cannot meet the practical ability requirements of enterprises for cost accounting talents in terms of data processing, intelligent analysis, and decision support.

2.4. Imperfect assessment and evaluation system

Currently, most assessments mainly adopt closed-book exams, and the question types revolve around theoretical knowledge and formula applications. They focus on examining students' memory and repetition of cost accounting methods and cost analysis theories, or simply conduct calculations and analyses according to the scenarios given in the book, usually accounting for more than 70% of the total score. This evaluation method simplifies the learning process into knowledge memorization and ignores students' performance in practical abilities such as big data processing and intelligent analysis, as well as innovative thinking.

The assessment of practical links also becomes a mere formality. The scoring criteria for manual simulation experiments and basic financial software operations are single, mostly centered around the accuracy of data calculation results, lacking the evaluation of students' abilities to solve practical problems using big data tools and propose innovative cost management solutions. Such a one-sided assessment and evaluation system cannot comprehensively measure students' learning achievements, is difficult to guide students to attach importance to the cultivation of practical skills and innovative abilities, and is even more unable to select professional talents who truly meet the needs of digital cost management for enterprises.

3. The application value of Big Data and Artificial Intelligence in Cost Accounting teaching

3.1. Enriching teaching content

With the help of the big data platform, teachers can obtain a vast amount of real corporate cost data and typical cases.

For example, manufacturing enterprises optimize supply chain costs through artificial intelligence algorithms, and e-commerce platforms use big data to analyze user behavior and precisely control marketing costs. Integrating these vivid materials into teaching can replace the traditional single theoretical model. At the same time, artificial intelligence technology can dynamically generate diverse cost simulation scenarios, simulating the cost management decisions of enterprises under different operating conditions. This enables students to be exposed to cutting-edge practical content such as cost prediction and intelligent analysis, making the teaching content closely conform to the actual digital operation of enterprises, and significantly enhancing the practicality and pertinence of teaching.

3.2. Innovating teaching methods

By analyzing students' learning behavior data through big data, teachers can accurately grasp each student's knowledge weaknesses and learning preferences, and realize the importance of personalized teaching plans to meet differentiated learning needs. The intelligent tutoring system supported by artificial intelligence algorithms can answer students' questions in real time and provide targeted guidance according to the types of questions, enhancing students' learning autonomy. Meanwhile, virtual simulation experiments use artificial intelligence to construct a cost management simulation environment that highly restores the actual enterprise scenarios. Students can operate big data analysis tools in the virtual space and use intelligent algorithms for cost prediction and decision-making, experiencing the digital cost management process firsthand, which greatly improves the teaching effect and students' learning immersion [7].

3.3. Strengthening practical teaching

By building an intelligent platform that simulates the real operation environment of enterprises, students can participate in the entire process of cost management work. From using big data tools to collect multi-dimensional cost data, to processing information with the help of data cleaning and mining technologies, and then conducting in-depth analysis of cost data through artificial intelligence algorithms, and finally completing cost prediction and optimization decisions based on the analysis results. This process enables students to get rid of the limitations of traditional manual simulation. In the digital and intelligent practical scenarios, students can effectively improve their data processing, intelligent analysis, and practical problem-solving abilities, achieve a deep integration of theoretical knowledge and practical operations, and effectively narrow the gap between classroom learning and actual enterprise work.

3.4. Improving the assessment and evaluation system

With the help of big data technology, it is possible to comprehensively record students' learning behavior data in various links such as classroom interaction, case analysis, and virtual simulation experiments, including participation, operation duration, data processing accuracy, etc. By conducting an in-depth analysis of these data in combination with artificial intelligence algorithms, an intelligent evaluation report covering multiple dimensions such as theoretical knowledge mastery, practical operation ability, and innovative thinking can be generated. This intelligent evaluation method breaks through the limitations of traditional assessment. It can not only more comprehensively and objectively reflect students' learning effects but also, through the analysis of evaluation results, accurately locate the weak links in teaching, providing strong data support for subsequent adjustments of teaching content and optimization of teaching methods, and promoting the continuous improvement of the teaching quality of cost accounting.

4. Teaching reform strategies for Cost Accounting course based on Big Data and Artificial Intelligence

4.1. Teaching content reform

In terms of updating the textbook content, it is necessary to break through the knowledge framework of traditional textbooks and systematically incorporate the application of cutting-edge technologies such as big data collection and preprocessing, artificial intelligence cost prediction models, and intelligent cost analysis systems into the textbook system. Not only should the technical principles be elaborated in detail, but also combined with typical enterprise cases, such as Haier Group using big data to optimize supply chain costs and Huawei using artificial intelligence to achieve dynamic control of R&D costs, to analyze the specific implementation paths of these technologies. At the same time, add highly practical chapters, design cost accounting processes based on big data analysis platforms, and provide experimental guidance on using tools like Python for cost data mining, enabling students to intuitively experience the work scenarios of digital cost management.

In terms of expanding teaching resources, efforts should be made to construct an open cost accounting teaching resource library. On the one hand, widely collect cost management practice cases of well-known domestic and foreign enterprises, covering multiple fields such as manufacturing, the Internet, and finance, to form a matrix of case resources. On the other hand, integrate high-quality cost accounting data sets, such as the publicly available financial data of listed companies and industry cost benchmark databases, and introduce mainstream data analysis software tools like Power BI and Tableau, as well as operation guides for intelligent financial robots. Open these resources to students through an online platform to assist students in independent exploratory learning, making the teaching resources truly a bridge connecting the classroom and the workplace.

4.2. Teaching method reform

- (1) Introduce data analysis software such as Tableau and Power BI, and visualization tools like Python in teaching. Guide students to use technologies such as data cleaning, modeling, and visualization to mine and analyze enterprise cost data, transforming abstract cost theories into practical skills that can be applied. This helps students intuitively present the trends of cost changes and improve their data insight ability.
- (2) Develop an intelligent tutoring system using artificial intelligence algorithms. According to students' learning progress, knowledge mastery level, and weak links, it can dynamically generate personalized learning plans [8]. For example, for students who have difficulty understanding the cost prediction model, the system automatically pushes resources such as intensive exercises and micro-lecture videos, and answers questions in real time, achieving "one-to-one" intelligent tutoring and breaking through the limitations of traditional teaching in terms of time and space.
- (3) Implement project-based learning. Design comprehensive project tasks around actual cost management issues of enterprises, such as the optimization of production costs of a manufacturing enterprise and the control of marketing costs of an e-commerce platform. Students work in groups and simulate the real business scenarios of enterprises throughout the process, from data collection and analysis to the formulation of cost optimization strategies. In the process of solving practical problems, they not only exercise their team collaboration ability but also improve their practical ability to handle complex cost problems using big data and artificial intelligence technologies.

4.3. Practical teaching reform

- (1) Build a virtual simulation laboratory and use big data and artificial intelligence technologies to set up an immersive cost accounting experimental platform, simulating the entire process of enterprises from cost data collection, intelligent analysis, to decision-making optimization. Students can operate intelligent financial systems in a virtual environment, use big data analysis tools to process complex cost data, and accumulate practical experience in highly restored enterprise scenarios.
- (2) Deepen school-enterprise cooperation in practice. Establish internship bases in cooperation with enterprises to create opportunities for students to participate in real cost management work ^[9]. Students go deep into the front line of enterprises, learn their cost management models and application methods of digital tools, and use the knowledge learned in class to solve problems such as cost accounting and budget control in actual projects, achieving a deep integration of theory and practice. This effectively improves their practical operation and practical problem-solving abilities and meets the needs of enterprises for high-quality cost accounting talents.

4.4. Reform of the assessment and evaluation system

In terms of diversified assessment methods, abandon the single summative examination mode and organically combine formative assessment with summative assessment. In formative assessment, add links such as practical operations ^[10], project reports, and group discussions. Practical operations focus on examining students' ability to use big data tools to process cost data, project reports evaluate students' ability to analyze and solve complex cost problems, and group discussions test their team collaboration and innovative thinking, comprehensively covering students' knowledge mastery, practical application, and comprehensive qualities.

Develop an intelligent evaluation system with the help of big data and artificial intelligence algorithms. By collecting students' learning behavior data, such as classroom interaction, assignment completion, and experimental operation in real time, and using machine learning algorithms for in-depth analysis, a multi-dimensional evaluation model is constructed. The system can not only quantitatively evaluate students' knowledge mastery level and practical skill level but also generate personalized evaluation reports, accurately pointing out students' strengths and weaknesses in each link of cost management and providing targeted learning improvement suggestions. At the same time, the intelligent evaluation system can also help teachers dynamically adjust teaching strategies, continuously optimize the teaching process, and effectively improve teaching quality.

Disclosure statement

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Data Center Virtualization and Secure Data Storage Architecture

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Abstract: With the rapid development of data center virtualization, secure data storage has become a crucial issue. This paper aims to explore and design an efficient secure data storage architecture to address the challenges of data security in virtualized environments. The article first analyzes the impact of virtualization technology on data storage security, including data leakage, tampering, and availability issues. Then, this paper proposes a comprehensive secure data storage architecture, which includes data encryption, access control, backup and recovery strategies, and audit and monitoring mechanisms. Through case studies and security performance evaluations, this paper verifies the effectiveness and feasibility of the proposed architecture. Finally, the paper summarizes the research findings and proposes suggestions for future research directions, to provide references for data center managers and policymakers.

Keywords: Data center virtualization; Secure data storage; Encryption technology; Access control; Backup and recovery; Audit and monitoring; Security architecture design

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1. Introduction

1.1. Research background and significance

Data center virtualization is the core of modern IT infrastructure, which optimizes the use of physical servers by creating virtual machines, thereby improving resource utilization and reducing costs. The advantages of virtualization include flexible allocation of resources, cost-effectiveness, system flexibility and scalability, and simplified maintenance and management. However, with the widespread application of virtualization technology, the security of data storage has become particularly critical, as data in virtual environments is more susceptible to unauthorized access and data leakage threats.

1.2. Research objectives and problem statement

The main objective of this study is to identify the need for secure data storage in virtualized environments and

address the shortcomings of existing security architectures. The research will focus on the following issues:

- (1) Clearly define the specific needs for secure data storage in virtualized data centers.
- (2) Evaluate the performance of existing secure data storage architectures in virtualized scenarios.
- (3) Identify and analyze the main challenges faced by data storage security in virtualized environments.
- (4) Provide strategies and solutions for data storage security in virtualized environments, to enhance data protection and reduce security risks.

2. Literature review and theoretical foundation

2.1. Overview of data center virtualization technology

Virtualization technology improves the flexibility and efficiency of resources by creating multiple virtual machines on a single physical server. Key technologies include server, storage, and network virtualization, which together promote dynamic resource allocation and management.

2.2. Basic concepts of secure data storage

The core principles of data storage security cover confidentiality, integrity, availability, and compliance. Practical methods involve data encryption, strict access control, regular backup and recovery mechanisms, and continuous monitoring and auditing.

3. Data storage security needs analysis in virtualized environments

3.1. Identification of data storage security needs

In the virtualized data center environment, the identification of data storage security needs is the cornerstone of building an effective security strategy. The core needs of data storage security include compliance, confidentiality, integrity, and availability. Compliance needs refer to adhering to data protection-related laws and regulations, such as GDPR, HIPAA, etc. Confidentiality ensures that unauthorized users cannot access sensitive data. Integrity needs to ensure that data is not tampered with during storage and transmission. Availability ensures that data can be accessed and recovered in a timely manner under any circumstances ^[1].

3.2. The impact of virtualization on data storage security

While virtualization technology improves resource utilization and flexibility, it also brings new challenges to data storage security. Data transfer between different physical servers during virtual machine migration may face leakage risks. Snapshots and cloning operations may be maliciously exploited due to insufficient isolation, leading to data tampering or loss. In addition, dynamic resource allocation in virtualized environments may lead to inconsistent execution of security policies, increasing the risk of data leakage and unauthorized access.

To address these challenges, a series of measures need to be taken. First, manage virtual machine migration securely, such as using encrypted channels and VPN technology to protect data during migration. Second, manage the migration of storage securely, for example, by adopting manual migration strategies for important data to reduce security risks in the automation process. In addition, monitor the dynamic migration process of virtualized storage to ensure the security of data during migration.

3.3. Security threat modeling and risk assessment

In virtualized environments, the analysis of data storage security needs must cover an in-depth understanding of potential threats and a quantitative risk assessment. The following is a detailed discussion of the threat modeling and risk assessment methods for data storage security in virtualized environments.

3.3.1. Threat modeling construction

The threat model in virtualized environments needs to comprehensively consider security issues during both static and dynamic migration processes. According to research from the CSDN library, security issues and countermeasures in virtual machine migration emphasize the risks of data leakage and service interruption during migration. In addition, the virtualization security risk list and professional security advice provided by Huawei Cloud Community also point out security issues in virtual machine isolation failure and snapshot cloning processes.

3.3.2. Risk assessment methods

Risk assessment should use both qualitative and quantitative analysis to identify and mitigate key security threats in virtualized environments. The following methods combine storage security compliance overviews and professional advice from Alibaba Cloud and Huawei Cloud:

- (1) Asset identification and classification: Identify and classify all data assets in the virtual environment in detail, especially focusing on the protection of sensitive data.
- (2) Threat identification: Use threat modeling tools, such as threat graphs, to identify potential threats such as virtual machine escape and virtual machine isolation failure.

3.3.3. Case study and data support

According to the Alibaba Cloud Table Storage Security Compliance Overview, data storage security in virtualized environments can be ensured through multiple features, including but not limited to compliance certification, access control, data security, network security, monitoring and logging, etc. (Table 1) [2].

The virtualization security risk list and professional security advice provided by Huawei Cloud Community provide practical guidance for assessing security risks in virtualized environments.

Table 1. Potential threats and risk assessment in virtualized environments

| Threat type | Description | Impact | Likelihood | Risk level | Mitigation measures |
|------------------------|--|--------|------------|---|---------------------|
| Virtual machine escape | Malware escaping from virtual machines | High | Medium | Implement strict access control and monitoring | |
| Isolation failure | Insufficient isolation between virtual machines | Medium | High | Strengthen security isolation measures between virtual machines | |
| Snapshot/cloning abuse | Insufficient data protection during snapshot and cloning | Low | Medium | Encrypt and control access to snapshot and cloning | |

| | processes | | | operations |
|------------------------------------|---|------|-----|---|
| Management interface vulnerability | Vulnerabilities in the management interface | High | Low | Regularly update and patch the management interface |

4. Secure data storage architecture design

4.1. Design principles of secure data storage architecture

When designing a secure data storage architecture in a virtualized environment, the core principles focus on ensuring the security, reliability, and maintainability of the system, while considering compliance and cost-effectiveness. The following is a detailed description of the design principles:

Architecture design must comprehensively consider the confidentiality, integrity, availability, and compliance of data to ensure comprehensive coverage of all critical security areas; The selected technological solution should be able to adapt to the constantly changing virtualization environment, including compatibility and support for emerging virtualization technologies; Ensure that security measures do not have a negative impact on system performance without sacrificing security, such as optimizing encryption algorithms and access control processes; The architecture design should support future expansion, including increased storage capacity, computing resources, and network bandwidth, while maintaining the ability to respond quickly to new business demands; The architecture design should support future expansion, including increased storage capacity, computing resources, and network bandwidth, while maintaining the ability to respond quickly to new business demands; Ensure that the architecture design complies with all applicable data protection regulations and industry standards, such as GDPR, HIPAA, etc., to avoid legal risks; Conduct cost-benefit analysis during the design phase to ensure that safety investments provide necessary protection while also being economically reasonable ^[1].

4.2. Data encryption and access control

When designing a secure data storage architecture for data center virtualization, data encryption, and access control are two core components that together ensure data security and compliance.

4.2.1. Data encryption

Data encryption is a key technology for protecting data from unauthorized access. In a virtualized environment, data may face leakage risks during transmission and static storage. To address these risks, strong encryption algorithms such as AES-256 are used to encrypt the data. The encryption process includes selecting the appropriate encryption key, initializing the vector, and ensuring the atomicity of the encryption operation, that is, the data will not be interrupted during the encryption process. In addition, the selection of encryption technology should consider a balance between performance and security, avoiding negative impacts on system performance.

4.2.2. Access control

Access control is a mechanism that ensures that only authorized users can access specific data. Role-based

access control (RBAC) is a common approach in virtualized environments. RBAC ensures that users can only access the data necessary for their work by defining permissions for different roles. When implementing RBAC, it is necessary to consider how to define roles, allocate permissions, and dynamically adjust these permissions based on the organization's security policies [3].

To further enhance security, a combination of attribute-based access control (ABAC) and policy-based access control (PBAC) can be used. ABAC determines access permissions based on user attributes such as department and position, while PBAC controls access based on predefined security policies. These methods can provide finer-grained access control, thereby reducing the risk of data leakage.

When implementing data encryption and access control, it is also necessary to consider key management to ensure the secure storage and transmission of encryption keys. In addition, access control policies should be regularly reviewed and updated to adapt to constantly changing business needs and security threats. Through these measures, secure data storage architecture can effectively protect data in virtualized environments, and prevent data leakage and unauthorized access, while also supporting compliance requirements.

4.3. Data backup and recovery strategies

In virtualized environments, data backup and recovery strategies are key components in ensuring data persistence, business continuity, and disaster recovery capabilities. An effective backup strategy should include regular backups, remote backups, cloud backups, mirror backups, and disaster recovery plans.

- (1) Regular backup: Implement regular backups through automated tools to ensure data consistency and integrity. A backup can be a full backup or an incremental backup, with the latter only backing up data that has changed since the last backup to reduce storage requirements and improve backup efficiency.
- (2) Remote backup: backing up data to remote servers or cloud storage through the network, which helps with data recovery in case of local disasters. Remote backup can reduce the impact of physical damage or theft on data.
- (3) Cloud backup: Utilizing cloud service providers such as AWS, Google Cloud, Azure, etc. for data backup, this method is suitable for secure storage and flexible recovery of large-scale data. Cloud backup provides convenience and scalability while reducing the need to maintain physical storage infrastructure.
- (4) Mirror backup: Create a mirror of the entire disk, including the operating system, applications, and data, for quick recovery to the previous state. Mirror backups are particularly useful in disaster recovery scenarios as they can be quickly deployed to new hardware.
- (5) Disaster recovery plan: Develop a detailed disaster recovery plan, including backup strategies, data recovery processes, and partnerships with professional data recovery service providers. Regularly test the recovery program to ensure successful data recovery when needed.
- (6) Scheduled automatic backup: Set up regular automatic backups to ensure that data is always protected.
- (7) Multiple backup: Using a combination of multiple backup methods (such as local and cloud backup) to improve data security.
- (8) Regular testing of recovery procedures: Conduct regular recovery drills to ensure successful data recovery when needed.
- (9) Strengthen security: Ensure that backup data is encrypted during transmission and storage to protect sensitive information.
- (10) Backup data encryption: Encrypt the backup data to prevent it from being stolen or tampered with during

transmission and storage. This helps to improve the security of data.

4.4. Audit and monitoring mechanisms

Audit and monitoring mechanisms are crucial for identifying and responding to security incidents. All accesses and operations should be recorded in logs for regular review to detect abnormal behavior. Real-time monitoring tools are used to track system status and performance, identifying potential security threats in a timely manner. Anomaly detection is achieved by setting alert thresholds to identify changes in abnormal login attempts or data access patterns (Table 2).

Table 2. Elements of secure data storage architecture design in virtualized environments

| Design element | Description | Implementation suggestions | Compliance considerations |
|------------------|--|---|---------------------------|
| Scalability | Support for dynamic increase of resources | Cloud storage solutions | GDPR |
| Flexibility | Adapt to new technologies and business processes | Multi-VM monitoring tools | NIST 800-53 |
| Maintainability | Simplify maintenance processes | Automated maintenance scripts | COBIT 50001 |
| Data encryption | Encryption of data in transit and at rest | AES-256, TLS | GDPR |
| Access control | Role-based permissions | Integration of RBAC with directory services | GLBA |
| Backup strategy | Combination of full, incremental backups | Regularly test recovery processes | HIPAA |
| Audit monitoring | Record all accesses and operations | SIEM and automated tools | GLBA |

Through these design principles and strategies, a secure data storage architecture that meets business needs and complies with security regulations can be constructed. The design elements in the table provide a comprehensive reference framework for secure data storage architecture in virtualized environments, ensuring the comprehensiveness and practicality of the design.

5. Implementation and evaluation of secure data storage architecture

5.1. Methods of architecture implementation

Implementing a secure data storage architecture involves carefully selecting technology, system integration, and deployment strategies. Technology selection should be based on a comprehensive consideration of performance, cost-effectiveness, and security. For example, adopting high-performance storage solutions while ensuring compatibility with existing systems. System integration emphasizes the collaborative work between components to ensure smooth data transfer and processing. Deployment strategies need to consider geographic distribution, load balancing, and disaster recovery capabilities.

5.2. Security performance evaluation

Security performance evaluation is a key step in measuring the effectiveness of architecture implementation. The evaluation includes encryption efficiency, access control effectiveness, and data recovery capability testing.

Encryption efficiency focuses on the impact of the data encryption and decryption process on system performance. Access control effectiveness is tested by simulating access attempts by different user roles to verify the effectiveness of RBAC policies. Data recovery capability testing is done by simulating disaster scenarios to verify the reliability and efficiency of data backup and recovery processes.

5.3. Case study

Case studies provide practical application scenarios and effectiveness evaluations of architecture implementation. For example, a financial institution has effectively prevented data leakage and unauthorized access by adopting advanced data encryption technology and strict RBAC policies. By comparing the number of security incidents and system response times before and after implementation, the effectiveness of the architecture is significantly proven.

5.4. Discussion and problem-solving

Problems encountered during implementation include technical compatibility, performance bottlenecks, and operational complexity. Solutions involve adopting modular design to improve compatibility, optimizing algorithms and hardware acceleration to enhance performance, and developing user-friendly management interfaces to simplify operational processes (Table 3).

Table 3. Overview of secure data storage architecture implementation and evaluation

| Implementation Element | Description | Technology selection | Performance evaluation | Case study | Problem and solution |
|------------------------|---|------------------------------------|---|---|---|
| Technology selection | Based on performance, cost, and security considerations | High-performance storage solutions | Encryption efficiency, access control effectiveness | Financial institution case | Compatibility issues, performance bottlenecks |
| System integration | Collaborative work between components | Compatibility and synergy | Recovery capability testing | Modular design, optimization algorithms | Deployment Strategy |

Through the above implementation methods and evaluations, the secure data storage architecture can provide strong data protection capabilities in virtualized environments. The table provides an overview, showing the key elements and considerations in the implementation and evaluation process.

6. Conclusion and future research directions

6.1. Research summary

This study proposes an innovative secure data storage architecture specifically designed for data protection needs in virtualized data centers. Through careful technology selection, system integration, and deployment strategies, the architecture has achieved enhanced protection for data confidentiality, integrity, and availability. The main achievements of the research include effective defense against security threats such as virtual machine

escape and data leakage, and the actual effectiveness of the architecture is verified through case analysis.

6.2. Research limitations and future work

Although this study has made certain progress in theory and practice, some limitations point the way for future work. First, the study mainly focuses on virtualized environments, and the applicability to other environments such as private clouds and hybrid clouds needs further exploration. Second, although the performance impact of the security architecture has been evaluated through simulation testing, more data is needed to support the long-term performance in real environments. Future work will extend to include emerging technologies such as the application of artificial intelligence in security monitoring.

6.3. Industry recommendations

For data center managers and policymakers, this study recommends considering security as an important aspect of data center virtualization from the design stage. Regularly conduct security performance evaluations to ensure that security measures can adapt to technological developments and changes in business needs. At the same time, it is recommended to invest in personnel training and new technology research to cope with the constantly changing security threats and challenges. In addition, it is recommended to cooperate with the academic community and third-party security organizations to share security intelligence and best practices, jointly improving the security level of the entire industry.

Through these conclusions and recommendations, this study provides a comprehensive perspective on secure data storage in virtualized environments and offers guidance for future research and practice.

Disclosure statement

The author declares no conflict of interest.

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Problems and Solutions of Safety Production Management of Expressway Maintenance

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Abstract: The safety management of expressways during maintenance is faced with many challenges, which aggravate the safety risk in the maintenance process and affect the overall safety and durability of the road. The detailed analysis of the root causes of these problems can provide a valuable reference for the formulation of follow-up countermeasures. Given the existing problems, the implementation of effective and practical measures has become particularly critical to enhance the effectiveness of safety management and ensure the smooth progress of expressway maintenance operations. This paper discusses several management solutions, aiming to provide guidance and suggestions for relevant industry practices.

Keywords: Expressway; Maintenance; Safety production management; Problem; Solution

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1. Introduction

The maintenance condition of the expressway directly determines the safety level of the road and its service life. As vehicle traffic increases, maintenance tasks become more complex and critical. Unfortunately, in many expressway maintenance projects, the problems of ineffective implementation of safety management systems and insufficient preventive measures are widespread ^[1]. Therefore, it is necessary to conduct a comprehensive discussion on the safety management of the current maintenance operations on the expressway and put forward specific and effective improvement strategies to improve the safety and efficiency of the work.

2. Problems existing in expressway maintenance and safety production management

2.1. Poor management systems

At present, there are some deficiencies in the safety management system of expressway maintenance, which are

mainly manifested as unclear responsibility definition and fuzzy management level. Due to the lack of clarity in the functional scope and authority of managers, the authority and execution of safety management are lacking. In this environment, once there is a problem, the relevant personnel often shirk their responsibilities to each other, and lack the necessary cooperation and support, which affects the overall safety management effect. In addition, the communication channels between senior managers and on-site staff are not smooth enough, and the information feedback mechanism is lacking, which further aggravates the potential security risks. These defects in the system make it difficult for safety work to form effective synergies, and the implementation of a safety responsibility system is not in place, which ultimately makes the actual effectiveness of safety management unsatisfactory and increases the risk of safety accidents [2,3].

2.2. Imperfect operation specifications

Currently, there are obvious deficiencies in the systematic norms and standards in the maintenance work of expressways, which directly leads to the frequent occurrence of non-standard operations in the field operation process. Such informal operation mode not only weakens the overall quality of maintenance work, but also brings risks and hidden dangers to safety production that cannot be ignored. Front-line staff generally have a low awareness of the established operating procedures, poor ability to implement them, and lack detailed operational guidance support, so they are prone to misoperation or improper behavior in the actual execution of tasks [4]. At the same time, due to the lack of clear operational guidelines, it is often difficult for employees to take appropriate measures quickly in the face of emergencies, and this uncertainty further increases safety risks and affects the safe operation efficiency of expressways.

2.3. Insufficient personnel training

In the field of road maintenance, the safety education and training of construction personnel are generally systematic and targeted. Many workers fail to accept comprehensive and in-depth safety guidance and have a vague understanding of potential risks in the working environment, which directly leads to their weak safety awareness [5]. The current safety training mainly focuses on the study of theoretical knowledge but lacks the teaching link closely combined with practical operation. This mode cannot effectively improve the practical operation skills of employees and their ability to respond to emergencies. Due to the lack of such education, front-line workers not only lack effective coping strategies when they encounter safety threats, but also reduce their enthusiasm to comply with safety regulations, which significantly increases the possibility of accidents during construction.

2.4. Adverse climates

Climatic conditions have a significant impact on the safety management of expressway maintenance projects, especially under extreme weather conditions. For example, severe weather conditions such as heavy rainfall, strong wind, and low temperatures often lead to construction machinery failure, thus interfering with the normal operation process [6]. In addition, such adverse weather conditions can reduce workers' productivity, cause delays in project schedules, and increase the likelihood of accidents. Working with obstructed vision leads workers to be prone to bad judgments, which undoubtedly increases the risk of accidents. In addition, the slippery ground caused by climate change or other potentially dangerous factors also increases the security risks of the construction site.

3. Solutions for safety production management of expressway maintenance

3.1. Strengthening safety training

Systematic safety education and training for expressway maintenance and construction personnel is one of the key ways to improve the efficiency of safety management in this field. The first step is to design a scientific and comprehensive training program that covers a wide range of dimensions, such as laws and regulations, operational norms, and emergency handling. Specifically, the training materials need to include the safety regulations issued by the national and local governments, special safety matters to be paid attention to during construction, and ways to identify and prevent common risks, so that every employee can deeply understand and master this knowledge. Secondly, in the process of education, we should not only pay attention to theoretical teaching but also strengthen the practical aspect. Through practical exercises under a simulated real working environment, participants have the opportunity to directly face and solve various emergencies that may be encountered. Such practical activities have a significant effect on enhancing the practical operation skills and quick reaction ability of employees, which helps them deal with accidents more calmly in practical work. In addition, regular safety knowledge competitions and emergency drills are also effective means to enhance the safety awareness of employees. The former can stimulate employees' interest in learning and encourage them to take the initiative to acquire more knowledge about safety; the latter helps to deepen employees' understanding of emergency plans, thus improving the tacit cooperation and response speed of the whole team in critical times ^[7]. Such activities are conducive to the formation of a positive safety culture and encourage each member to pay more attention to their own safety responsibilities. Finally, in order to accurately measure the training results, it is suggested to conduct a questionnaire survey after each course to collect feedback from participants, so as to continuously improve the future teaching content and form. This process not only helps to enhance the relevance and effectiveness of the training activities, but also increases the staff's sense of participation and personal identity in the training program, thereby further stimulating their enthusiasm for learning and responsibility for safe work.

3.2. Improving the management system

Improving the safety management system of expressway maintenance is the key to increasing the efficiency of safety management. The first step is to define the specific responsibilities of managers at all levels and ensure that each manager can find his or her own place in the work safety system. By refining the responsibility distribution table, managers can be clearer about the scope of personal security responsibilities and promote the effective implementation of responsibilities, preventing management loopholes caused by unclear rights and responsibilities. Secondly, the construction of a complete set of safety production responsibility systems is also one of the core links of system construction. The safety responsibility of each position should be accurate to the individual, and a top-down responsibility chain should be formed to ensure that every employee can clearly understand their own safety tasks ^[8]. In addition, management systems should be regularly evaluated and updated in order to better adapt to changes in the working environment and technical conditions. Through the periodic review of the existing system, the shortcomings can be identified and remedied in time, so as to ensure its applicability and implementation effect. In addition, it is also important to encourage front-line employees to actively participate in the system improvement process. Since they have the most direct understanding of the practical problems, their feedback is of great value to further optimize the management system. Establishing an effective communication platform, such as holding regular

staff meetings or consultation activities, so that employees' voices are heard, will help improve the actual effectiveness of the system and its enforcement. Finally, the introduction of external professional consultants or references to industry standards can also contribute to the continuous improvement of the system. The new insights and expert advice provided by these professionals can help companies stay at the forefront of workplace safety management.

3.3. Improving operation specifications

In the maintenance of expressways, the establishment of detailed operation guidelines and standards is the basis of operation normalization and standardization. First, it is necessary to prepare operation manuals based on the characteristics of different maintenance tasks. These manuals should cover specific operating procedures, lists of required tools and equipment, safety instructions, and risk assessment and prevention strategies to provide clear operational guidance for workers. At the same time, in order to facilitate understanding, the manual should also contain easy-to-digest verbal descriptions and graphical instructions to help workers better grasp the key points. Second, regular review and adjustment of the code of practice is essential to maintain its effectiveness. In view of technological progress and changes in the construction environment, the original specifications may gradually lose their applicability. Therefore, it is important to establish a periodic review system, involving professionals and front-line employees, and constantly update and improve the content of the code by collecting feedback and case studies to ensure that it is up-to-date. The implementation of a unified operation process not only can effectively reduce the possibility of accidents but also significantly improve the quality of maintenance work. Consistent operating standards help reduce the incidence of errors and misconduct and enable employees to perform their tasks efficiently within the established framework ^[9]. In addition, the standardized process also helps to strengthen the ability of team collaboration, ensure that maintenance activities can be carried out in an orderly manner, and further strengthen the safety and efficiency of the expressway. More importantly, the improvement of operation standards also needs to be combined with the application of modern information technology.

3.4. Strengthening emergency management

Building a sound emergency management system is significant to ensure construction safety in the maintenance of expressways. First of all, a detailed emergency plan should be developed to deal with various potential emergencies, such as natural disasters (such as heavy rain, strong winds, and snow), mechanical failures, and personnel injuries ^[10]. These plans need to clarify specific procedures for different emergencies, the allocation of responsibilities, and communication coordination mechanisms so that the relevant departments can work together quickly and efficiently in times of crisis. Secondly, holding regular emergency drills is an effective means to improve employees' emergency response skills. By simulating real emergencies, participants can better grasp emergency procedures and improve their adaptability. This will not only increase the safety awareness of individuals but also give management the opportunity to identify problems in existing plans and fix them. In addition, the provision of the necessary emergency supplies and facilities is also a critical component of emergency management. This includes emergency lighting systems, communication tools, first aid supplies, and firefighting equipment, which are designed to enable timely rescue operations when emergencies occur ^[11]. Especially in the face of extreme weather conditions, special emergency plans must be developed to ensure the safety of the construction site, such as specific countermeasures for

heavy rain or snow. In addition, it is particularly necessary to establish an effective information exchange mechanism to report the details of the accident. This helps speed up emergency response and gives stakeholders timely access to the dynamics on the ground to make quick decisions. Strengthening emergency management can not only minimize the damage caused by accidents, but also protect the safety of expressway maintenance projects. Good emergency management is not only a direct reflection of emergencies but also a strong support for daily safety management, which is conducive to ensuring the continuous development of conservation activities.

3.5. Strengthening the supervision mechanism

It is important to construct a perfect production safety supervision system to enhance safety management during expressway maintenance. The first step is to perform regular safety reviews, which is a key step in ensuring the safety of the construction site. By carefully planning the inspection process, managers can fully cover all maintenance projects and construction phases and identify potential risk points in a timely manner. Safety audits should not only pay attention to whether the equipment and materials meet the regulations, but also focus on whether the workers comply with the safe operation procedures to ensure that all work is performed in accordance with the established standards ^[12]. The results of each review should be documented in detail and analyzed in depth so that targeted improvement measures can be taken. Secondly, the application of modern technology can greatly improve efficiency and real-time supervision. For example, the installation of video surveillance equipment in important construction areas enables managers to grasp the safety situation of the site in a timely manner and respond quickly to any abnormal behavior. At the same time, integrating all kinds of safety information with the help of information management systems can help managers quickly assess the overall safety situation, formulate reasonable countermeasures, and improve decision-making levels ^[13]. In addition, encouraging the public and the media to participate in safety management is also one of the effective ways to strengthen the supervision mechanism. By regularly announcing the safety situation of maintenance projects and inviting all sectors of society to jointly supervise, it is conducive to creating a good atmosphere for the whole society to share responsibility. This not only increases the transparency, but also enhances the responsibility of the construction unit, and further promotes the improvement of the level of safety management. Regular training and exchange activities to familiarize relevant personnel with the latest security policies and technological developments are also an indispensable part of strengthening supervision. Through multi-party cooperation, the establishment of a comprehensive safety management system will provide a more solid safety guarantee for the maintenance of expressways.

3.6. Handling security accidents

In the process of expressway maintenance and safety management, it is very important to deal with safety accidents properly. First of all, a detailed accident response plan should be formulated to clearly specify the disposal process of various accidents and the allocation of responsibilities. Such a plan should cover on-site response in emergencies, casualty rescue measures, accident investigation mechanisms, report writing, etc., so as to ensure rapid and effective response in the event of an accident and minimize casualties and economic losses ^[14,15]. Secondly, we must pay attention to the collection and analysis of information in the process of accident handling. Once an accident occurs, on-site evidence should be collected immediately, and detailed investigation and research should be carried out to deeply analyze the causes of the accident, so as to identify possible safety hazards. Through thorough analysis of

accident cases, it can provide a valuable reference for future safety management and prevent similar incidents from repeating. In addition, it is necessary to inform all relevant parties of the results of the accident treatment in a timely manner and carry out safety education training based on actual cases. This not only helps to sum up the experience and lessons, but enhances the safety awareness and vigilance of employees, so that they more strictly abide by the safety norms in their daily work. Finally, it is critical to strengthen communication with local authorities, law enforcement agencies, and the media to ensure an open and transparent process. Through rapid and accurate information dissemination, it can not only maintain the good image of the enterprise, but also enhance the public's confidence in the maintenance of the expressway. In the face of possible legal problems, it is necessary to consult with legal advisers in advance to ensure that the entire processing process complies with the requirements of laws and regulations ^[16]. During this period, the proactive attitude of management, the courage to take responsibility, and the effective remedial measures are essential to enhance the external trust in the level of expressway maintenance safety management.

4. Conclusion

Expressway maintenance safety management is critical to ensure smooth traffic and improve maintenance quality. To address the existing challenges, an effective solution must be constructed from multiple perspectives, including but not limited to management strategies, professional training, and standardized operations. By strengthening the safety awareness education of the staff, improving the relevant management system, optimizing the on-site operation process, strengthening the ability to respond to emergencies, strengthening the supervision, and properly handling all kinds of accidents, the possible risk factors in the maintenance process can be significantly reduced to ensure the smooth progress of all kinds of work.

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Research on Secure Data Transmission and Storage Based on Blockchain Technology

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Abstract: With the ongoing advancement of information technology, there has been a growing focus on the security issue of information transmission and storage. Ensuring the secure transmission and efficient storage of data in the digital age has emerged as a critical issue. This article explores innovative solutions based on blockchain technology, aiming to enhance the security and reliability of data management systems. Such systems can accelerate work efficiency across various sectors, safeguard the security of data applications, ensure the rationality of advanced data utilization, and offer fresh insights for the sustainable development and construction of our digital society.

Keywords: Blockchain technology; Data transmission; Data storage; Hash function

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1. Introduction

At present, with the increase in social business activities, the scale of data is also constantly expanding. The transmission and application of various data information are extensive and comprehensive, aiming to ensure the security and reliability of data application in this evolving background. In this development context, blockchain technology, as a decentralized distributed ledger system, has garnered increasing attention and is tamper-resistant. Currently, blockchain technology serves as an innovative approach to mitigating security risks in data transmission and storage, enhancing stability, and preventing data loss and issues ^[1]. This paper emphasizes secure data transmission and accurate processing using blockchain technology. By combining the analysis of the basic characteristics of blockchain technology, we hope to build a verifiable and truly decentralized data management system.

2. Application of blockchain in data transmission

Presently, the volume of data in our country is continually increasing, possessing immense value and providing significant assistance to various aspects of production and life ^[2]. In this regard, it is necessary to combine the basic characteristics of blockchain technology and understand the main trend of data growth in China; on this basis, the use

of blockchain technology to store data reasonably can ensure the security of data storage and data transmission process, ensuring data integrity is crucial to prevent irreversible losses and problems, as it safeguards against data loss risks [3].

2.1. Integrity verification of data transmission

Data must be utilized sensibly and efficiently, necessitating precise transmission. During data transmission, blockchain technology's distributed and immutable traits become particularly evident [4]. Hence, blockchain technology, when applied to data transmission, offers a more robust and comprehensive data integrity verification mechanism, whose significance cannot be overlooked. In the process of the application of blockchain technology, each data transaction will be fully recorded on the distributed ledger in the form of blocks, without any omissions. During data transmission, nodes can contain multiple hash values [5], and each block links to the previous one through its hash value, forming a complete data chain. In the process of data transmission, nodes involved in data transmission can also form accurate verification with the help of consensus algorithms, and can fully guarantee the consistency of data, which is conducive to the efficient application of data. It is important to note that any attempt to tamper with the data may be detected by these systems in a timely manner, and the system can respond immediately to deal with and detect the behavior of data tampering, so as to avoid irreparable serious impact. Therefore, blockchain technology serves as a third-party trust institution in data transmission, ensuring data integrity and comprehensiveness, and effectively preventing potential damage or tampering. This process ensures the safe transmission of information and data, making data transmission and storage more reliable and reducing unnecessary risks as much as possible [6].

2.2. Decentralized control

Promoting data transmission with blockchain technology showcases its unique decentralized control, forming a perfect mechanism that maximizes its positive role and comprehensive value. Eliminating centralized authority allows for comprehensive management of the distributed network. Traditional data transmission relies on other technical means in the process of promotion, however, it fails to ensure security and rationality during the transmission [7], potentially leading to increased issues of omission and data loss. Within this system, the central server or authority verifies and strictly controls the information flow, yet this results in an increasing number of organizations and third parties being exposed to data, thereby hindering strict security management and comprehensive utilization of the information. However, blockchain technology is different from these traditional technologies mentioned above, the blockchain is distributed in the network nodes, which participate in the verification and accurate recording of this data information, so as to eliminate the single point of control that exists in traditional systems. This fundamental feature of decentralization holds immense significance and value for data transmission, as it embodies the fairness and transparency of the process, which can minimize the risk of a single point of failure, and reduce the over-reliance on centralized entities. By effectively utilizing the node consensus mechanism, the security of data applications during transmission is fully ensured, enhancing the consistency of data transmission. This minimizes the risk of any omissions or losses. All staff involved in the data transmission process can gain greater trust, enabling a more seamless realization of data transmission objectives. A more open and democratic model of governance.

3. Effective application of blockchain technology in data storage

Combined with the above, it is evident that blockchain technology, apart from its comprehensive application in data

transmission, also plays a significant and non-negligible role in data storage. The use of blockchain technology to store data can ensure the security and effectiveness of the data, can fully play the value and role of relevant technologies, and avoid irreversible risks in the process of storing data and data loss problems, affecting the value of these data and reasonable applications [8].

3.1. Distributed storage

In the field of storing a large amount of data information, the application of blockchain technology cannot be ignored. Blockchain technology, with its distributed storage mechanism, offers new opportunities for the storage and management of data information, providing a revolutionary solution to the problem. This represents a major innovation in the field of information data storage. In the process of data information storage, the traditional centralized storage system is commonly used, thus posing risks of data loss and issues related to a single point of failure. When these problems arise, the impact is severe, dealing a significant blow to the value of the data itself. Blockchain technology enables a novel approach to distributed data storage, distinct from traditional methods. This advanced technology facilitates decentralized storage by distributing data across numerous nodes, ensuring enhanced security and transparency. In the network, each node saves complete data copies, and the application effect is ideal. It should also be noted that the distributed storage method, with the help of smart contracts and decentralized protocols, can ensure the integrity and security of data applications, as well as the data involved. Distributed storage systems like HBase and Hive implement robust data recovery strategies. For instance, in a distributed storage environment with 16 physical servers, each hosting multiple virtual machines [9], the integrity of HBase and Hive databases can be maintained by backing up physical servers, analyzing block file structures, and carefully piecing together and validating block files before importing them back into the databases. Effective implementation of this distributed storage method can significantly enhance the application efficiency of these data, while their robustness and anti-attack performance also experience rapid development and progress. This results in enhanced accessibility and more prominent availability of the data. Therefore, we must pay attention to the improvement of the distributed storage of these data, and change the backward storage technology means through the relevant technologies and methods of distributed storage, reflecting the efficient development of data technology storage and application.

3.2. Security and scalability

Blockchain technology, unlike previous technologies, offers a multitude of advantages and values. Among these, security and scalability stand out as particularly significant. For instance, its decentralized nature ensures that transaction records are immutable and transparent, enhancing security. Additionally, blockchain's architecture allows for increased scalability by adding more network nodes, enabling it to handle large volumes of transactions more efficiently. In data storage, a well-designed blockchain application system can further emphasize its security and scalability, playing a crucial role. Blockchain leverages cryptographic techniques, hash functions, and asymmetric encryption algorithms to ensure the confidentiality and integrity of data, as evidenced by its application in financial industries and other sectors, but also makes these data more complete [10]. Smart contracts and distributed consensus mechanisms, once effectively implemented, can further bolster the consensus mechanism applied to these data, playing a crucial verification role and yielding positive outcomes. During the actual application of these data, the promotion of these technologies, coupled with various preventive measures, can effectively thwart malicious tampering and mitigate

undesirable outcomes or unauthorized access as far as possible. This form obviously forms a comprehensive protection for this data information, which can effectively improve the application security of data information. After many practices, the application of blockchain technology has formed a perfect security framework, which can make the data in the process of storage and transmission comprehensive and provide more adequate and reliable protection ^[11].

At the same time, we must recognize that blockchain scalability hinges on optimizing the distributed node network. During data storage and distribution in blockchain technology, distributed ledger technology will be incorporated. There are multiple nodes in the network, and data is stored in these different nodes. Overall, a decentralized storage structure is formed. The implementation of this storage structure can continuously share the burden of data storage and processing, and can also rapidly improve the scalability of the system, and dynamically increase various nodes required in combination with the development and change of relevant needs. It can realize the flexible adjustment and optimal configuration of the existing system information resources. The purpose of data storage through such measures is to effectively cope with the growing amount of data information and the expanding and evolving scale of data information, while meeting storage requirements without compromising security or performance. While ensuring data transmission security and data storage performance, it can also store a large number of multi-faceted and diversified data information content ^[12].

4. Application of blockchain technology

In the above systematic description of the data transmission and data information storage process, the advantages and value of blockchain technology become evident, enabling the reasonable application of data information and tapping into its application value and underlying potential. In the subsequent analysis, we will delve into the application of blockchain technology and its foundational principles, aiming to enhance our understanding and facilitate more effective execution of various tasks in the reasonable application of these blockchain technologies ^[13,14].

4.1. Integration method of blockchain

The main blockchain network constitutes the core content of the blockchain technology system, responsible for managing the overall distributed ledger and effectively maintaining the consensus mechanism. Its purpose is to enhance efforts in this field, ensuring system application security while fully showcasing decentralized characteristics. The backbone of the system is the main chain, which carries the infrastructure development and construction of the overall blockchain.

In addition to the network of the main blockchain mentioned above, there is a dedicated side chain, the role of the side chain is to accurately handle the security risks in the process of secure data transmission and data storage, with special work responsibilities, and the strategy is an independent blockchain connected with the main chain. Therefore, it also has relatively independent rules and covers smart contracts, which can provide flexibility and efficient preparation for the effective implementation of specific tasks, thereby enhancing the flexibility of the work ^[15].

The customized data transmission function can be perfected in the policy, including the transmission, accurate verification of data, and the establishment of a basic confirmation mechanism. The purpose is to ensure the integrity of these data in the process of transmission, reflecting the reliability of these data. Undoubtedly, the effective implementation of this mechanism can also make the application of various data information in the network more secure and ensure that the flow process can be more stable.

The smart contract deployed on the side chain covers the logic of data processing and transmission, is responsible for the validity and invisible verification of the data, manages the basic rights of each participant, and records key data information when needed. The design of this smart contract results in automatic operation and safe execution in the system.

The implementation of the side chain serves as a storage function, encompassing both the secure storage of these data and the efficient storage of vast amounts of diverse data. By leveraging smart contract data, the distribution of storage across different nodes of the side chain helps ensure data confidentiality and integrity and facilitates a more efficient system, thus providing more stable and reliable data storage solutions.

The main chain and side chain can achieve the goal of interactive development with the help of smart contracts, which are conducive to ensuring the safe transmission and stable storage of data. The verification of key source data and data information is transmitted to the main chain with the help of smart contracts, in the hope that the consistent needs of the system can be maintained. This interaction mechanism can realize the synergistic development of the main chain and the side chain, and ensure the safety and stability of the development and progress of the system.

4.2. Technical details of data transmission and storage

The choice of the hash function is crucial. During data transmission and storage, there is a tendency to utilize hash functions with enhanced security to guarantee efficient data processing in these processes. By applying the corresponding hash function selected, the data block can be hashed, and a fixed-length hash value can be generated. The original data uniquely identified by this hash value can be verified for data integrity, and the data identification can be completed.

5. Conclusion

This paper mainly focused on the role and value of blockchain technology in the safe transmission and storage of data. By applying blockchain technology, a robust and comprehensive data management system can be more effectively established, while the utilization of hash functions and digital signatures with enhanced security further guarantees the secure transmission and storage of data. A substantial and more efficient digital data management system can be built in future development.

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Exploration of the New Way to Use Recessive Educational Resources in Ideological and Political Education in Colleges and Universities

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Abstract: Within the scope of ideological and political work in higher education, potential educational resources—hidden educational paths play an indispensable role. Compared with the direct and obvious form of curriculum teaching, recessive educational resources penetrate students' daily lives more subtly and continuously, quietly encouraging students to establish positive ideas and social responsibility awareness. This paper systematically analyzes the characteristics of recessive educational resources and the challenges encountered in the practice of ideological and political education in colleges and universities and puts forward innovative strategies.

Keywords: Recessive education; Ideological and political education; Application path

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1. Introduction

The continuous progress of society has brought new challenges and opportunities to the field of ideological and political education in universities ^[1]. Although traditional explicit education plays a role in guiding students to establish correct values, its influence is often limited ^[2]. In contrast, as a silent educational force, recessive educational resources continue to impact students' daily lives and have a value that cannot be underestimated in improving students' ideological and political literacy.

2. Characteristics of recessive educational resources

2.1. Imperceptible

One of the characteristics of potential educational assets is their inadvertent educational power, which is reflected in

the small details of daily life and long-term immersion, and has a subtle educational effect on students [3]. Factors such as cultural atmosphere, architectural design, and school motto in institutions of higher learning will gradually penetrate students' values and behavior patterns. Compared with direct and specific classroom teaching, students often do not realize the educational significance in the process of receiving these educational resources.

2.2. Long-term performance

The educational effect of potential educational factors is often not immediately apparent, but through continuous contact and the edification process, the long-term influence is gradually planted in students [4]. This long-lasting effect allows these underlying educational factors to continue to release energy in students' learning careers and personal development. Cultural festivals, traditional festivals, and inspirational stories of alumni in institutions of higher learning, for example, may still have an imprint on students' values and behavior patterns after a long time [5].

3. Problems in the application of recessive educational resources in ideological and political education

3.1. Insufficient development and utilization of recessive educational resources

At present, many institutions of higher education face a significant problem in the field of ideological and political education: insufficient development and application of potential educational resources, especially recessive educational resources [6]. Although campus culture, social practices, and events on and off campus are rich in underutilized educational potential, these valuable resources often suffer from systematic exploration and full use [7]. At the same time, educational practitioners devote more attention to explicit educational resources in daily teaching activities, inadvertently ignoring the great value contained in implicit educational resources, resulting in insufficient integration of these resources in ideological and political education practice, limited scope of application, and failure to fully display their educational influence.

3.2. Difficulty evaluating the educational effect of recessive educational resources

Since the characteristic of recessive educational resources lies in their subtle influence, their educational effectiveness is often difficult to be directly quantified. This evaluation difficulty challenges educators in planning and implementing ideological and political education programs, making it difficult to accurately assess the actual effectiveness of these resources [8]. Due to the limitation of evaluation methods, it is difficult for educators to adjust and optimize the application strategy of recessive educational resources by relying on specific quantitative data or immediate feedback, which indirectly restricts the efficient release of these resources in the field of ideological and political education.

3.3. Low awareness of recessive educational resources among students

For recessive educational resources, students' awareness level is generally low, which hinders the full effectiveness of these resources in the field of education [9]. Many students are not fully aware of the existence and importance of recessive educational resources, lack a deep understanding of their educational potential, or even turn a blind eye to

the implicit ideological and political education implications such as campus cultural activities and traditional festival activities, which is partly due to the hidden nature of these educational resources ^[10].

4. A new way to use recessive educational resources in ideological and political education in colleges and universities

4.1. Constructing campus culture and environmental atmosphere

The campus culture and environmental atmosphere in institutions of higher learning constitute an important part of the hidden educational capital and exert far-reaching influence ^[11]. Unfortunately, in the process of shaping campus culture, many colleges and universities often lack a holistic design and fail to fully tap their inherent potential in the field of ideological and political education. Colleges and universities should be committed to strengthening the construction of campus culture, naturally integrating these hidden educational elements into the campus ecology, and creating a ubiquitous educational atmosphere ^[12].

The specific measures cover the optimization and upgrading of the physical environment of the campus, involving the design of architectural style, landscape layout, and sign guidance system, aiming to convey positive values and profound ideological and political implications. For example, in areas such as the school history memorial hall and the school motto stone tablet, exhibitions and detailed explanations are used to present the glorious historical evolution and fine traditions of the school, indescribably stimulating students' love for the school and sense of social responsibility. In addition, regular planning and implementation of campus activities with educational significance is a key strategy to enhance campus culture. Institutions of higher learning can rely on the background of important historical nodes and traditional cultural festivals to hold red culture commemorative activities, alumni experience exchange meetings, culture and art festivals, etc., in order to enhance students' cognition of social history and cultivate national self-esteem and social responsibility. Thus, higher education institutions can make full use of the potential educational resources of campus cultural ecology and environmental atmosphere, and promote ideological and political education to naturally integrate into students' daily learning and life, so as to achieve the effect of education imperceptibly.

4.2. Strengthening social practice and volunteer service

Participation in social practice and volunteer service is an important way for college students to contact and experience social reality and enrich their life experience, and it also constitutes the carrying medium of invisible educational resources ^[13]. Through these activities, students can penetrate the grassroots of society, experience the current social situation, and then stimulate a strong sense of social responsibility and historical mission. In spite of this, in the current practice of integrating social practice with ideological and political education in higher education institutions, there are still challenges such as the uniformity of practice mode and insufficient combination of practical activities and ideological and political education content ^[14]. In view of this, colleges and universities urgently need to strengthen the overall planning and guidance of social practice activities and volunteer services to ensure that they can be organically embedded in the overall framework of ideological and political education, so as to achieve the ideal teaching and learning effect.

Specifically, when planning social practice courses, institutions of higher learning can focus on topics that are closely related to national policy guidance and social concerns, such as rural revitalization strategy, poverty alleviation and development measures, and ecological and environmental protection. Through these practical

activities, students can not only gain insight into the country's development blueprint and the actual demands of society, but also experience the responsibility of being a member of society in actual operations. For example, when students are involved in rural education support or poverty alleviation projects, they can personally experience the reality of life and the current situation of education at the grassroots level, and have a strong resonance in their inner world, thus strengthening the sense of responsibility and the call of duty to contribute to society. In addition, volunteering is another effective use of invisible educational resources. By encouraging students to participate in community service, environmental protection, social assistance, and other volunteer work, the school aims to lead students to cultivate dedication to altruistic actions and enhance their awareness of social responsibility. Through these experiences of social practice and volunteer service, students can get the baptism of ideological and political education in a real social environment, and enhance their ideological and political literacy and social responsibility.

4.3. Utilizing new media and network platforms

The evolution of information technology makes new media and network platforms the key field of ideological and political education in higher education, and also a major source of potential educational resources ^[15]. In spite of this, colleges and universities are currently faced with several limitations in the application of these new media and network platforms, which are specifically reflected in the uniformity of content presentation, the lack of interactivity, and the separation from students' daily lives ^[16]. In view of this, it is urgent for colleges and universities to explore new strategies for implementing ideological and political education through new media and network platforms in a pioneering way, and adopt a variety of forms and contents, so as to align ideological education work more closely to students' actual life and individual needs.

As a first step, higher education institutions can adopt new media means such as WeChat public accounts, short video platforms, and online forums to promote diverse forms of ideological and political education materials. For example, by creating short videos that combine the core of ideological and political education with students' attention to current affairs and popular culture, the appeal and infectivity of ideological and political education content can be enhanced. In addition, schools should develop and promote ideological and political education online courses and online learning systems, giving students the right to choose and learn independently. Online education environment makes learning unlimited, students can participate in learning at any time, and be deeply involved in the course through online communication, testing, and other ways. This flexible learning mode not only fits the personalized learning needs of students but also promotes the cultivation of independent learning skills and responsibility. Through the integration of new media technology and network education platforms, schools can make hidden education resources naturally penetrate students' daily learning and life, making ideological and political education more flexible and interactive, thus greatly improving its actual effect and social impact.

5. Conclusion

In the field of ideological and political education in colleges and universities, potential educational resources show their unique advantages and great value. Through scientific exploration and effective use of these resources, we can effectively make up for the defects of explicit education and promote the overall growth of students' ideological and political literacy. Looking forward to the future, colleges and universities need to continue to explore and practice such novel approaches to further enhance the application efficiency of potential educational resources, make their

influence in the field of ideological and political education more significant, and provide strong support for the comprehensive development of students.

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A Comparative Study of Eugene Nida's and Lin Yutang's Translation Theories with an Examination of Lin's *Six Records of a Floating Life*

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Abstract: Eugene Albert Nida proposed “Functional Equivalence” as a translation principle, emphasizing that the version’s reception by readers should closely align with the source text’s effect on its readers. Lin Yutang introduced the triple translation principle of “Faithfulness, Smoothness, and Beauty,” advocating for translation as an art. Both Nida and Lin have significantly influenced Chinese translators. However, their distinct eras, cultural contexts, and life experiences have led to evident differences in their translation theories. This study, intended to facilitate a deeper understanding and practical application of their ideas, holds both theoretical and practical significance.

Keywords: Eugene Albert Nida; Lin Yutang; Translation principles; Comparative study

Online publication: March 26, 2025

1. A comparative study of Lin Yutang's and Nida's translation theories

1.1. Similarities in Lin Yutang's and Nida's theories

1.1.1. Consistency of “fidelity, smoothness” and “functional equivalence”

Translation involves transmitting information from one language to another, making the extent to which information is conveyed a central concern in translation research. Both Eugene Albert Nida’s “functional equivalence” and Lin Yutang’s “faithfulness and fluency” prioritize the effective transmission of the source text’s original meaning into the target language [1].

Nida’s definition of “dynamic reciprocity” emphasizes that “translating means translating meaning.” His concept of “dynamic equivalence” focuses on ensuring that the translated meaning corresponds to the original, aiming for equivalent reception of information between source and target texts. Similarly, Lin’s notion of “feeling-tone” aligns with Nida’s “expressive factor.” Both scholars stress that translation not only conveys meaning

but also ensures that the target text reproduces the effect of the source text. Only by achieving this can a translation meet the standards of “fidelity, smoothness, and beauty” while fulfilling the goal of “closest natural equivalence.”

1.1.2. Consistency in their understanding of form

Nida argued that the best translations should not read like translations and that a rigorous translator must seek the closest natural equivalence. He emphasized that because languages differ in form, adaptations in form are necessary to preserve content. The extent of these adaptations depends on the linguistic and cultural gaps between the source and target languages ^[2]. Here, “form” refers to the formal features of the language, which are typically arbitrary and conventional.

In his essay *On Translation*, Lin distinguished between two types of literary works: those rooted in the author’s experience and thought, and those grounded in language itself. Both Nida and Lin recognized the importance of form in translation. Nida contended that translation is always possible unless the form is essential for conveying the message. Lin similarly acknowledged that some literary works are intrinsically tied to the language in which they are written.

1.2. Differences between Lin Yutang’s and Eugene Nida’s theories

1.2.1. Literary-oriented vs. linguistic-oriented

The formation of any translation theory is shaped by its historical and cultural context. Nida’s translation theory is rooted in linguistic research and emphasizes the communicative function of the translated language. He argued that preserving the content of the message often necessitates changes to its form. This focus on linguistic factors reflects Nida’s belief that “any message that can be conveyed in one language must also be conveyed in another,” a perspective likely influenced by his work in Bible translation, where he aimed to make God’s message accessible in all languages ^[3].

In contrast, Lin, as a writer and translator, prioritized the communication of aesthetic concepts in literary translation. His principle of “faithfulness, fluency, and beauty” places significant emphasis on the aesthetic value of a text. Lin believed that translation should be regarded as an art form, with the conveyance of aesthetic qualities as a critical task for translators ^[4]. Consequently, the divergent focuses of their translation theories—linguistic versus literary—stem from their respective backgrounds and areas of expertise.

1.2.2. Traditional study approach vs. scientific study approach

Nida introduced scientific methods into translation studies, grounding his theories in contemporary developments in linguistics, communication theory, information theory, semiotics, and anthropology. He argued that the translation process could be described scientifically, much like linguistics is classified as a descriptive science. According to Nida, transferring information between languages can be systematically analyzed and understood ^[3].

Both Nida and Lin sought to address the longstanding debate between “direct translation” and “literal translation.” Nida resolved this debate by proposing “dynamic equivalence,” shifting the focus from a strict comparison of source and target texts to the reader’s reaction. This provided a practical standard for evaluating translations.

Lin, on the other hand, rejected both “direct translation” and “literal translation” as traditional methods, advocating for a single, appropriate approach to guide translation activities. However, his perspective lacked a specific methodology, resulting in a more subjective and less standardized view of translation. This subjectivity makes it challenging to use his approach as an objective guide for translation practices [5].

2. Appreciation of Six Records of a Floating Life

2.1. Lin Yutang’s view of literature and translation

Lin believed that the ideal prose is one that embodies “the natural rhythm of language.” He creatively translated the Western concept of humor into the Chinese term “幽默” (humor) and, throughout his life, maintained an artistic paradigm characterized by a conversational style, leisurely humor, and a Taoist spirit. This approach reflected his view of literature as a medium for expressing spirituality and light-heartedness. As Lin stated, “A faithful version will not only convey the meaning of the source text, but also its spirit. The version should be faithful to the spirit of the words and their implications. It’s not possible to achieve absolute faithfulness” (On Translation, 1933:14).

Lin’s writing transcends reality, embodying a liberal spirit and the wisdom of “seeing the world with a warm heart and cold eyes.” While he explores themes of confronting life, his work avoids bleakness. Similarly, his discussion of transforming cultural identity refrains from criticism or attacks. Viewing the world’s troubles from a detached perspective, Lin captures their comical and absurd aspects, ultimately pursuing spiritual enlightenment to achieve an ideal state of mind [6].

Lin’s translations are characterized by accessibility, avoiding excessive jargon to ensure comprehensibility for readers with moderate cultural backgrounds. He employed poetic and evocative language, describing nature with phrases such as “chanting with the wind,” “seeing the clouds,” “hearing the rain,” “enjoying the snow,” “gathering the moon,” “admiring the mountains,” and “playing with the water.” This approach infused delicate and moving Oriental moods into his writing, contrasting the fast-paced and competitive modern Western lifestyle.

Rejecting philosophical abstractions and political slogans, Lin’s writing style achieved a harmonious blend of the elegant and the vulgar, free from pedantry. He sought to attract the ordinary toward refinement and elevate refinement to meet the ordinary, thus unifying both elements. His principles of “Lightness,” “Timelessness,” “Sweetness,” “Spirituality,” and “Leisure” collectively defined his notion of “Beauty.”

2.2. The selective adaptation of the original text

Six Records of a Floating Life is an autobiographical essay written by Shen Fu during the Qing Dynasty, consisting of four surviving volumes: *Boudoir Records of Happiness*, *Leisure Records of Interest*, *Troubled Records of Sorrow*, and *Quick Records of Wanderings*. The book chronicles the author’s marital life, family changes, leisure activities, and his observations and experiences during travels. It is interspersed with vivid depictions of mundane yet fascinating details of home life and travel anecdotes. However, capturing the unique charm and unconventional nature of this work in English is a challenging task that not all translators can accomplish [7].

Lin began his translation of *Six Records of a Floating Life* in 1935. The protagonists, Mr. and Mrs. Shen Fu, were ordinary yet refined individuals who did not achieve significant acclaim. Nevertheless, they cherished life, found joy in nature’s beauty—mountains, forests, springs, and rocks—and explored picturesque destinations despite their modest means. Their life, described by the hostess Yun as one of “rice and cloth, and a lifetime of happiness,”

was regarded by Lin as a rare treasure. Lin himself outlined his vision of an ideal life: a study for uninterrupted work, a family providing freedom and comfort, the liberty of a casual home, a circle of close friends, a skilled cook specializing in vegetable dishes, a valuable collection of books, some Ming Dynasty novels, and a garden adorned with bamboo trees and plum blossoms [8]. His ideals closely mirrored the free, leisurely, and unrestrained lifestyle portrayed in Shen Fu's writing.

Lin's philosophy of life is most notably reflected in his literary creation, particularly through his "spirituality theory." He asserted:

"Each person has his own individuality, and the literature in which this individuality is freely expressed without restriction is called spirituality."

Elaborating on the characteristics of "spirituality," Lin added:

"The essential word in spiritual literature is 'truth.' Expressing one's individual spirit leads to truth; achieving truth resembles a ceaseless source of flowing water—unstoppable, day and night. Matters of great importance or minor joys and sorrows can all be articulated with pen and ink. Every sentence must be true, and every sentence should be recitable. The language should not strive for eccentricity but must retain natural elegance, aiming not merely for clarity but achieving it effortlessly." [2]

It is evident that Lin's concept of "spirituality" aligns with the philosophy of open-mindedness, detachment from fame and fortune, optimism, and contentment embodied in *Six Records of a Floating Life*.

2.3. The adaptive selection of the translators to the translated text

2.3.1. Dimension of the language

The adaptive choice of language dimension refers to the translator's "adaptive choice of language form transformation" in various aspects and levels of translation. When Lin discussed the principle of translation, he emphasized that translation should be based on the sentence, rather than the word. According to Lin, the sentence is a structured and organized unit, with the words within it coherently integrated [9].

For example:

"... then put away the little stone incense tripod and tried to crawl in. The shrine was, however, too small for my body by half and managed to sit on the ground, leaving my legs outside. I turned my traveling cap round, using the back to cover my face, and thus sat there listening with my eyes closed, but all I could hear was the whistling of winds blowing by." [5]

This passage describes the scene in which Shen Fu gets lost while searching for his relatives and spends the night in a shrine. The original text primarily consists of short sentences with few connecting words, arranged in a logical sequence of actions and events. By contrast, English is an analytical language that often reflects tense and clarifies logic through grammatical structures such as morphology, word order, and related words. Therefore, applying the structure of Chinese run-on sentences directly to English would create reading difficulties.

As a translator proficient in English grammar, Lin skillfully adds conjunctions such as "and," "however," "thus," and "but," as well as participial phrases like "leaving my legs outside," "using the back," "listening with my eyes closed," and prepositions such as "away," "in," "for," "on," and "with." These additions make the discourse more natural, logical, and coherent [10]. Although the word "shrine" does not appear directly in the original text, Lin

adds it to clarify the location, using “however” afterward to convey the transitive relationship, emphasizing the limited space and the resulting discomfort.

In the original, Shen Fu describes his posture by stating: “with the wind hat on back to cover his face, sitting halfway in the middle and out on his knees.” Lin cleverly adapts this to “sitting halfway in the middle and out on his knees,” where the former represents the cause and the latter the effect. The phrase “using the back to cover my face” is transformed into “all I could hear was the whistling of winds blowing,” seamlessly integrating the sentence structure to achieve logical clarity and fluent articulation. This makes the translation more fluent and natural.

2.3.2. Dimension of the culture

The adaptive choice of cultural dimension requires translators to focus on conveying and interpreting bilingual cultural connotations during the translation process. *Six Records of a Floating Life* contains numerous culturally specific terms that carry a strong Eastern flavor. In the 1930s, Western countries were undergoing industrialization, and many people’s minds were overwhelmed by material pressures. In his translation, Lin sought to preserve as much of the original’s unique Chinese cultural characteristics as possible, aiming to introduce Western readers to the full depth of Eastern aesthetic heritage ^[12].

For example:

“After the drinking of the customary twin cups between bride and groom, we sat down together at dinner...” ^[5]

The “twin cups” refer to an ancient Han Chinese wedding ceremony in which the bride and groom drink together in the bridal chamber. Lin does not merely gloss over this ritual; instead, he provides a detailed explanation, allowing English-speaking readers to fully experience this unique Eastern wedding custom ^[13].

2.3.3. Dimension of communication

In contrast to linguistic and cultural adaptation, communicative adaptation focuses on whether the communicative intent of the original text is faithfully conveyed in the translation ^[14].

For example:

“While we were thus bandying words about, it was already midnight.” ^[5]

The term “leak” in the original refers to a “funnel,” a timekeeping instrument commonly used in ancient times. In this context, “three leaks” indicates that it was midnight. Lin adapts the term to “midnight” to ensure the communicative intent is preserved while making the translation more accessible to the target audience ^[15].

3. Conclusion

In summary, a comparative study of Eugene Nida’s and Lin Yutang’s views on translation reveals that each perspective has its strengths and weaknesses. Lin, as an outstanding writer and translator, approached translation from a literary standpoint. His view is deeply rooted in traditional Chinese aesthetics and literary criticism, emphasizing the transmission of aesthetic elements in the translation of literary works. These translation ideas have positively impacted the high-quality translation of numerous literary works.

Lin’s decision to translate *Six Records of a Floating Life*, a work that aligns with his cultural values, fully reflects his adaptation to the ecological environment of translation. Furthermore, Lin employs various translation

strategies, such as alienation and naturalization, across linguistic, cultural, and communicative dimensions. This approach effectively fulfills the communicative function of translation while also promoting Eastern culture.

Disclosure statement

The authors declare no conflict of interest.

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Research on the Role of Health Industry Development in Promoting Rural Revitalization

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Abstract: The development of the health industry is a crucial factor in promoting rural revitalization, as it directly impacts the well-being and economic stability of rural communities. This paper investigates the current state of the health industry in rural areas, identifying key challenges such as inadequate infrastructure, limited access to healthcare services, and the scarcity of skilled healthcare professionals. The study aims to explore effective strategies to leverage the health industry to enhance rural development. By analyzing various case studies and data from rural regions, the research highlights successful models and practices that have contributed to the growth of the health sector in similar settings. The findings suggest that integrating modern healthcare technologies, improving healthcare accessibility, and fostering public-private partnerships are essential strategies to overcome existing challenges. Additionally, the paper emphasizes the importance of government support and policy reforms in facilitating these changes. The conclusion synthesizes the insights gained from the study, offering practical recommendations for policymakers and stakeholders to implement sustainable health industry practices that align with the goals of rural revitalization. Future research directions are suggested to further explore innovative solutions and assess their long-term impacts on rural communities.

Keywords: Health industry; Rural revitalization; Healthcare accessibility; Public-private partnerships; Policy reforms

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1. Introduction

The health industry has increasingly been recognized as a pivotal element in the overarching framework of rural revitalization. This paper seeks to explore the intricate relationship between the development of the health industry and its impact on rural communities, particularly in enhancing their socio-economic conditions. The emerging concept of the “big health industry” underscores a comprehensive approach that transcends traditional medical care,

encompassing preventive healthcare, wellness, and environmental health, all of which are integral to the sustainable development of rural areas ^[1].

Historically, rural areas have faced significant challenges in accessing quality healthcare services. The inadequacy of healthcare infrastructure, the shortage of skilled healthcare professionals, and limited access to advanced medical technologies have collectively hindered the well-being of rural populations. Consequently, these communities often experience higher morbidity and mortality rates compared to their urban counterparts. Addressing these disparities is essential not only for improving health outcomes but also for fostering economic stability and growth in rural regions ^[2].

The theoretical foundation for integrating the health industry into rural revitalization is well-established. Existing literature emphasizes the importance of holistic development strategies that consider health as a crucial component of socio-economic progress. In line with the principles of urban-rural integration, the development of the health industry in rural areas can lead to the equitable distribution of resources, enhancing both health and economic outcomes. The potential for the health industry to catalyze rural development lies in its ability to create employment opportunities, stimulate local economies, and improve the quality of life for rural residents.

This research identifies several key objectives ^[3]. First, it aims to assess the current state of the health industry in rural areas, highlighting the persistent challenges that impede its development. By examining the existing infrastructure, workforce limitations, and technological gaps, the study seeks to provide a comprehensive overview of the barriers to healthcare access and quality in rural communities. Second, the research intends to explore innovative strategies that leverage the health industry to promote rural revitalization effectively. This includes examining successful models and practices from various rural settings that have demonstrated the potential to enhance healthcare accessibility and quality ^[4].

Furthermore, the study will investigate the role of modern healthcare technologies and public-private partnerships in overcoming existing challenges. The integration of digital health solutions, telemedicine, and mobile health units holds promise in bridging the urban-rural healthcare divide. By connecting rural areas with urban medical resources, these technologies can enhance diagnostic and treatment capabilities, ultimately improving health outcomes in remote locations. Additionally, fostering partnerships between government, private sector, and non-governmental organizations can facilitate resource mobilization and capacity building, vital for the sustainable growth of the health industry in rural settings ^[5].

The importance of government support and policy reforms cannot be overstated in this context. Effective policy frameworks are essential for creating an enabling environment that encourages investment in rural healthcare infrastructure and services. The research will analyze current policies and propose recommendations for reforms that align with the goals of rural revitalization ^[6]. By prioritizing health in rural development agendas, policymakers can ensure that the health industry becomes a driving force for economic and social progress in these areas ^[7].

In conclusion, the introduction sets the stage for a comprehensive exploration of the health industry's role in rural revitalization ^[8]. By addressing the research background and objectives, this chapter lays the groundwork for subsequent sections that will delve deeper into the challenges, strategies, and implications of health industry development in rural settings ^[9]. Through a detailed analysis of case studies and empirical data, the paper aims to provide actionable insights for stakeholders seeking to harness the potential of the health industry to transform rural communities ^[10].

2. Current status and challenges of the health industry in rural areas

2.1. Overview of the health industry in rural regions

The health industry in rural regions represents a complex and multifaceted sector, essential for the transformation and revitalization of rural communities. Historically, rural areas have encountered numerous obstacles in developing a robust health industry, primarily due to their geographical isolation, limited economic resources, and lack of infrastructure. The notion of the “big health industry” extends beyond mere healthcare provision, encompassing wellness, preventative measures, and environmental health, all of which are crucial for sustainable rural development. This comprehensive approach seeks to address the unique health challenges faced by rural populations while promoting broader socio-economic growth.

In rural regions, healthcare services often suffer from a lack of adequate infrastructure. Many rural health facilities are outdated, under-equipped, and unable to provide a full range of medical services. This inadequacy is compounded by the scarcity of healthcare professionals willing to work in rural areas. The rural healthcare workforce is often characterized by an insufficient number of trained doctors, nurses, and specialists, leading to increased workloads and decreased quality of care. The disparity in healthcare accessibility between rural and urban areas is further exacerbated by limited access to advanced medical technologies. Rural health facilities frequently lack the technological resources necessary for accurate diagnostics and effective treatment, putting rural populations at a significant disadvantage.

Furthermore, the health industry in rural areas is hindered by economic challenges. Many rural communities face economic instability, with lower average incomes and higher poverty rates compared to urban centers. This economic disparity makes it difficult for rural residents to afford healthcare services, even when they are available. Additionally, rural healthcare systems often operate with limited funding, restricting their ability to expand services, invest in new technologies, or attract and retain skilled professionals. The economic challenges faced by rural health systems are intertwined with broader socio-economic issues, such as unemployment, education, and transportation, all of which impact the overall health and well-being of rural communities.

Despite these challenges, there are significant opportunities for growth and development within the rural health industry. The integration of modern healthcare technologies, such as medicine and mobile health units, presents a promising avenue for improving healthcare access and quality in rural areas. Medicine, for instance, enables rural communities to connect with urban healthcare providers, allowing for remote consultations, diagnostics, and treatment plans. This technological integration can help bridge the healthcare gap between rural and urban areas, offering rural residents access to specialized care without the need for extensive travel.

Public-private partnerships also play a pivotal role in advancing the rural health industry. Collaborations between government entities, private companies, and non-governmental organizations can facilitate the mobilization of resources and expertise necessary for the development of rural healthcare infrastructure. These partnerships can also drive innovation and provide financial and logistical support for health initiatives tailored to the specific needs of rural populations. By fostering an environment conducive to investment and development, public-private partnerships can help overcome the challenges facing the rural health industry.

The role of government in supporting the health industry in rural areas is critical. Effective policy frameworks that prioritize rural healthcare development are essential for creating an enabling environment. Government policies should focus on increasing funding for rural healthcare infrastructure, incentivizing healthcare professionals to work

in rural areas, and promoting the adoption of modern healthcare technologies. Additionally, policy reforms should aim to reduce economic barriers to healthcare access, ensuring that all rural residents can obtain the medical services they need.

In conclusion, the health industry in rural regions is at a critical juncture, facing significant challenges but also possessing substantial potential for growth and development. By addressing the infrastructure, workforce, and economic issues that currently impede progress, and by leveraging modern technologies and public-private partnerships, the rural health industry can become a driving force for rural revitalization. Through strategic interventions and support from both government and private sectors, the health industry can contribute to the overall well-being and economic stability of rural communities, aligning with the broader goals of sustainable rural development.

2.2. Key challenges facing the health industry in rural development

The health industry in rural areas, despite its crucial role in driving rural revitalization, faces a myriad of challenges that significantly impede its development. One of the primary obstacles is the profound inadequacy of healthcare infrastructure. Many rural regions are plagued by outdated and insufficient health facilities that cannot deliver comprehensive medical services. This infrastructure deficit is not merely a result of financial limitations but also of logistical challenges inherent in remote areas. The geographical isolation of rural communities often leads to higher costs and complexities associated with building and maintaining healthcare facilities, further exacerbating the disparity between rural and urban healthcare services.

A significant challenge that dovetails with infrastructure inadequacy is the acute shortage of skilled healthcare professionals in rural areas. The rural healthcare workforce is often characterized by a scarcity of trained doctors, nurses, and specialists, creating a bottleneck in the provision of quality care. Several factors contribute to this shortage, including the reluctance of healthcare professionals to work in isolated and resource-constrained environments, limited career advancement opportunities, and inadequate incentives. Consequently, rural healthcare facilities struggle with increased workloads and reduced care quality, which in turn, affects patient outcomes and further diminishes the attractiveness of rural medical practice.

Adding to the complexity is the limited access to advanced medical technologies that rural health facilities face. Technological advancements are pivotal in enhancing diagnostic accuracy and treatment efficacy; however, rural areas often lack the necessary infrastructure and funding to integrate these technologies. The absence of modern medical equipment and digital health solutions not only hampers the quality of care but also widens the healthcare gap between rural and urban areas. This technological divide is particularly problematic given the potential of innovations like telemedicine to mitigate geographical barriers and improve healthcare access in rural settings.

Economic challenges also loom large over the rural health industry. Many rural communities experience economic instability, characterized by lower average incomes and higher poverty rates compared to urban counterparts. This economic disparity limits the ability of rural residents to afford healthcare services, even when available. Furthermore, rural healthcare systems typically operate with constrained financial resources, which restricts their capacity to expand services, invest in new technologies, or attract and retain skilled professionals. The economic constraints faced by rural healthcare systems are intricately linked to broader socio-economic issues, including unemployment, education disparities, and inadequate transportation networks, all of which impact the

overall health and well-being of rural populations.

Another critical challenge is the socio-cultural barriers that affect healthcare delivery in rural areas. Cultural beliefs and practices, along with a lack of health literacy, often influence the healthcare-seeking behavior of rural populations. Misconceptions about medical treatments, reliance on traditional medicine, and skepticism towards modern healthcare practices can lead to delays in seeking care and poor adherence to treatment regimens. These socio-cultural factors necessitate culturally sensitive health interventions and education programs to improve health outcomes in rural communities.

Furthermore, the lack of robust public health policies tailored to the unique needs of rural areas presents a significant challenge. While national health policies provide a framework for healthcare delivery, they often fail to address the specificities of rural contexts, resulting in a one-size-fits-all approach that is ineffective in addressing rural health disparities. Policy gaps in areas such as rural healthcare financing, workforce incentives, and the integration of modern technologies must be addressed through targeted reforms that consider the socio-economic and cultural landscape of rural regions.

In conclusion, the health industry in rural areas is confronted with multifaceted challenges that require comprehensive and innovative solutions. Addressing these challenges necessitates a strategic approach that involves improving healthcare infrastructure, enhancing workforce capacity, integrating modern technologies, and implementing culturally sensitive policies. By overcoming these barriers, the health industry can play a pivotal role in promoting rural development and improving the quality of life for rural populations.

3. Strategies for leveraging the health industry to promote rural revitalization

3.1. Innovative approaches to integrating health services in rural areas

Innovative approaches to integrating health services in rural areas are essential to overcoming the persistent challenges that these communities face in accessing quality healthcare. One promising strategy is the implementation of telemedicine and digital health solutions. By leveraging technology, rural areas can overcome geographical barriers and connect with urban medical centers, providing residents with access to specialized care without the need for extensive travel. Telemedicine enables remote consultations, diagnostics, and follow-ups, significantly enhancing the quality and availability of healthcare services in rural settings. This approach not only improves patient outcomes but also optimizes resource utilization by reducing the need for physical infrastructure and on-site medical personnel.

In addition to telemedicine, mobile health units represent an innovative solution to healthcare delivery in rural areas. These mobile units can travel to remote locations, offering a range of services such as preventive screenings, immunizations, and basic medical care. By bringing healthcare services directly to the community, mobile units address the challenge of distance and transportation, ensuring that even the most isolated populations have access to essential health services. This model has been successfully implemented in various regions, demonstrating its effectiveness in increasing healthcare access and reducing health disparities.

Developing community-based health initiatives is another innovative approach to integrating health services in rural areas. These programs focus on empowering local communities to take charge of their health and well-being through education, prevention, and self-care. Community health workers, who are often members of the community themselves, play a crucial role in these initiatives by providing culturally sensitive health education, facilitating

access to services, and supporting patients in managing chronic conditions. By fostering a sense of ownership and responsibility for health within the community, these initiatives can lead to sustainable improvements in health outcomes.

Public-private partnerships are also instrumental in advancing rural healthcare integration. Collaboration between government entities, private companies, and non-governmental organizations can facilitate the development of innovative health solutions tailored to the specific needs of rural populations. These partnerships can drive investment in rural healthcare infrastructure, support the adoption of new technologies, and provide training and resources to healthcare professionals. By pooling resources and expertise, public-private partnerships can create a more efficient and effective healthcare system that addresses the unique challenges of rural areas.

Furthermore, integrating health services with other sectors, such as agriculture and education, can create synergies that enhance overall rural development. For instance, health initiatives can be linked with agricultural programs to promote nutrition and food security, addressing the social determinants of health that contribute to rural health disparities. Similarly, collaboration with educational institutions can support health literacy programs, empowering individuals to make informed health decisions and engage in preventive health behaviors. These integrated approaches recognize the interconnectedness of health and other aspects of rural life, promoting holistic development that benefits entire communities.

Incorporating traditional medicine practices into the formal healthcare system is another innovative approach to consider. In many rural areas, traditional medicine is a trusted and widely used form of healthcare. By integrating traditional healers into the healthcare delivery system, it is possible to bridge cultural gaps and improve trust in modern medical practices. Training traditional healers to recognize and refer cases that require conventional medical intervention can enhance the overall effectiveness of healthcare delivery and improve patient outcomes.

Lastly, policy innovations are critical to supporting the integration of health services in rural areas. Governments can develop policies that incentivize healthcare professionals to work in rural settings, such as offering loan forgiveness programs, housing assistance, and career development opportunities. Additionally, policies that promote the use of technology in healthcare, streamline regulatory processes, and provide financial support for healthcare infrastructure are essential to creating an enabling environment for innovation.

In conclusion, innovative approaches to integrating health services in rural areas require a multifaceted strategy that leverages technology, empowers communities, fosters collaboration, and aligns with broader rural development goals. By adopting these approaches, rural areas can overcome the challenges they face in accessing quality healthcare, ultimately improving the health and well-being of rural populations and contributing to the overall revitalization of rural communities.

3.2. Policy recommendations for enhancing health industry impact on rural revitalization

To effectively leverage the health industry in promoting rural revitalization, comprehensive policy recommendations must be formulated to address the unique challenges faced by rural areas. These policies should be designed to foster an enabling environment for health industry growth, facilitate access to healthcare services, and promote sustainable development in rural communities. An integrated approach, combining regulatory reforms, financial incentives, and strategic partnerships, is essential to enhance the impact of the health industry on rural revitalization.

Firstly, regulatory frameworks should be reformed to encourage investments in rural healthcare infrastructure.

Governments can implement policies that streamline approval processes for healthcare projects, reduce bureaucratic hurdles, and provide tax incentives for private sector investments in rural health facilities. Additionally, creating special economic zones for health-related industries in rural areas can attract businesses and stimulate local economies. These zones could offer benefits such as reduced corporate taxes, subsidies for infrastructure development, and assistance in acquiring land, thereby incentivizing the establishment of healthcare facilities and related enterprises in rural regions.

Secondly, policies that address the shortage of healthcare professionals in rural areas are crucial. Governments should develop targeted programs to recruit and retain healthcare workers in rural settings. These programs might include offering scholarships and loan forgiveness to medical students who commit to practicing in rural areas, providing housing and relocation assistance, and ensuring competitive salaries and career advancement opportunities. Furthermore, establishing rural health academies or training centers can serve as hubs for professional development, equipping healthcare workers with the skills needed to address the specific health challenges faced by rural populations.

Moreover, policies that promote the adoption of modern healthcare technologies are essential for improving healthcare access and quality in rural areas. Governments should invest in digital infrastructure to support telemedicine and mobile health applications, ensuring that rural communities have reliable internet connectivity and access to digital health services. By subsidizing the cost of telehealth equipment and services, policymakers can encourage healthcare providers to integrate these technologies into their practices. Additionally, regulations should be updated to facilitate the use of mobile health units, allowing them to operate across regions without administrative barriers.

Public-private partnerships are instrumental in advancing the health industry in rural areas. Policies that incentivize collaboration between government agencies, private companies, and non-governmental organizations can foster innovation and resource mobilization. For instance, governments can offer matching grants or co-funding opportunities for projects that address rural health needs, encouraging private sector participation. Establishing platforms for knowledge exchange and collaboration between stakeholders can also facilitate the development of tailored health solutions for rural communities.

Furthermore, integrating health services with other sectors, such as agriculture and education, can create synergies that enhance rural development. Policies that support cross-sector collaboration can address the social determinants of health, such as nutrition, education, and living conditions, which significantly impact rural health outcomes. For example, health initiatives could be linked with agricultural programs to promote healthy eating and food security, while partnerships with educational institutions could support health literacy campaigns.

Cultural considerations should also be incorporated into policy frameworks to ensure that health services are culturally sensitive and accessible. Governments can support the integration of traditional medicine practices into the formal healthcare system, recognizing the role of traditional healers in rural communities. Training programs that equip traditional healers with knowledge about modern healthcare practices and referral systems can enhance trust and cooperation between traditional healthcare providers.

Lastly, sustainable financing mechanisms are essential to support the long-term development of the health industry in rural areas. Governments should explore innovative financing models, such as health impact bonds or community health funds, to mobilize resources for rural health initiatives. These models can engage a wide range of stakeholders, including international donors, philanthropic organizations, and local communities, in financing health

projects that align with rural development goals.

In conclusion, enhancing the impact of the health industry on rural revitalization requires a comprehensive policy approach that addresses regulatory, economic, technological, and cultural dimensions. By implementing these policy recommendations, governments can create a conducive environment for health industry growth, ultimately contributing to the sustainable development and transformation of rural communities.

4. Conclusion

The exploration of the health industry's role in rural revitalization has elucidated several critical insights and strategic directions. This research has underscored the profound connection between a robust health industry and the socio-economic upliftment of rural communities. The comprehensive analysis provided in this study highlights the multifaceted challenges that rural health sectors face, such as inadequate infrastructure, workforce shortages, and limited access to advanced medical technologies. These challenges are compounded by economic disparities and socio-cultural barriers, which collectively impede the effective delivery of healthcare services in rural areas.

A key finding of this research is the potential of modern healthcare technologies, such as telemedicine and mobile health units, to bridge the healthcare divide between rural and urban areas. By enabling remote access to specialized care, these technologies can significantly enhance healthcare delivery in isolated regions. Furthermore, the integration of digital health solutions has been identified as a critical factor in improving diagnostic and treatment capabilities, thereby reducing health disparities. The study also emphasizes the importance of developing public-private partnerships to mobilize the resources and expertise necessary for the advancement of rural health infrastructure.

The role of government policy is paramount in creating a supportive environment for the health industry's growth in rural areas. Effective policy frameworks that prioritize rural healthcare development are essential for facilitating investments in infrastructure, encouraging healthcare professionals to work in rural settings, and promoting the adoption of modern technologies. The research advocates for policy reforms that address the unique challenges faced by rural communities, such as economic barriers to healthcare access and the integration of traditional medicine practices into the formal healthcare system.

Looking forward, the study suggests several future research directions to further enhance the impact of the health industry on rural revitalization. One area of interest is the exploration of innovative financing models, such as health impact bonds, to support rural health initiatives. These models could engage a diverse range of stakeholders, including international donors and local communities, in financing projects that align with rural development goals. Additionally, future research could investigate the long-term impacts of integrated health services on rural socio-economic development, providing valuable insights for policymakers and stakeholders.

Another promising avenue for future research is the examination of cross-sector collaborations that integrate health services with other areas such as agriculture and education. By addressing social determinants of health, such as nutrition and health literacy, these collaborations could further enhance rural health outcomes and contribute to holistic community development. Moreover, understanding the role of cultural factors in healthcare delivery and developing culturally sensitive health interventions could improve the acceptance and effectiveness of health services in rural areas.

In conclusion, the health industry holds significant potential to drive rural revitalization through strategic

interventions that address infrastructure, workforce, and technological challenges. By fostering an enabling environment through policy reforms and innovative approaches, stakeholders can harness the power of the health industry to transform rural communities, ultimately achieving sustainable development and improved quality of life for rural populations.

Disclosure statement

The author declares no conflict of interest.

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Research on Hotel Guests' Acceptance of Face Recognition Systems Based on the UTAUT

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Abstract: Integrating emerging technologies into the accommodation industry can provide tourists with a better experience. This paper focuses on guests' acceptance of face recognition systems in hotels and studies the influencing factors that affect guests' choice of staying in hotels with face recognition systems. Through research and analysis, hotels can understand the needs of different guests, make improvements, and more accurately explore relevant markets. At the same time, developers of face recognition systems can also understand the market demands of the accommodation industry, providing professional advice for their entry into the tourism service industry. This paper first reviews the application of face recognition systems in the tourism industry. By combing through relevant literature on the technology acceptance model, the research model of this paper is determined, and hypotheses are proposed. Meanwhile, based on existing literature on face recognition systems, the variable of privacy and security is added to form a research model for the influencing factors of guests staying in hotels with face recognition systems. Finally, development suggestions are put forward for hotels with face recognition system technology based on the research results.

Keywords: Biometric system; Face recognition system; UTAUT; Privacy concerns

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1. Introduction

With the development of society and the continuous update and iteration of emerging technologies, the current era relies on intelligent technology. Intelligent technology has a wide coverage, including content in fields such as the Internet of Things, big data, biometrics, and artificial intelligence. Höjer et al. ^[1] believe that intelligence is not just the independent progress of a certain technology but the result of the joint composition and collaborative use of many technologies. The development of emerging technologies has changed business models and the structures of some industries to a certain extent.

The development of the tourism industry and technological progress are usually inseparable. Since the 1980s, the continuous development of information and communication technology has been changing the development and innovation of the global tourism industry. Since 1995, consumers have increasingly relied on the Internet to obtain travel information. From the traditional tourism industry, combined with comprehensive and complex technological capabilities, it has transformed into today's smart tourism.

The hotel industry is an important part of the tourism industry. With the development of technology, the software and hardware in hotels have been upgraded to a certain extent. Hotels upgraded by technology are collectively referred to as smart hotels. The emergence of smart hotels not only changes the traditional hotel industry model and brings guests a better accommodation experience but also improves hotel management efficiency and reduces human resource costs [2]. Building intelligent hotels is a necessary way to adjust the structure of China's hotel industry and can also enable its sustainable development [3]. It can be seen that smart hotels will occupy a broader space in the future hotel market. Therefore, this paper will conduct research on face recognition systems in the direction of smart hotels in smart tourism.

2. Concept and related applications of face recognition systems

Biometric features are the automatic recognition of a person's identification or a form of identity verification. The research of many scholars divides biometric features into physiological features, such as fingerprints, pupils, irises, faces, etc. Or behavioral features, such as signature handwriting, voices, etc. These biometric features have personal attributes, are unique, and difficult to replicate.

Face recognition technology is a specific branch of the biometric system. Face recognition technology creates a "template" of a face image based on the human face and compares it with previous face images. It identifies and verifies a unique person based on the facial contour of the human body. Different from other biometric information, such as fingerprints, face recognition technology can be used to "passively" identify users. This feature makes it more convenient to collect facial information. Moreover, people feel more relaxed when using face recognition for biometric identification.

Although most biometric systems are for employees, tourism service providers such as the Disney World Resort provide face recognition systems for their guests. In the catering industry, many fast-food restaurants such as McDonald's, Burger King, and Dunkin Donuts have experimented with face recognition systems, aiming to improve their human resource management and provide convenience for employees. Face recognition systems have also been used in the recruitment of the tourism and hotel industries. By identifying the facial expressions of candidates, their emotions can be inferred, and their emotional intelligence can be evaluated. Some scholars have also researched the intention to use face recognition technology in fast-food restaurants and indicated that customers' hedonic motivation has a certain impact on their use of face recognition technology. Compared with the fingerprint recognition system, which was more acceptable to users before and was added to door locks to open hotel rooms, the face recognition system can better avoid contact between customers and items, as well as between employees and customers. At the same time, the face recognition system can more actively capture user information and improve work efficiency.

3. UTAUT technology acceptance model

The Unified Theory of Acceptance and Use of Technology (UTAUT) was developed by Venkatesh et al. [4] based on

eight basic models, including the Task-Technology Fit Model (TTF), Innovation Diffusion Theory (IDT), Theory of Reasoned Action (TRA), Theory of Planned Behavior (TPB), Motivational Model (MM), the Composite Model of TAM and TPB (C-TAM-TPB), Model of PC Utilization (MPCU), and Social Cognitive Theory (SCT). The UTAUT technology acceptance model mainly includes five variables: performance expectancy, effort expectancy, facilitating conditions, social influence, and behavioral intention. The UTAUT model is mainly applicable to exploring why and how individuals use emerging technologies or tools.

Lai [5] added two variables, informativeness and entertainment, based on UTAUT to study the usage intention of mobile-terminal tour guide software users. Xu used UTAUT to explore the usage intention of users of UGC (User Generated Content)-type smart tourism service platforms [6]. At the same time, according to the research needs, the influencing variable of trust level (TR) was added. Araújo, Vila et al. [7] studied spa tourism in Spain based on the UTAUT2 model derived from UTAUT. Some scholars have also researched the intention to use face recognition technology in fast-food restaurants based on UTAUT. Hateftabar [8] used the UTAUT model with personal innovation as a moderating variable to study the effective factors of consumers' intention to book online travel products.

The above-mentioned research results show that the UTAUT model can be well-adapted to the research on users' acceptance and usage intention of emerging technology products in tourism. After comprehensively considering the advantages and disadvantages of each model, this paper selects the UTAUT model to study guests' acceptance of face recognition systems in smart hotels.

3.1. Privacy and security

Through the search and collation of literature, it is found that in the research literature on biometrics and face recognition systems, many scholars have added privacy and security as variables affecting usage intention to adjust the UTAUT model and verified that privacy and security are one of the considerations affecting users' use of emerging technologies. Some research indicates that citizens in different countries and regions have similar concerns about face recognition technology, that is, its convenience and enhanced security.

Morosan [9] proposed that for smart hotels to survive and develop better, one of the basic goals related to consumers that must be achieved is to protect the safety and personal privacy of consumers, that is, hotel guests. In the research on existing literature using the UTAUT model as the research model, it is also found that many scholars will also adjust the original UTAUT model by adding external variables suitable for the research object, according to the specific needs of the research object. Since the research object of this paper is smart hotels with face recognition, based on previous literature research, this paper explores the impact of privacy and security on the usage intention of biometric systems or face recognition systems. Therefore, privacy and security are added as variables affecting usage intention to adjust the UTAUT model, improving the accuracy of the research.

3.2. Research methods and design

This paper uses the research methods of literature research, questionnaire survey, and the combination of theoretical and empirical analysis for investigation and research. Based on the summary of literature review materials and the application of relevant theories combined with the basic framework of the integrated technology acceptance model, four variables affecting guests' intention to use the face recognition system in hotels are constructed, namely

performance expectation (PE), effort expectation (EE), social influence (SI), and facilitating condition (FC). At the same time, through the analysis and research of the literature on face recognition technology, it is found that many scholars regard privacy and security as one of the important variables affecting users' experience of face recognition technology. Therefore, based on the framework of the integrated technology acceptance model (**Figure 1**), this paper adds the explanatory variable of privacy concerns (PC) to test and analyze guests' intention to choose hotels with face recognition technology.

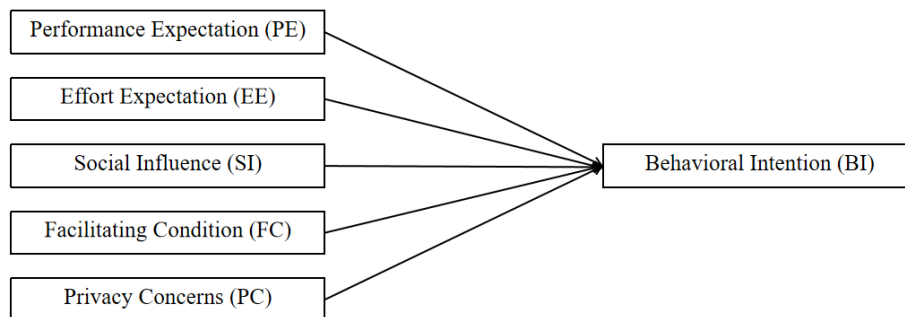


Figure 1. Framework of integrated technology acceptance model.

This study uses the questionnaire survey method for data collection and investigation. The structure and questions of the questionnaire are designed with reference to existing literature. The questionnaire is generally divided into three parts: questionnaire introduction, a scale for measuring the influencing factors of guests' acceptance behavior of face recognition systems in smart hotels, and a survey of the respondents' personal basic information.

3.3. Statistical results and analysis

According to the research object of this paper, the survey objects are determined to be guests who have stayed in smart hotels in Guangzhou that use face recognition systems for room unlocking. This paper conducted a pre-survey in November 2023 and then conducted a questionnaire survey from January to May 2024. The questionnaires were mainly collected through on-site surveys and online surveys using Wenjuanwang. The questionnaires were distributed through travel platforms (Ctrip, Fliggy, Tongcheng Travel) and mainstream social media. A total of 318 questionnaires were collected, with 308 valid questionnaires, and the effective recovery rate was 96.68%.

The data collected were analyzed using SPSS 26.0. The data were analyzed through descriptive analysis, reliability analysis, validity analysis, correlation analysis, regression analysis, and an independent-sample T-test. Under the background that the reliability analysis and validity analysis of this study passed the test and each scale had a good correlation, regression analysis was carried out on the five independent variables of performance expectation (PE), effort expectation (EE), social influence (SI), facilitating conditions (FC), and privacy concerns (PC) on the dependent variable of behavioral intention (BI) using SPSS 26.0. The analysis results are as follows:

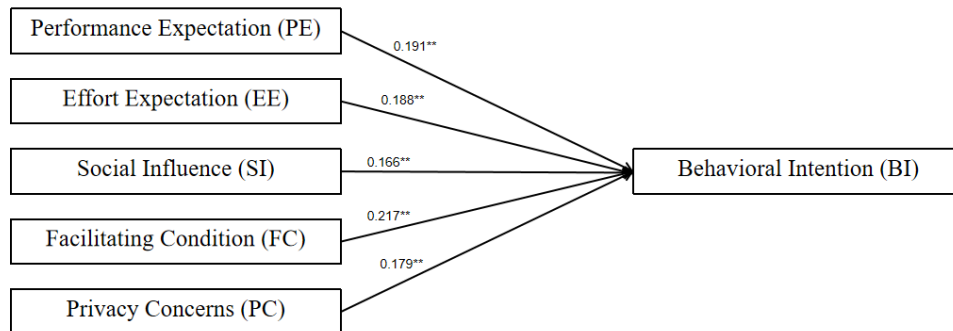


Figure 2. Analysis result of behavioral intention.

The non-standardized coefficients B of all variables are greater than 0, indicating that the five independent variables of performance expectation (PE), effort expectation (EE), social influence (SI), facilitating conditions (FC), and privacy concerns (PC) all have a significant positive impact on the dependent variable of behavioral intention (BI).

4. Conclusions

This paper is based on the UTAUT model scale and adds the impact of privacy and security on usage intention according to the research object of this paper to form the research model and scale of this paper. According to the cultural background of the survey objects, the questionnaire of this paper was formed. The data collected were tested using the analysis software SPSS 26.0, indicating that the scale used in this paper has good reliability and validity. Therefore, it can be proved that the UTAUT model, plus the factor of privacy and security, applies to the research on the usage intention of face-recognition-enabled smart hotels.

Combined with the research results of this paper, it shows that performance expectancy, effort expectancy, social influence, facilitating conditions, and privacy and security are all closely related to guests' choice of staying in smart hotels with face recognition systems. Based on the research objectives and survey results, management suggestions are put forward for current smart hotels with face recognition technology and developers of face recognition technology in subsequent operations.

4.1. Attach importance to the development and research of face recognition technology

Through the analysis of the statistical results of this study, it is found that performance expectancy, effort expectancy, and facilitating conditions all have a positive impact on guests' intention to stay in smart hotels with face recognition systems. It is also found that the variable of facilitating conditions has the greatest positive impact on usage intention. This indicates that the facilitating conditions brought by the face recognition system during hotel check-in account for a relatively large proportion in guests' choice of the hotel. When guests use the face recognition system during

check-in, they need to provide fewer hardware conditions themselves, mainly using the hardware facilities provided by the smart hotel itself. Therefore, if smart hotels hope to attract more guests or increase the repeat-stay rate of guests, they should pay attention to selecting the face recognition technology system and hardware facilities of the hotel, making the technology used in the hotel convenient and fast and in line with customers' usage habits. At the same time, attention should be paid to maintaining the hardware and software facilities of the equipment to ensure the ease of use for customers during the use process, improve guests' satisfaction with the face recognition system, and thus ensure that the face recognition system can meet the usage needs of guests and enhance their willingness to use it.

4.2. Attach importance to the social influence and market promotion of hotels

The survey results of this paper show that social influence has a significant positive impact on the usage intention of smart hotels with face recognition. Therefore, smart hotels should pay attention to the publicity and promotion of this emerging face recognition technology in the hotel to attract more potential customers. Through the research results, it can be found that the age group of guests who have stayed in smart hotels with face recognition systems is concentrated between 18 and 39 years old. This group of young people is the group most affected by social media. Hotels can take advantage of this by launching corresponding promotional activities. For example, launching activities that encourage guests to upload information such as usage evaluations and photos of the face recognition system in smart hotels to online social media or OTA platforms in exchange for coupons and other preferential offers, to encourage guests to share their hotel experiences, which will virtually promote the smart hotel. At the same time, hotels can add the highlight of the face recognition system to various travel reservation platforms and OTAs, so that potential guests interested in the face recognition system can learn about this information and increase their willingness to choose smart hotels. Developers of face recognition technology can also promote their own technology to more hotels with intelligent upgrade needs through the relevant promotion of smart hotels, thereby expanding their business volume.

4.3. Improve the privacy and security of face recognition systems

According to the research results of the newly added moderating variable of privacy and security on usage intention, it shows that the factor of privacy and security has a significant positive impact on users' usage intention in the use of face recognition in smart hotels. If smart hotels want guests to be willing to choose the face recognition system for check-in, they first need to address guests' concerns about personal privacy security leaks. Hotels can communicate with guests during check-in, providing a personal privacy protection agreement or commitment of the hotel's own face recognition system, so that customers can perceive that the system is safe and secure. At the same time, during the guests' use process, the face recognition system must ensure that it operates correctly and does not allow guests to enter a room that does not belong to them. If such an error occurs, the smart hotel must have corresponding remedial measures. In addition, hotels can choose system platforms that guests trust, such as Alipay and WeChat. Using platforms that already archive and use the face information of most people for interactive authentication can reduce guests' concerns.

Disclosure statement

The author declares no conflict of interest.

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