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EYE-TRACKER ANALYSIS OF CAR POSTER LAYOUT'S IMPACT ON THE ACQUISITION OF CAR PARAMETERS

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Abstract: Using eye-tracking technology, we conducted an in-depth exploration of how the differences in vehicle placement and layout structure in three Mercedes-Benz C-Class advertisement posters influence participants' attention to the performance specification text. By employing perception device data collection methods to capture participants' visual attention areas and combining eye-tracking technology to obtain data, we conducted an analytical study. The research found that different placement positions and layout structures led to significant differences in viewers' attention to the performance specification text in the advertisements, further affecting the effectiveness of information transmission in the ads. By studying visual attention, the aim is to provide useful references and guidance for future automobile advertisement design.
Keywords: Automobile advertisements; Eye-tracker analysis; Vehicle placement; Layout structure; Performance specification text

1 INTRODUCTION

In recent years, with the rapid development of the Internet, the ways of information dissemination and presentation have also been changing in countless ways. Obviously, with its large - scale creative space, strong visual impact, high degree of artistic expression, low production cost, and convenient application and other competitive advantages, posters play an irreplaceable role in the market. For example, in product - sales - related poster design, health - related public - welfare poster design, drama poster design, and movie poster design, etc. Through analysis, it is found that although the expressions of posters are emerging in an endless stream, the elements of posters are traceable. Symbols, texts, compositions, colors, and themes are all key elements for evaluating posters [1].
In poster design, composition is particularly important. It is the first step in the whole process and is of great significance for the combination and application of elements, the conveyance of information, and the creation of artistic sentiment [2].
In most automotive cultural environments, each vehicle adheres to its own different automotive design languages. Over time, these design languages have gradually evolved into intangible contemporary commercial values, forming a bottom - up DNA culture of automobile enterprises and carrying the value and price positioning of automotive products [3]. The emergence of eye - trackers has provided novel and effective tools for psychologists to use eye - movement technology to explore human visual information processing mechanisms under various conditions and to study their direct or indirect, wonderful and interesting relationships with psychological activities [4].
Automobile advertisements serve as a crucial means for brand promotion and product marketing, and their design plays a vital role in attracting viewers' attention and conveying product performance characteristics. However, the question of how vehicle placement and layout structure in advertisements affect viewers' attention to performance specification text has not been adequately explored. Therefore, this paper employs eye-tracking technology to conduct an in-depth analysis of three Mercedes-Benz C-Class advertisement posters, aiming to uncover the impact mechanism of vehicle placement and layout structure on the attention to performance specification text.

1.1 Experimental Objectives

The primary objective of this study is to thoroughly analyze and understand how differences in vehicle placement and layout structure within automobile advertisement posters impact participants' attention towards car performance specification text. The research aims to explore the influence of vehicle placement (such as centering versus off-centering and horizontal versus inclined positions) on participants' focus on performance specification text. Furthermore, it analyzes how varying layout structures (such as symmetrical balance, dynamism, and tension) affect participants' attention towards the performance specification text. By utilizing eye-tracking analysis technology, this study provides empirical data support to offer scientific justification for optimizing vehicle placement and layout structure in future automobile advertisement designs.

2 LITERATURE REVIEW

2.1 Research Background

Development of Advertising Psychology: Advertising psychology applies fundamental principles of psychology to advertisement design, aiming to design advertisements that most effectively stimulate consumers' purchasing desires through in-depth exploration of their psychological processes and characteristics. With the continuous development of advertising psychology, an increasing number of research tools have been applied to evaluate advertisement effectiveness, among which the eye tracker is one. As an advanced psychological measurement instrument, the eye tracker can accurately record and analyze data such as viewers' gaze trajectories, fixation durations, fixation counts, and pupil diameter changes when viewing advertisements. These data provide an objective and scientific basis for evaluating advertisement effectiveness.

2.2 Experimental Significance

Complexity of Automobile Poster Design: Automobile poster design involves multiple elements such as brand, imagery, and copywriting, and the matching relationships, layout size, color schemes, and spatial positions among these elements all impact advertisement effectiveness. Therefore, how to design automobile posters that are both eye-catching and effectively convey information has become the focus of attention for advertisement designers and advertisers.And eye - tracker tracking technology will still be the most effective and scientific research method for a long time [5].

At present, there are a lot of studies on automotive print advertisements. Wedel and Pieters studied print advertisements by using the advertisement inserts in magazines. The results showed that the subjects looked at the pictures the most times, followed by the copy, and the brand received the fewest times of being looked at. However, because the average area occupied by pictures is the largest, followed by the copy and brand elements [6].

Enhancing Advertisement Effectiveness: By studying automobile poster design using an eye tracker, we can first understand viewers' visual behavior characteristics when viewing advertisements, such as gaze order and fixation durations. These data help advertisement designers optimize advertisement layout, adjust color schemes, and highlight important information, thereby enhancing advertisement attractiveness and dissemination effectiveness through design.

Guiding Advertisement Strategy Formulation: Eye tracker research can also reveal viewers' psychological activities when viewing advertisements, such as interest points and cognitive processes. This information helps advertisers understand consumer needs and preferences, thereby formulating more precise advertisement strategies and improving the targeting and effectiveness of advertisement placement.

Promoting Interdisciplinary Research: Studying automobile poster design using an eye tracker involves not only fields such as advertising and psychology but also design, engineering, and other disciplines. This interdisciplinary research helps drive the development and innovation of related disciplines, providing richer perspectives and ideas for the theory and practice of advertisement design.

Providing Objective Evaluation Basis: Traditional evaluation of advertisement design effectiveness often relies on subjective judgments and empirical summaries, lacking objectivity and scientificity. Eye tracker research provides an objective and quantitative evaluation method, offering a more reliable and accurate basis for evaluating advertisement design effectiveness

2.3 Domestic and Foreign Literature

2.3.1 Domestic literature

Research in "The Application of Eye Tracker Technology in Evaluating the Effectiveness of Automobile Print Advertisements" uses eye tracker technology to record viewers' gaze trajectories when viewing automobile posters, analyzing the impact of different design elements (such as color, layout, and text) on viewers' attention. These studies aid designers in more scientifically optimizing poster design and improving advertisement effectiveness.

Research in "A Study on Color Design of Vehicle Human-Machine Interface Based on Eye Movement Experiments" not only focuses on poster design but also extends to color design within vehicle interiors. Through eye movement experiments, researchers can understand drivers' visual attention patterns under different color schemes, providing a scientific basis for vehicle interior design [7].

In other aspects of eye tracker applications in the automobile industry, although literature directly addressing automobile poster design may be limited, eye tracker applications in other areas of the automobile industry (such as automotive styling feature line design and driving fatigue complexity judgment) also provide indirect references and inspiration for poster design.

2.3.2 Foreign literature

Research in "Evaluating Advertisement Effectiveness" by foreign scholars uses eye tracker technology to assess the attractiveness and effectiveness of automobile posters, revealing which elements in advertisements most attract viewers' attention by analyzing parameters such as fixation durations, fixation counts, and pupil changes.

Research in "Multimodal Data Fusion" indicates that with technological advancements, foreign studies have begun combining eye movement data with other biometric technologies (such as facial expression recognition and voice analysis) to obtain more comprehensive consumer response data. This multimodal data fusion method provides richer analytical dimensions for automobile poster design.

Using an eye tracker to study automobile poster design has important backgrounds and significance. It not only helps enhance advertisement effectiveness, guide advertisement strategy formulation, and promote interdisciplinary research

but also provides an objective and scientific basis for evaluating advertisement design effectiveness. However, domestic and foreign literature supporting the use of eye trackers to study automobile poster design is not abundant. These studies primarily focus on the visual design elements of posters themselves, lacking exploration of viewers' psychological mechanisms and cognitive processes during viewing, as well as the first point of retrieval for poster information. We hope that through continuous research by our group, the use of eye trackers in the field of automobile poster design will provide deeper insights into viewers' psychological activities and the first point of retrieval for poster information.

2.3.3 Domestic and foreign research status

Domestic researchers primarily use eye tracker technology to record and analyze key indicators such as viewers' eye movement trajectories, fixation durations, and fixation counts when viewing automobile posters. These data provide a scientific basis for evaluating poster design effectiveness.

The application of eye tracker technology in automobile poster design primarily focuses on advertisement effectiveness evaluation, consumer behavior analysis, and design optimization. Through eye movement data, researchers can reveal which design elements attract viewers' attention more and how these elements impact viewers' cognitive and emotional responses.

Domestic scholars have achieved some research results, such as discovering the influence patterns of specific color schemes, image layouts, or text content on viewers' attention through the analysis of eye movement data. These results provide valuable references for improving automobile poster design.

However, despite some progress in domestic research on automobile poster design using eye trackers, there are still challenges and deficiencies. For example, research objects may be relatively homogeneous, and there is a lack of exploration of viewers' psychological mechanisms and cognitive processes during viewing, as well as the first point of retrieval for poster information, which is the direction of our research. Domestic research methods may lack integration with other advanced technologies (such as electroencephalography), resulting in the comprehensiveness and accuracy of research results needing improvement.At the same time, in the aspect of automobile print advertising, the research recorded by eye tracker shows that the number of times that pictures are paid attention to is the most, followed by copywriting [8].

Foreign research on automobile poster design using eye trackers is relatively deeper and broader in scope. Researchers not only focus on the visual design elements of posters but also deeply explore viewers' psychological mechanisms and cognitive processes during viewing. Foreign research often involves cross-disciplinary collaboration among fields such as psychology, cognitive science, design, and marketing. This interdisciplinary collaboration provides a broader perspective and richer theoretical basis for the application of eye tracker technology in automobile poster design.

Foreign applications of eye tracker technology are more innovative and diverse. For example, eye movement data is combined with other biometric technologies such as facial expression recognition and voice analysis to obtain more comprehensive consumer response data; virtual reality (VR) and augmented reality (AR) technologies are used to simulate viewing experiences in real scenarios.

Foreign research results have not only had a wide impact in academia but have also received widespread attention and application from automobile companies and advertisers. Many automobile brands use eye tracker technology to optimize their poster designs, enhancing advertisement effectiveness and market competitiveness.

3 EXPERIMENTAL METHODS

This experiment aims to explore the impact of vehicle placement and layout structure in automobile advertising posters on participants' attention allocation towards performance indication text. The design is divided into three groups of experimental pictures, including center type and inclined composition for comparison [9].

3.1 First Group: Text Layout Variations

With the vehicle position held constant, the layout positions of the performance indication text within the posters (e.g., top, middle, right, etc.) are altered. This group analyzes changes in participants' attention to the text under different text layouts.

3.2 Second Group: Vehicle Orientation Changesv

Keeping the text layout fixed, the placement position and angle of the vehicle (e.g., front-facing, side-facing, etc.) are adjusted. This group observes how vehicle orientation affects participants' level of attention towards the performance text.

3.3 Third Group: Combined Factors

Combining the variables from the first two groups, both the vehicle placement and text layout are simultaneously altered. This group assesses the impact of these two factors combined on participants' attention.

An equal number of samples are selected for each experimental group to ensure the fairness of the experiment and the reliability of the results. Eye-tracking technology is employed to collect and analyze participants' attention duration and

focus on the performance indication text, quantifying attention allocation under different conditions and thus providing an in-depth analysis of the influence of vehicle placement and layout structure on participants' attention allocation.

4 EXPERIMENTAL PROCEDURE

4.1 Participant Preparation

Participants are informed of the experiment's purpose and procedure, then equipped with an eye tracker and calibrated to ensure accurate recording of eye movement data.

4.2 Experimental Tasks

Participants view three groups of images on a screen, each presented for 10 seconds, while their eye movement data is recorded. Experimental tasks include observing static images and conducting visual searches.

4.3 Data Recording

The eye tracker records participants' eye movement data during the experiment, including gaze scanpaths and fixation durations. These data will be used for subsequent data analysis and result interpretation.

5 EXPERIMENTAL RESULTS

The experimental results indicate that the placement of text and vehicles in automobile advertising posters significantly influences participants' attention. Specifically, when the text layout is near the top of the poster, participants' attention significantly increases, suggesting that shifting the visual center of gravity upwards can effectively attract viewers' attention. Experimental data shows that, across all observations, participants spent more time attending to performance indications on posters with text positioned at the top compared to those with text in the middle or bottom.

Furthermore, even when text position remains consistent, the orientation of the vehicle also has a notable impact on participants' attention. When vehicles are placed at dynamic, oblique angles, participants' focus on performance indication text significantly improves compared to front-facing or horizontal placements. The dynamic feel of the vehicle not only enhances the poster's visual impact but also indirectly guides viewers' gaze towards the text information, enhancing the reception of the message.

In the third group experiment, which considers both text layout and vehicle placement, we found that when vehicles are placed in a dynamic, oblique position and text is located at the top of the poster, participants' attention duration towards performance indications reaches a peak, significantly higher than the average attention duration under other combinations of conditions. This suggests that the synergistic effect of text layout and vehicle orientation can greatly enhance the communication effectiveness of advertising information.

These results reveal that in automobile advertising design, carefully arranging the layout of text and vehicle placement can effectively enhance the attractiveness of target information, providing important practical guidance for advertising design.

6 EXPERIMENTAL ANALYSIS

6.1 Data Visualization Analysis

6.1.1 Analysis of pupil diameter variations

The experimental results indicate that there are significant fluctuations in pupil diameter among subjects when viewing images. Specifically, pupil diameter expands correspondingly when the image content evokes high interest or increases cognitive load in the subjects; conversely, it contracts. This suggests that changes in pupil diameter can indeed reflect the subjects' visual attention state and cognitive processing.

It is noteworthy that there are differences in pupil diameter variations among different subjects under the same visual stimulation, which may be related to factors such as individual cognitive styles, interest preferences, and prior experiences (Figure 1).

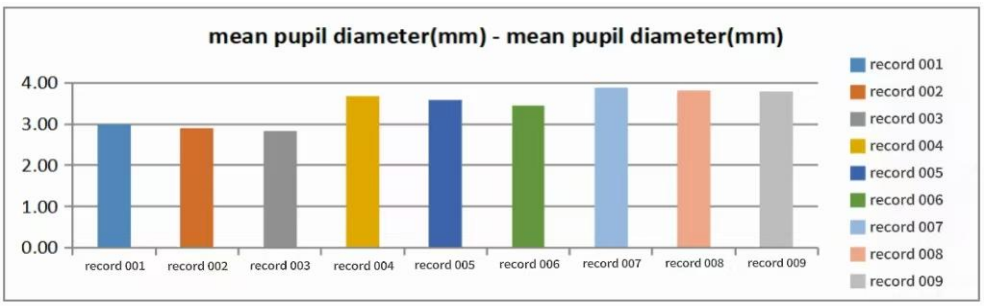

Figure 1 Mean Pupil Diameter

6.1.2 Analysis of saccadic eye movements and blinking behavior

The frequency and duration of saccadic eye movements reflect the efficiency of information acquisition in subjects' visual search processes. Experimental data show that both the number of saccades and the duration of saccadic movements increase when subjects view complex or information-dense images. This indicates that they need to employ more saccades to quickly locate and acquire information. The frequency of blinking may be associated with factors such as subjects' fatigue levels, interest levels, and cognitive loads. The experiment found that blinking rates increase when subjects are highly concentrated or feeling fatigued (Figure 2-3).

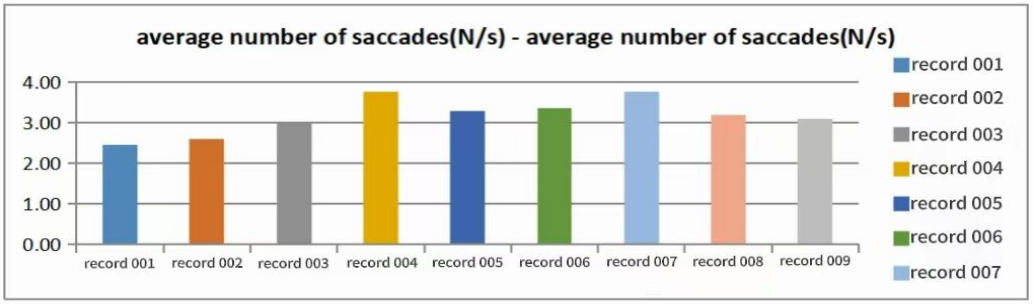

Figure 2 Average Number of Saccades

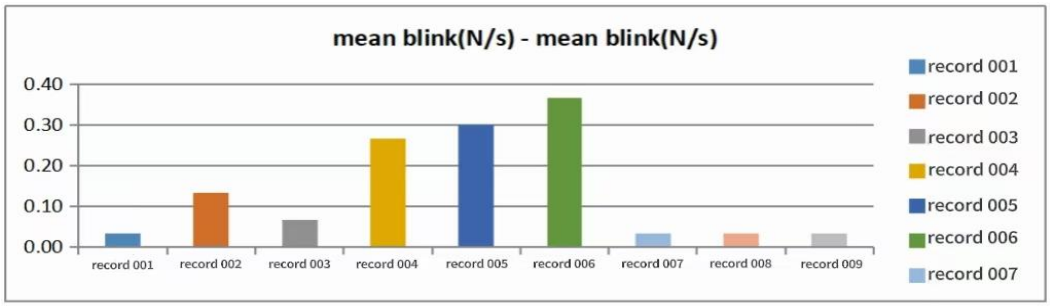

Figure 3 Mean Blink

6.1.3 Analysis of gaze point trajectories

The gaze point trajectory maps reveal the visual search paths and attention allocation patterns of subjects when viewing images. Emphasize the process of gazing [10], as well as the gazing time. The longer the gazing time is, the higher the degree of attention of the subjects to this area is [11]. We observed that subjects tend to first focus on salient areas in the image (such as objects, text, brightly colored sections, etc.), and gradually expand their gaze to other regions based on these initial focal points. Additionally, there are certain individual differences in gaze point trajectories among subjects, with some exhibiting more systematic search strategies while others appear more random and leapfrogging.

Analysis of Visual Preferences and Attention Allocation:

By analyzing data such as average horizontal distance, average vertical distance, and average absolute distance, we found that subjects exhibit specific visual preferences and attention allocation patterns when viewing images. Specifically, subjects are more inclined to focus on the central and salient feature areas of the image and spend more time gazing at these regions. Furthermore, there are also differences in visual preferences among subjects, with some possibly preferring to focus on detailed sections of the image while others prioritize the overall layout and aesthetic composition.

6.2 Comparative Analysis

6.2.1 Analysis of the impact of vehicle placement

Experimental results indicate that the placement of vehicles has a significant impact on subjects' attention to performance indication text. When the vehicle is positioned at the center of the poster, subjects' gaze primarily focuses on the vehicle's exterior design, with relatively lower attention paid to the performance indication text. This suggests that a centrally placed vehicle is more likely to capture the audience's attention but may result in the performance information being relatively overlooked.

In contrast, when the vehicle is positioned towards one side of the poster, subjects' gaze, while still attending to the vehicle's exterior, also notices the performance indication text more frequently. This placement breaks the symmetrical balance and guides the audience's gaze to move within the poster, thereby increasing attention to the performance information (Figure 4-5).

Figure 4 Car Poster a Comparison of the Placement of Vehicles in the Order of Attention

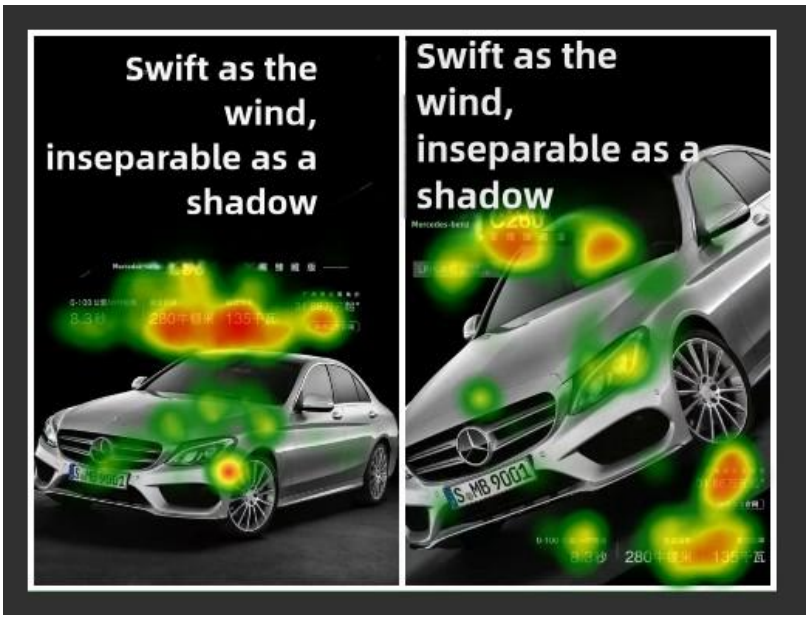

Figure 5 Car Poster Car Placement Position Comparison of Gaze Frequency Chart

6.2.2 Analysis of the impact of layout structure

Further analysis reveals that the impact of layout structure on subjects' attention to performance indication text is even more significant. A symmetrical and balanced layout draws viewers' attention more towards the overall image and aesthetic appeal of the vehicle, while neglecting the communication of performance information. In such layouts, performance indication text is often placed in a secondary position, resulting in lower attention from viewers.

Conversely, layouts with a sense of dynamism and tension can guide viewers' gaze to move within the poster, increasing attention to performance information. These layouts enhance visual impact, allowing viewers to appreciate the vehicle's exterior while also paying closer attention to its performance characteristics. Especially when performance indication text is integrated with dynamic elements of the vehicle, viewers' attention to it increases significantly (Figure 6-7).

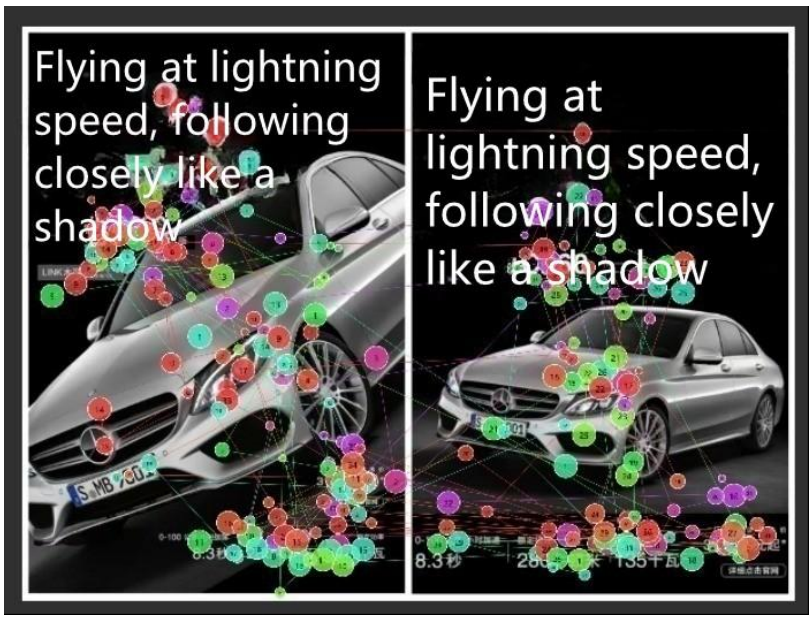

Figure 6 The Sequence Diagram of the Comparison of the Layout Structure of Car Posters The Sequence Diagram of the Comparison of the Layout Structure of Car Posters

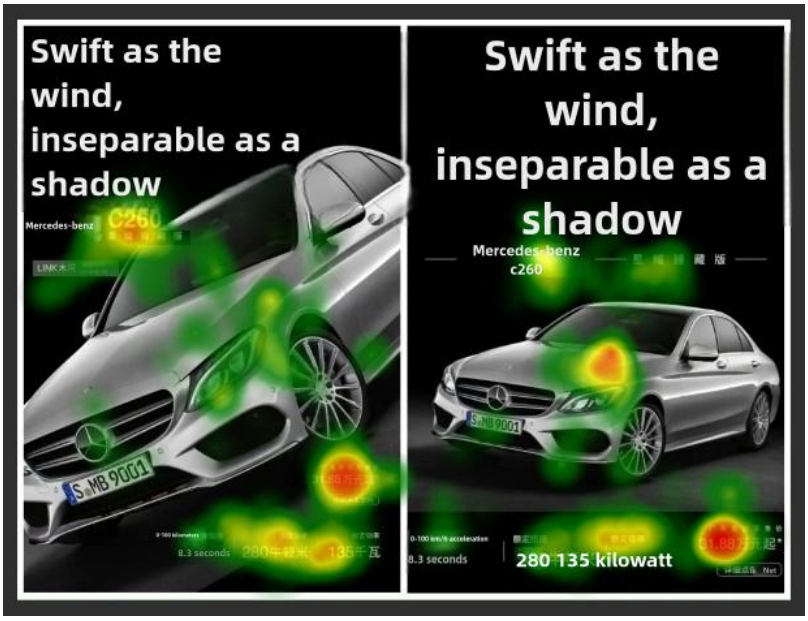

Figure 7 The Fixation Frequency Chart of the Comparison of Car Poster Layout Structure

6.2.3 Analysis of the impact of visual symmetry and balance

When a vehicle is positioned at the center of a poster, it acts like the protagonist on a stage, instantly capturing all attention. Subjects' focus primarily concentrates on the vehicle's exterior design, as they are deeply drawn by its elegant lines and unique styling. However, this central placement tends to make the performance indications easy to overlook, resulting in significantly lower attention. On the other hand, when the vehicle is positioned towards one side of the poster, it breaks the balance of the stage and creates a new visual flow. Subjects' gaze, while enjoying the vehicle's exterior, naturally shifts towards the performance indication text. This placement not only makes the vehicle's exterior more eye-catching but also allows the performance information to be discovered like a treasure, significantly increasing its attention.

In summary, visual symmetry and balance play a crucial role in determining how viewers perceive and engage with the content of a poster. A centrally placed vehicle may dominate the scene but may overshadow important performance information. Conversely, a more dynamic and off-center placement encourages viewers to explore the poster more thoroughly, increasing their engagement with both the vehicle's aesthetics and its performance details (Figure 8-9).

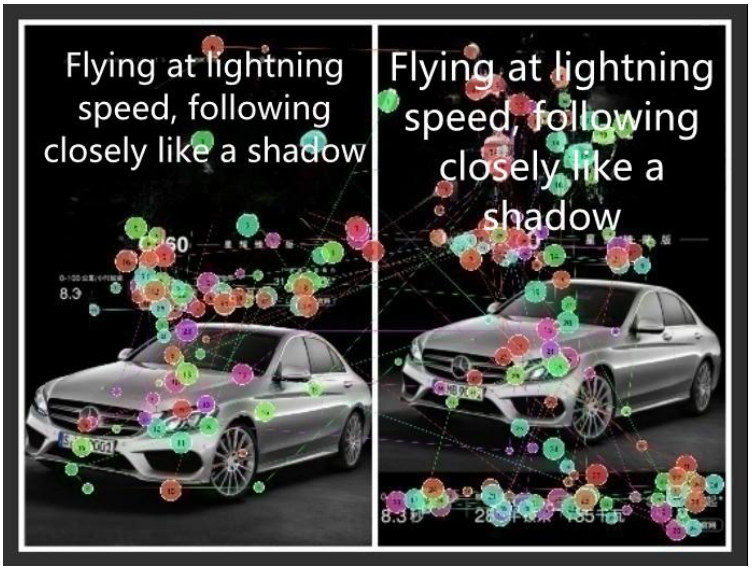

Figure 8 The Car Poster Layout Structure is Balanced or not to Look at the Sequence Diagram

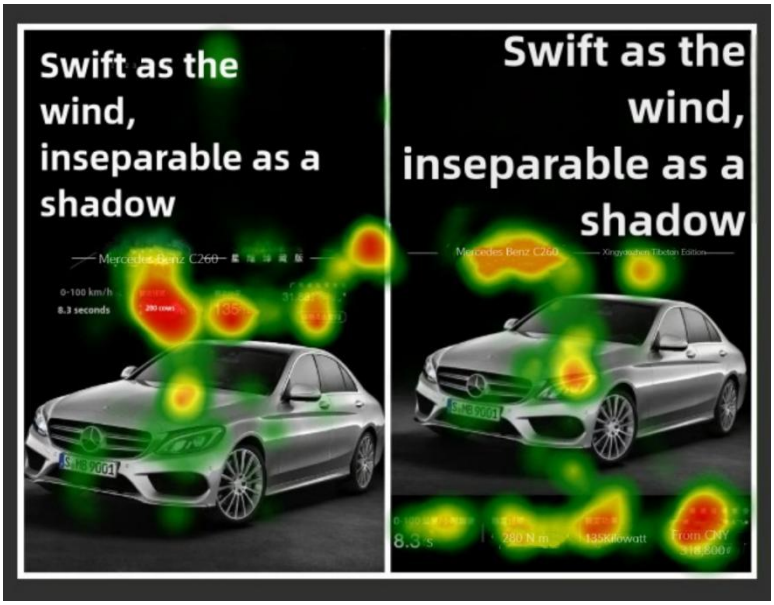

Figure 9 Car Poster Layout Structure Balance or not Fixation Frequency Chart

7 DISCUSSION

The study employed sophisticated eye-tracking technology to conduct an in-depth and systematic analysis of the complex impacts of vehicle placement and layout structure on viewers' attention to automobile parameters in automotive poster design. The research results indicate that both vehicle placement and text layout are core factors influencing viewers' visual attention. These findings provide invaluable practical guidance for the field of automotive advertising design. The conclusions of this study align with numerous previous research findings in the areas of advertising psychology and visual attention, while further refining the specific roles of vehicle placement and layout structure in the communication of advertising information. The research reveals that when vehicles are laid out in a non-central position,biased to one side,and text is designed at the top of the poster, it can effectively guide viewers' gaze flow and significantly increase their attention to performance indication text.

Despite these findings, the study still faces some limitations. For example, the representativeness of the experimental samples could be improved, and the individual differences in eye-tracking data may also affect the research results. To overcome these limitations, future research should strive to further expand the sample size to include more brands, models, and advertising styles, thereby validating the universality and reliability of the findings of this study. Additionally, by combining other advanced biometric technologies and electroencephalogram (EEG) technology, researchers can delve deeper into the psychological mechanisms and cognitive processes of viewers when they view automotive posters, providing more comprehensive and scientific guidance for the field of automotive advertising design.

8 CONCLUSION AND FUTURE DIRECTIONS

This study demonstrates that variations in vehicle placement and layout structure have a significant impact on the attention paid to performance indication text in automotive advertisements. To optimize the effectiveness of advertising design, designers are advised to consider placing vehicles off-center to direct viewers' attention to performance indication text. Additionally, adopting dynamic and tension-filled layout structures can further enhance viewers' attention to performance information.Designers can also pay attention to the influence of top - down or bottom - up factors on consumers to carry out poster design [12].

For future research, it would be beneficial to further explore the impact of vehicle placement and layout structure on the attention paid to performance indication text in automotive advertisements for different brands and models. Furthermore, there is potential to investigate the application of new technologies in automotive advertising design. By doing so, the field can continue to evolve and adapt, leveraging the latest advancements to create more engaging and effective advertisements. In addition, the experimental objects in this study are applied - type poster designs. Different from the research in other fields of psychology, the classification of its design languages is somewhat fuzzy in itself. Therefore, this experiment is only applicable to the discussion of the application effects of the two pun techniques of figure - ground conformal and figure - ground collinear in poster design [13].

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COMPETING INTERESTS

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

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DATA-DRIVEN EVALUATION OF REGIONAL SCI-TECH FINANCE EFFICIENCY

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Abstract: Sci-tech finance is the catalyst for the transformation of technological progress into real productivity. Hence, to improve sci-tech finance efficiency and promote high-quality regional economy development, a data-driven evaluation model of sci-tech finance efficiency is constructed. The collected data are processed using the DEA-Malmquist index. The efficiency level of sci-tech finance is determined according to the Total Factor Productivity index, and the main influencing factors of sci-tech finance efficiency are determined through the decomposition analysis of this index. This study calculates the efficiency level and dynamic change of sci-tech finance in the Yangtze River Delta. The results show that technological progress is an important factor affecting sci-tech finance efficiency. Surprisingly, the growth of R&D personnel has a negligible effect on sci-tech financial efficiency instead, and Shanghai ranked third in terms of sci-tech financial efficiency, which is no match for Zhejiang and Jiangsu provinces. Hence, we propose targeted suggestions to improve sci-tech finance efficiency in the Yangtze River Delta. This study not only provides theoretical and methodological support for the evaluation of regional sci-tech financial efficiency but also provides a reference for sci-tech finance policymakers and researchers.
Keywords: DEA-Malmquist index; Sci-tech finance; High-quality development

1 INTRODUCTION

1.1 Background

Sci-tech is a primary productive force, and the activation of innovation processes in the sci-tech field has become essential for economic and efficient development [1]. Scientific and technological innovation in innovative countries has a greater than 70% average contribution rate worldwide, and sci-tech innovation has increasingly become decisive in enhancing international competitiveness. The development of sci-tech innovation requires sufficient scientific and technological investment as a fundamental guarantee. Strengthening the integration of sci-tech and finance can greatly promote economic and social development. Sci-tech finance has the important function of optimizing the allocation of innovation resources and resolving risks. It is a new tool to effectively address the capital and risks faced by sci-tech innovation. Therefore, it is very necessary to study the allocation efficiency of sci-tech financial resources in sci-tech innovation.

The relationship between sci-tech innovation and finance was first established by Austrian economist Schumpeter as part of his "innovation theory" in 1912. He believed that banks and other financial institutions promote the flow of funds through credit creation, guide the industrial sector, and stimulate technological innovation activities [2]. Thereafter, the relationship between sci-tech innovation and finance has been widely studied by many scholars. Financial capital has a positive impact on sci-tech innovation [3–5]. Moreover, a long-term equilibrium relationship exists between finance and technological innovation [6]. Through an empirical study of Italian companies, Benfratello proved that local bank support has significantly improved the success rate of technological innovation activities [7]. Khan et al. used data from a survey of enterprises in 21 countries of the World Bank to prove that bank-based financing is key in promoting various innovative methods in developing countries [8]. Lee proved that innovative financing can improve the technological innovation ability and business performance of innovative small and medium-sized enterprises (SMEs) using a structural equation model [9]. Financial support for sci-tech innovation can improve enthusiasm for R&D activities according to several theoretical and empirical analyses [10,11].

Scholars have extensively examined the impact of different sources of financial capital on sci-tech innovation. Davidenko et al. determined the close relationship between various financing channels and innovation [12]. While researching selected African countries' enterprise data, Fombang found that the form of overdraft promoted innovation more significantly than trade credit and asset financing [4]. Based on cross-border samples from 52 countries or regions, Zhang Ling concluded that equity financing is more conducive to supporting technological innovation than debt financing [13]. Adikari also found that foreign direct investment does not yield higher innovation [14]. Compared with the dominant position of national R&D funds, market capital presents more significant achievements in sci-tech innovation [15]. Scholars have also demonstrated the importance of bank financing and bank structure in enterprise innovation activities [16,17].

Continuous science & technology and finance integration has resulted in the coining of "sci-tech finance" [18]. Moreover, the evaluation and optimization of sci-tech finance efficiency have received increasing attention. Sci-tech

finance efficiency is considered a measure of the integration of science & technology and finance. This helps accelerate sci-tech innovation and promote rapid and efficient economic development [19]. Experts and scholars evaluated and optimized sci-tech finance efficiency.

Many scholars use stochastic frontier analysis (SFA) [20], data envelopment analysis (DEA) [21,22], and the analytic hierarchy process (AHP) [23] to evaluate sci-tech finance efficiency. As a parameter estimation method, although SFA considers the impact of random factors on output, it produces only an efficiency measurement of multiple inputs and a single output. As a nonparametric estimation method, not only does DEA make up for this deficiency, but it also has significant advantages. DEA can be used for multi-input and multi-output efficiency evaluation [24]. It can evaluate the efficiency of Decision-Making Units (DMUs) with complex production relations. The weight is generated by mathematical programming and, therefore, is not affected by human subjective factors. The evaluation of DMUs is relatively fair. By analyzing relaxation variables, we can further understand the resource utilization of inefficient DMUs and move toward improving inefficient DMUs. Using DEA, Adamovsky selected several EU countries to analyze the innovation efficiency of each country [25]. However, neither SFA nor DEA can decompose the total factor productivity (TFP) index to study the change in efficiency. Thus, this is often combined with the Malmquist index to measure sci-tech financial efficiency. Liu Lanjian used DEA and the Malmquist index to analyze the static and dynamic aspects of the sci-tech input-output of China and the OECD innovative countries from 2003 to 2016 [26]. To identify the preferred solution, scholars introduce secondary objectives in DEA cross efficiency evaluations [27] or establish a model of CCR and multi-objective linear programming [28]. The AHP is also used to study the input-output efficiency of sci-tech finance. However, the standard AHP model requires accurate judgment and, hence, is rarely used.

To measure sci-tech finance efficiency, Li Junxia constructed an evaluation index system based on the relative values of direct financing ratio, venture capital intensity, and incubation capacity of sci-tech business incubators from the perspective of financial resources and innovation achievement quality [22]. Overall, sci-tech finance investment indicators are mostly considered from the state, enterprise, financial institution, and financial market perspectives. Therefore, R&D activity investment, state R&D investment, loans from financial institutions, and venture capital often become investment indicators for efficiency evaluation of sci-tech finance [29,30]. Output indicators of sci-tech finance are mostly considered in terms of both knowledge and value outputs. Therefore, implementing new processes and developing new products [12], scientific papers, patent authorization, new product sales revenue, technology market turnover [31], and so on will more likely become output indicators for evaluating sci-tech financial efficiency [32,33]. Different scholars choose evaluation indicators according to their research needs.

1.2 Study Limitations

Based on the analysis of the above results, many scholars have made great progress in sci-tech finance research, but several limitations remain. (1) Currently, many achievements have been made in researching sci-tech financial efficiency. However, the measuring of sci-tech financial efficiency needs to consider the policy environment, capital environment, human environment, and other factors of the sci-tech innovation ecosystem. Therefore, selecting a reasonable evaluation index of sci-tech finance efficiency to objectively evaluate sci-tech finance efficiency is necessary. (2) Data-driven methods [34] can establish a more objective and accurate evaluation system based on actual sci-tech finance development data. (3) Correctly evaluating the efficiency level of regional sci-tech finance, revealing the relationship between influencing factors and sci-tech financial efficiency, and proposing targeted opinions are practically significant for improving the efficiency of using sci-tech finance resources. This promotes industrial upgrading and high-quality economic development.

1.3 Theoretical Contribution and Practical Value

To address the aforementioned research limitations, this study establishes a new evaluation model of regional sci-tech finance efficiency and analyzes the regional sci-tech finance efficiency of the Yangtze River Delta (YRD). This study has both theoretical contribution and practical value. This study subdivides the types of sci-tech financial resources and measures sci-tech finance efficiency from the two main sources of sci-tech financial capital investment—state and enterprises—which is more realistic. We study the evaluation of sci-tech financial efficiency from a data-driven perspective and further broaden the types of research on sci-tech finance. Taking YRD as an example, we focused on the effect of regional financial resource support and enriched the theoretical knowledge of sci-tech innovation and sci-tech financial development. Moreover, the results of this study are practically significant as they can help national decision makers identify the factors that affect the efficiency of sci-tech finance and provide decision support for formulating sci-tech innovation policies, improving the ecological environment of sci-tech finance, and promoting the transformation of sci-tech achievements, which has important practical value. The research results on sci-tech finance efficiency have clear practical guiding significance for the practice subjects of sci-tech finance. Finally, we propose research methods and conclusions, providing research reference for academic researchers.

1.4 Overview

The remainder of this paper is organized as follows. The second section presents the method, which mainly includes data-driven data collection, data modeling, and data analysis and application. The third section contains a case study comparing and analyzing the TFP of sci-tech finance and the decomposition factors of TFP in three provinces and Shanghai in YRD. Finally, the fourth section concludes the paper.

2 MATERIALS AND METHODS

This section introduces the data-driven evaluation method of regional sci-tech finance efficiency, including the method, data collection, data model, and data analysis.

2.1 Method and Process

To determine the efficiency level of regional sci-tech finance and propose ways to improve it, based on determining both research scope and purpose, this study constructs a data-driven evaluation method of sci-tech financial efficiency to measure regional sci-tech finance efficiency. Essentially, we gather the original input and output data of sci-tech finance in YRD, process the original data using the DEA-Malmquist index method, and obtain the index results. These results comprise the technical efficiency, technological progress, pure technical efficiency, scale efficiency, and TFP of sci-tech finance in YRD. Finally, according to the evaluation results of regional sci-tech finance efficiency in YRD, this study proposes methods and suggestions to improve regional sci-tech finance efficiency. The flowchart of the method is shown in Figure 1.

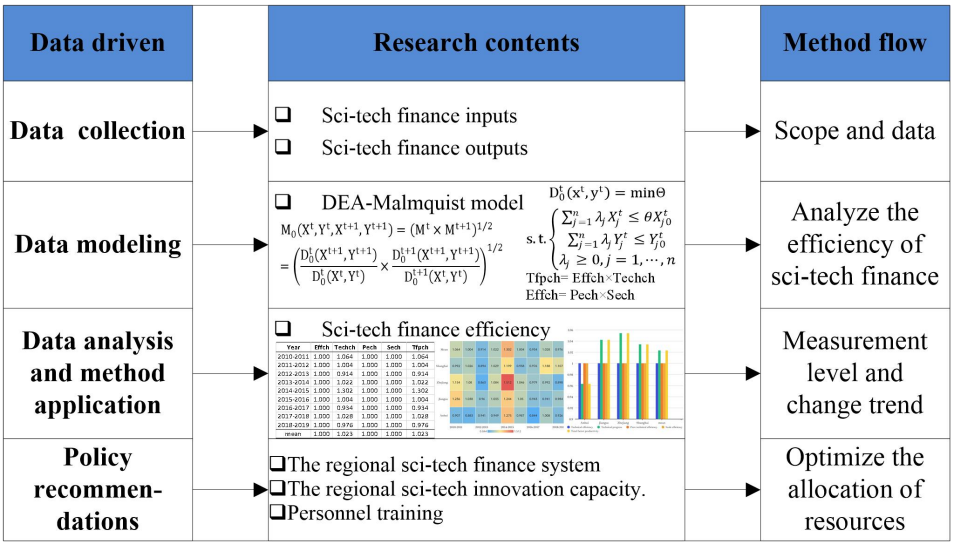

Figure 1 Method Flow

2.2 Evaluation Index

Sci-tech finance comprises states, enterprises, markets, and social intermediaries providing financing resources and their activities in the sci-tech innovation financing process. Therefore, sci-tech finance is a multi-input, multi-output system. In Figure 2, we distinguish the operation system of sci-tech finance from the perspective of input-output.

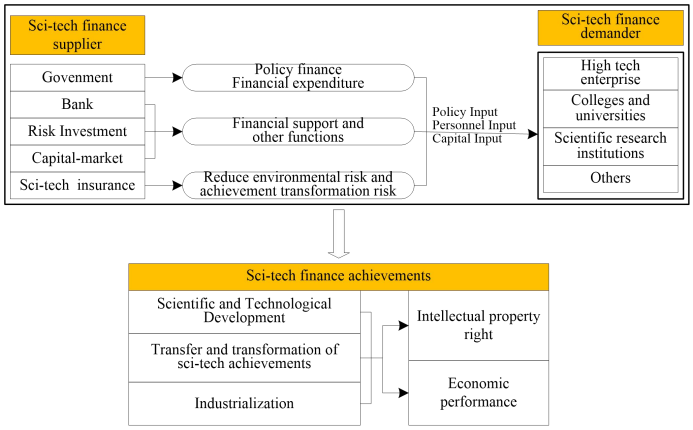

Figure 2 Sci-Tech Finance System Based on Input-Output Perspective

Sci-tech finance investment comprises the state, financial markets, and the financial environment. The state not only directly allocates capital for financial sci-tech expenditures but also guides and optimizes the sci-tech finance environment through systems and policies. The financial market supports sci-tech enterprises through scientific and technological loans, venture capital, and other financial instruments. Moreover, it is the main source of sci-tech finance funds. Although the financial environment does not directly fund sci-tech enterprises, it supports sci-tech activities, such as intermediary service institutions. However, financial environment support will not be transformed into direct and specific investment forms. Therefore, both the state and financial market provide sci-tech finance suppliers with policy, manpower, and capital investments. Considering that quantifying policy resources is difficult, this study selects personnel and capital investment as the investment index of sci-tech finance. The personnel investment index comprises R&D personnel converted into full-time equivalent and R&D personnel investment. Conversely, the capital investment index adopts R&D internal expenditure and financial sci-tech expenditure. Sci-tech finance output can be divided into two categories: economic and knowledge outputs. The economic output indicators are technology market turnover and sales revenue of new high-tech products. These can better reflect the effect of sci-tech investment on economic development. Patents and scientific papers were selected as indicators of knowledge output. The specific index system is shown in Table 1.

Table 1 Input-Output Indicators of Regional Sci-Tech Financial Efficiency

	Primary index	Secondary index
Input in sci-tech finance	Personnel input	Full-time equivalent of R&D personnel (x_1) R&D personnel input (x_2)
	Capital input	Internal expenditure of R&D funds (x_3) Financial sci-tech expenditure（X_4）
Output in sci-tech finance	Economic output	Technology market turnover（Y_1） Sales revenue of high-tech new products（Y_2）
	Knowledge output	Patent（Y_3）
		Scientific papers（Y_4）

Based on data accuracy and availability, this study collected and sorted panel data of sci-tech finance input and output in Anhui Province, Zhejiang Province, Jiangsu Province, and Shanghai City from 2010 to 2019. All data are from the China Statistical Yearbook [35] and the Statistics Bureaus of three provinces and Shanghai in YRD [36–39]. Because the number of sci-tech papers in Anhui Province in 2019 cannot be queried, it was calculated using SPSS software according to data on scientific and technological papers in Anhui Province from 2010 to 2018.

2.3 Data Modeling

Sci-tech innovation is a complex activity with multi-factor input and output. Thus, the specific form of its production function is difficult to estimate. Therefore, we chose to conduct DEA.

American operations research scientists Charnes, Cooper, and Rhodes (1978) proposed DEA based on Farrell's method and the concept of deterministic nonparametric frontier and relative efficiency. Its advantage is that it does not need to standardize the data and set the weight. Moreover, its operation is simple and convenient, and there are many models to choose from. Hence, the most representative DEA models are the CCR, BCC, FG, and ST models.

The Malmquist index was first proposed in 1953 and applied to measuring production efficiency changes by Caves, Christensen, and Diewert in 1982. In 1994, Fare et al. combined a nonparametric linear programming method of this theory with the DEA theory to form the DEA-Malmquist model, which is widely used for analyzing the efficiency changes of DMUs in different periods. Thereafter, to improve the applicability and effectiveness of calculating the DMU productivity change in a fuzzy environment, an extended Malmquist model was proposed [40].

This study analyzes regional sci-tech finance efficiency using the DEA-Malmquist model and panel data. First, regional sci-tech finance involves multi-financial resources and different types of output. Therefore, the evaluation should consider multiple inputs and outputs simultaneously. Second, regional sci-tech finance is complex; thus, more objective evaluation is needed. Therefore, the data-driven DEA model is an effective method to overcome these difficulties. DEA is a mathematical programming method to evaluate the relative efficiency of a group of decision-making units with multiple inputs and outputs. From the result, the combination of data-driven and DEA-Malmquist models ensures the clarity of data and the objectivity of the evaluation results. DEA can clarify which regions should further improve sci-tech finance efficiency. Based on the DEA, the Malmquist index and its decomposition are used to reveal the law of sci-tech finance efficiency changing with time and the reasons for those change. Therefore, this study constructs a data-driven DEA-Malmquist evaluation model to evaluate the regional sci-tech finance efficiency to promote the high-quality development of the regional economy.

The basic principle is as follows: assuming n DMUs (J = 1, 2,..., n) and that each DMU has m inputs (I = 1, 2,..., m) and s outputs (r = 1, 2,..., s), X_{ij} is the DMU, and $X_j^t$and Y_j^t represent the input and output index values of sci-tech finance in the j DMU of period t.

$$X_j^t = \left(X_{1j}^t, X_{2j}^t, \cdots X_{mj}^t\right)^T \tag{1}$$

$$Y_j^t = \left(Y_{1j}^t, Y_{2j}^t, \cdots Y_{sj}^t\right)^T \tag{2}$$

D_0^t (X^t,Y^t) represents the technical efficiency of the input-output configuration of the DMU in period t; thus,

$$D_0^t(x^t, y^t) = \min\Theta$$
$$\text{s.t.}\begin{cases} \sum_{j=1}^{n} \lambda_j X_j^t \le \theta X_{j0}^t \\ \sum_{j=1}^{n} \lambda_j Y_j^t \le Y_{j0}^t \\ \lambda_j \ge 0, j = 1, \cdots, n \end{cases} \quad (3)$$

Similarly, $D_0^{t+1}(x^{t+1}, y^{t+1})$ represents the technical efficiency of the input-output configuration of the DMU in period t+1.

The construction of the Malmquist index was based on the distance function. By comparing distance functions, the change in technical efficiency was analyzed from a dynamic perspective.

Hence, under the technical conditions of period t, the change in technical efficiency from period t to period t + 1 is as follows:

$$M^t = \frac{D_0^t(X^{t+1},Y^{t+1})}{D_0^t(X^t,Y^t)} \quad (4)$$

Under the technical conditions of period t+1, the change in technical efficiency from period t to period t + 1 is as follows:

$$M^{t+1} = \frac{D_0^{t+1}(X^{t+1},Y^{t+1})}{D_0^{t+1}(X^t,Y^t)} \quad (5)$$

Thus, the change in productivity from period t to period t+1 is as follows:

$$M_0(X^t, Y^t, X^{t+1}, Y^{t+1}) = (M^t \times M^{t+1})^{1/2}$$
$$= \left(\frac{D_0^t(X^{t+1},Y^{t+1})}{D_0^t(X^t,Y^t)} \times \frac{D_0^{t+1}(X^{t+1},Y^{t+1})}{D_0^{t+1}(X^t,Y^t)}\right)^{1/2} \quad (6)$$

The calculated M index is used for analyzing regional sci-tech finance efficiency from a dynamic perspective. If the M index is above 1, the TFP is in a state of growth from period t to period t+1, and sci-tech financial efficiency improves. If the M index is equal to 1, both the TFP from period t to period t+1 and sci-tech financial efficiency remain unchanged. If the M index is less than 1, the TFP shows a downward trend from period t to period t+1, and sci-tech financial efficiency decreases.

Using the Malmquist index to analyze regional sci-tech finance efficiency, TFP can also be decomposed into a technical efficiency change index and a technical progress index. Moreover, the technical efficiency change index can be further decomposed into the product of the pure technical efficiency and scale efficiency indices as follows:

$$\text{Tfpch} = \text{Effch} \times \text{Techch} \quad (7)$$
$$\text{Effch} = \text{Pech} \times \text{Sech} \quad (8)$$

By decomposing TFP, we can further observe whether the investment decision of sci-tech finance is correct and measure the degree of technological progress. If the technical efficiency change index is greater than 1, then technical efficiency has improved. This indicates that the investment decision of sci-tech finance was correct. If the change index of technical efficiency is less than 1, then the technical efficiency has deteriorated. This means that the investment decision of sci-tech finance was unproductive. A technological progress index greater than 1 indicates the overall scientific and technological progress. Finally, if the technological progress index is less than 1, overall sci-tech is experiencing a declining trend.

2.4 Data Analysis and Application

This research is a data-driven evaluation method for regional sci-tech finance efficiency. The specific data analysis and application are as follows. First, we construct the input-output index of regional sci-tech finance, evaluate the dynamic change of TFP of regional sci-tech finance using the DEA-Malmquist index, determine the level of regional sci-tech financial efficiency, and evaluate the change trend of regional sci-tech financial efficiency.

Second, we evaluate the dynamic changes in the TFP of sci-tech finance in different provinces and cities according to the DEA-Malmquist index of regional sci-tech finance and analyze the level and change trend of sci-tech financial efficiency in different provinces and cities within the region.

Third, we identify the main factors affecting the improvement of the TFP of regional sci-tech finance according to its decomposition.

Fourth, we propose policy suggestions to improve regional sci-tech finance efficiency according to the actual input-output environment of regional sci-tech finance (Figure 3).

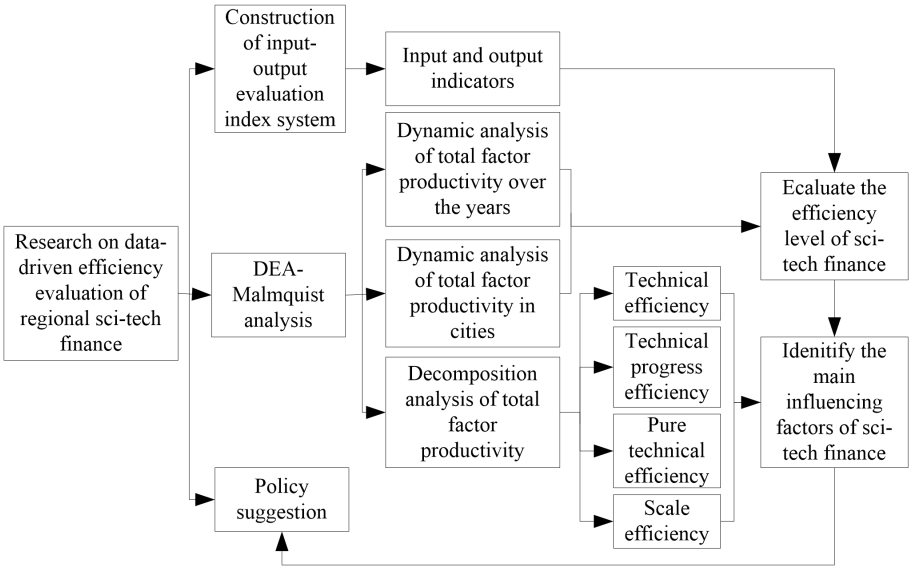

Figure 3 Analysis and Application of Regional Technology Financial Efficiency Data

3 CASE STUDY

Because of the differences in regional sci-tech finance resource endowment and environmental policies, this study selects YRD as the research object and proposes targeted policy suggestions.

3.1 Case Study Background

YRD region, including Shanghai, Jiangsu Province, Zhejiang Province, and Anhui Province, is significant for China's economic development. The region has a strong economic foundation, an excellent system, and strong overall competitiveness. The integrated development strategy of YRD requires that it strengthen its innovation drive, build a modern economic system, improve the industrial chain level to play to regional drivers and demonstration, and form a regional cluster with high-quality development. Increasing financial investment is more conducive to promoting scientific and technological innovation and development. For the past decade, the input and output of sci-tech finance in three provinces and Shanghai in YRD have increased significantly.

3.2 Results

Based on the input-oriented DEA-Malmquist index method, without considering output lag, this study uses DEAP 2.1 software to calculate the sci-tech finance efficiency of YRD from 2010 to 2019.
(1) Full-sample technology financial efficiency.
According to the software calculation results, the TFP, technical efficiency, technological progress, pure technical efficiency, and scale efficiency of regional sci-tech finance are obtained. See Table 2 for details.

Table 2 Malmquist Index and Breakdown of Sci-Tech Finance in YRD from 2010 to 2019

Year	Effch	Techch	Pech	Sech	Tfpch
2010-2011	1.000	1.064	1.000	1.000	1.064
2011-2012	1.000	1.004	1.000	1.000	1.004
2012-2013	1.000	0.914	1.000	1.000	0.914
2013-2014	1.000	1.022	1.000	1.000	1.022
2014-2015	1.000	1.302	1.000	1.000	1.302
2015-2016	1.000	1.004	1.000	1.000	1.004
2016-2017	1.000	0.934	1.000	1.000	0.934
2017-2018	1.000	1.028	1.000	1.000	1.028
2018-2019	1.000	0.976	1.000	1.000	0.976
mean	1.000	1.023	1.000	1.000	1.023

TFP can comprehensively reflect the comprehensive level of technology and management in provinces and cities. The average TFP of the three provinces and Shanghai is 1.023, which is greater than 1. This indicates that the overall sci-tech financial efficiency in YRD is good. On the one hand, YRD has high scientific research strength, a good foundation for modern industrial development, and competitive high-tech industries and is thus in a leading position in the country. It gives full play to its own scientific and technological endowment resources to conduct cutting-edge innovation. On the other hand, the state's policy support for YRD not only increased scientific and technological

investment but also distributed some key scientific research institutes and major scientific and technological research projects in YRD. These actions promoted the scientific and technological progress of YRD.

(2) Sci-tech finance efficiency in the time dimension.

According to the calculation results, Figure 4 provides the line chart of sci-tech finance TFP in three provinces and Shanghai in YRD split to describe the change trend of sci-tech financial efficiency of the three provinces and Shanghai from 2010 to 2019.

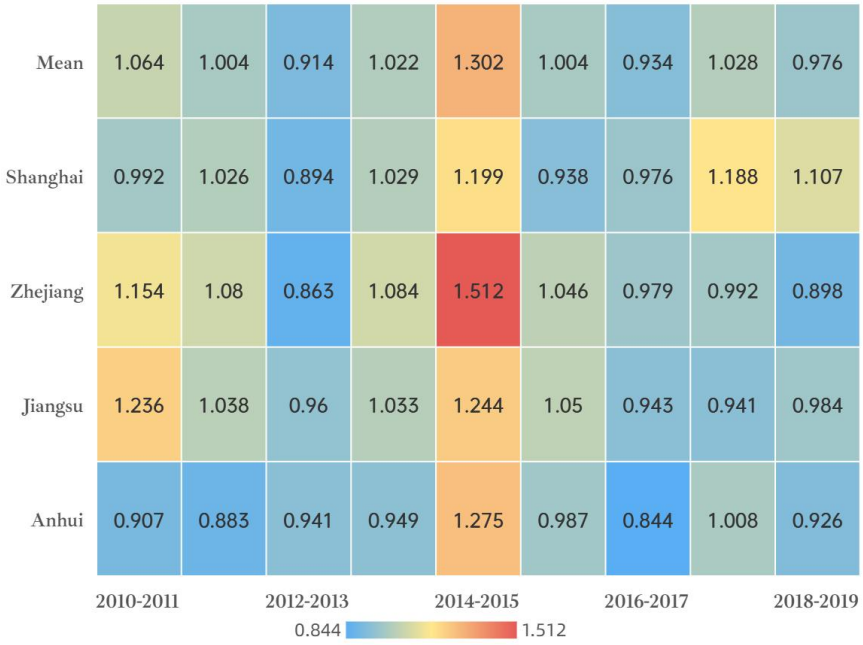

Figure 4 Change Trend of Sci-Tech Financial Efficiency in YRD

Overall, sci-tech finance efficiency in three provinces and Shanghai in YRD is unstable. Sci-tech finance efficiency in YRD presented the first concave point from 2012 to 2013, increased rapidly, and reached its highest point from 2014 to 2015. However, it soon fell back, showing the second concave point from 2016 to 2017. It then increased slightly, resulting in the second convex point from 2017 to 2018. Given the increasing investment in sci-tech finance, the efficiency of sci-tech finance is unstable, mainly due to the uncertainty of technology research and development.

(3) Comparison of scientific and technological financial efficiency between provinces and cities

The efficiency values of sci-tech finance in YRD are presented in Figure 5.

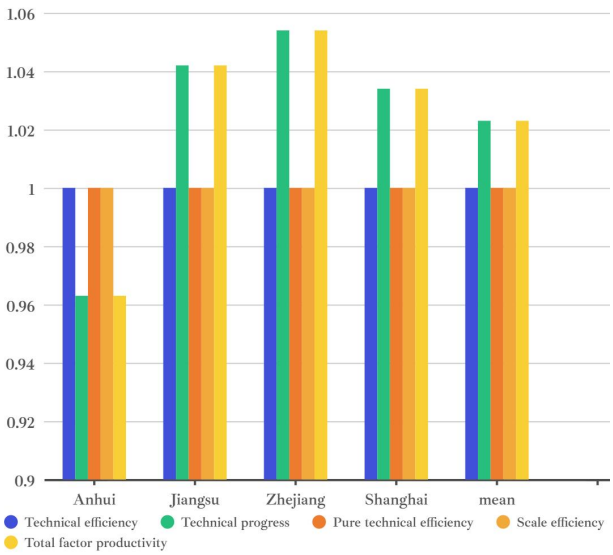

Figure 5 Malmquist Index and Decomposition of Sci-tech Finance in YRD

According to the results in Figure 5, sci-tech financial efficiency in Zhejiang Province was the highest (1.054), followed by Jiangsu (1.042) and Shanghai (1.034). In contrast, TFP in Anhui is slightly lower than 1 (0.963). In combination with Figure 3, sci-tech financial efficiency in Zhejiang Province has remained above average in the recent decade; however, the fluctuation range is the largest. Anhui Province was below the average level. Sci-tech financial efficiency in Jiangsu

Province and Shanghai fluctuates slightly above and below average, and sci-tech finance efficiency in Jiangsu Province is slightly higher than that in Shanghai.

Based on the decomposition results, the technical efficiency, pure technical efficiency, and scale efficiency of YRD reach 1, indicating good performance. This also means that TFP is directly affected by technological progress. Zhejiang Province has a technological progress value of 1.054, ranking first among the three provinces and Shanghai. This shows that Zhejiang Province is at the production frontier composed of the optimal DMU. Moreover, it demonstrates that resource allocation of financial input and output in Zhejiang Province is reasonable, and the contribution of technological progress to TFP has reached 5.4%. The technological progress index of Jiangsu Province and Shanghai is higher than 1, and only the technological progress value of Anhui Province is lower than 1. The reason is that among the three provinces and one city, the sci-tech development of Anhui Province is relatively late, and its sci-tech level is relatively low.

(4) Low personnel input efficiency

When DEA-Malmquist is used for processing index data, the impact of R&D personnel investment on the measurement results of scientific and technological financial efficiency can be ignored. This demonstrates that although R&D personnel investment is increasing yearly, the quality of scientific and technological personnel is low, and an internal roll phenomenon is found. In fact, the quality of research talents is a key factor in the application of technological innovation and technology marketization [41].

3.3 Policy Recommendations

This study is based on a data-driven evaluation of regional sci-tech finance efficiency and provides a clear evaluation of sci-tech finance efficiency in YRD. According to the analysis, since 2010, YRD has vigorously promoted sci-tech innovation and strengthened the financing support of sci-tech innovation and sci-tech innovation enterprises, which have not only continuously improved the sci-tech innovation ability but also developed the financial industry. Based on the purpose of optimizing the efficiency of resource allocation, to further improve sci-tech financial efficiency in YRD, we propose the following policy suggestions.

(1) Improve the regional sci-tech finance system

To improve the innovation capability of key core technologies, we should improve the innovation investment mechanism and sci-tech finance policies. To improve sci-tech finance resource allocation efficiency, we must establish a regional sci-tech finance resource allocation system covering the entire life cycle of high-tech enterprises to ensure sci-tech finance resource investment in different stages of technological innovation and development. Simultaneously, we accelerate innovation of financial instruments, achieve sci-tech finance risk management, and provide diversified investment channels for sci-tech enterprises.

(2) Accelerate the improvement in regional scientific and technological innovation capacity.

Sci-tech innovation is essential for cultivating and developing strategic emerging industries, which is highly significant for high-quality economic development. According to the above analysis, sci-tech finance efficiency is directly affected by technological progress. Therefore, to improve regional sci-tech finance efficiency, we must improve the ability of regional sci-tech innovation. From the perspective of enterprises, improving sci-tech innovation depends on introducing and retaining medium and high-end sci-tech talents. From a regional perspective, an efficient sci-tech park should be built and promote the agglomeration of innovative industries. The state should develop and improve business incubators in the region to facilitate the formation and rapid growth of new high-tech enterprises in the region.

(3) Strengthen the training of scientific, technological, and financial talent

The development of sci-tech finance is inseparable from the introduction and training of sci-tech finance talents, especially medium- and high-end sci-tech finance talents who understand both finance and sci-tech. The talent introduction policy and service system after the introduction of sci-tech finance talents must be improved. Simultaneously, the policy must strengthen the evaluation system for sci-tech finance talents, encourage sci-tech personnel to maximize their scientific research abilities, and reduce the continuous internal turnover of human resources.

(4) Strengthening the synergy of regional sci-tech finance

This region is the center of national economic development. Provinces and cities in the region are not only geographically adjacent but also have a greater spillover effect. Shanghai's financial innovation leads the country, and its universities and scientific research institutes lead the region. Jiangsu Province has built a relatively complete sci-tech finance system, the speed of sci-tech innovation in Zhejiang Province is accelerated, and the market in Anhui Province is larger. Establishing cooperative relationships, which are expected to improve sustainability performance, is crucial for regional development [42]. Therefore, enterprises, universities, and scientific research institutes in the region should be actively encouraged to cooperate in tackling key sci-tech problems and transforming sci-tech achievements to create a new regional win-win collaborative development system.

3.4 Discussion and Management Enlightenment

Compared with the existing literature [30,31], this study has three advantages. First, the efficiency evaluation indicators of regional sci-tech finance are more representative. The input indicators comprehensively consider the personnel input and capital input. The capital input indicators select the internal expenditure of R&D funds and the financial sci-tech

expenditure, which represent the enterprise sci-tech innovation investment and the state sci-tech innovation investment, respectively, and are the main source of financial resources for sci-tech innovation. The output index comprehensively considers knowledge and economic output, which is in line with sci-tech's goal of industrialization and economy. The turnover of the technology market and the sales revenue of high-tech products can better represent the economic achievements of the sci-tech industry. Second, based on the data-driven method for measuring sci-tech financial efficiency, the combined data-driven and DEA-Malmquist model ensures not only clear results, but also the objectivity of the results. Finally, it analyzes the efficiency of sci-tech finance from static and dynamic aspects and determines the main factors affecting sci-tech financial efficiency. Based on the improvement of the allocation efficiency of regional sci-tech finance resources, this study proposes countermeasures and suggestions for improving the sci-tech finance system and enhancing the more targeted regional innovation ability and talent training. These allow for more targeted decisions.

Combined with the above research and conclusions, we get the following management enlightenment.

(1) In the long run, all provinces and cities in China need to accelerate the transition from extensive to intensive economic growth, and sci-tech finance is of great significance to the quality of economic development [43]. Different regions have different sci-tech finance resources, state policies, and financial environments. Hence, designing a scientific and reasonable evaluation index system for regional sci-tech finance efficiency is necessary. This is not only conducive to grasping and understanding the current situation of regional sci-tech finance but also helps clarify the main influencing factors and change trend of regional sci-tech financial efficiency.

(2) Developing regional sci-tech finance is crucial to improving regional sci-tech innovation. Many subjects related to regional sci-tech finance and the internal and external environment cooperate through currency circulation and credit flow to form a dynamic balance system. The regional sci-tech finance system directly affects regional sci-tech finance efficiency. Therefore, clarifying the operation mechanism of regional sci-tech finance systems and scientifically decomposing input-output elements of regional sci-tech finance improve the comprehensiveness and accuracy of the efficiency analysis of regional sci-tech finance.

(3) In the digital economy era, through standardized and modeled processing and big data use, data are organized to form an information flow, which is conducive to scientific decision-making with the support of data [44]. Therefore, research on regional sci-tech finance should make full use of big data and explain the development status and change trends of sci-tech finance more accurately and scientifically through data driving.

4 CONCLUSIONS

The degree of sci-tech innovation and financial integration represents a country's social productivity and comprehensive competitiveness. Improving the efficiency of sci-tech finance is an important factor in giving full play to the advantages of financial resources, promoting the deep integration of sci-tech, finance and industry, and promoting the transformation of sci-tech achievements and high-quality economic development. This study proposes a data-driven evaluation method for regional sci-tech finance efficiency. Taking YRD as an example, the DEA-Malmquist index is used to calculate the efficiency of sci-tech finance in YRD, analyze the factors affecting the input-output efficiency of sci-tech finance in YRD, and propose suggestions to improve regional sci-tech finance efficiency.

The main innovations of this study are as follows. (1) This study constructs an evaluation index of regional sci-tech finance efficiency. The index system includes four input indices: R&D personnel equivalent, R&D personnel investment, internal expenditure of R&D funds, and financial scientific and technological expenditure. Moreover, four output indices are included: technology market turnover, sales revenue of high-tech new products, patents, and sci-tech studies. The evaluation indices are more representative, and evaluating sci-tech financial efficiency is more reliable. (2) This study constructs a data-driven evaluation of regional sci-tech finance efficiency, which allows for a more objective and accurate evaluation process and more credible evaluation results. (3) The data-driven efficiency evaluation of regional sci-tech finance can accurately identify factors influencing the improvement of regional sci-tech financial efficiency to provide an accurate decision-making basis for the effective use of sci-tech finance.

This study also has several limitations. First, the sci-tech finance system is a complex system, the factors affecting sci-tech finance efficiency are diverse, and it is difficult to obtain more data. Therefore, the evaluation indices of sci-tech finance efficiency in this study cannot be comprehensively selected. The DEA method also has limitations. As DEA assumes a linear model, it cannot measure efficiency with negative output, such as energy consumption and pollution emission, which restricts the application scope of the model. Additionally, this method is usually used to evaluate past performance [45], so it cannot be used to plan future performance objectives.

Evaluating regional sci-tech finance efficiency is complex. We only evaluate the efficiency of sci-tech finance based on a time series, and there is a lack of spatial dynamic analysis of regional sci-tech finance efficiency. This will be our next research direction. On this basis, we will further improve the input-output index system of sci-tech finance in terms of the aspects of ecological environment and investment risk, explore ways to promote the deep integration of finance and sci-tech innovation, and promote the high-quality integrated development of the regional economy.

COMPETING INTERESTS

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

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AUTHOR CONTRIBUTIONS

Conceptualization, Y.Y. and Y.W.; methodology, Y.W. and X.S.; software, X.S.; validation, Y.W. and X.Z.; formal analysis, C.W.; investigation, Y.W.; resources, X.Z.; data curation, Y.W. and X.S.; writing—original draft preparation, Y.W. and Y.Y.; writing—review and editing, X.Z. and C.W.; visualization, X.S.; supervision, X.Z. and Y.Y.; project administration, Y.W.; funding acquisition, Y.W., X.Z., C.W..All authors have read and agreed to the published version of the manuscript.

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WASTE FOAM POLYURETHANE TO PRODUCE NITROGEN DOPED POROUS CARBON TO ADSORD CARBON DIOXID

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Abstract: The purpose of this study is to obtain activated carbon adsorbent with good carbon dioxide adsorption performance by pyrolysis of waste polyurethane, and solve the two problems of environmental pollution and carbon dioxide emission of waste polyurethane. At 600℃, the waste polyurethane was carbonized with urea and activated with KOH at 800℃. The obtained product has large specific surface area, pore size of 0.5nm-1nm, and good adsorption capacity of UC-5-1.5, which is 6.5mmol/g at 1 bar at 0℃. In this study, foam polyurethane was used as raw material, nitrogen was doped by mixing different nitrogen sources and activated by KOH to obtain porous carbon adsorbent. The prepared adsorbent has larger specific surface area and higher carbon dioxide adsorption capacity.
Keywords: Activated carbon; Waste polyurethane; Carbon dioxide adsorption; Selectivity

1 INTRODUCTION

Since the Industrial Revolution, the continuous emission of greenhouse gases has led to a continuous rise in atmospheric temperature, of which carbon dioxide is the main factor leading to climate warming [1]. With the progress and development of industrial technology, a large number of emissions of industrial waste gas, the concentration of carbon dioxide in the atmosphere continues to increase, from 331ppm to 420ppm, and is still increasing, if not controlled will cause inestimable consequences to the environment. Carbon dioxide capture, storage and conversion (CCUS) can solve the problem of increasing the average temperature of atmospheric environment caused by excessive carbon dioxide emission [2].

Carbon dioxide capture can be divided into pre-combustion capture, oxygen-rich combustion capture and post-combustion capture. Pre-combustion capture is the reaction of fuel with oxygen, air and water vapor under certain conditions, mainly to produce CO2andH2; Oxygen-rich combustion capture is the use of pure O2(95-99%) instead of air for oxygen rich combustion, resulting in high CO2 concentration of flue gas; The separation of carbon dioxide from the flue gas produced by the combustion of the fuel in the air is called postcombustion capture. Among them, post-combustion capture has a good prospect in solving the problem of environmental CO2 concentration [3]. Amine washing as the most important commercial CO2 adsorption method, its technology is mature and the amount of CO2 adsorption is large, but it has the disadvantages of large corrosion to the equipment and high regeneration cost [4]. Therefore, the research of solid adsorbents has been further increased, including carbon-based adsorbents, metal-organic frameworks, zeolite, mesoporous silica, oxides and so on. And carbon-based adsorbent because of its cheap and easy to obtain, large specific surface area, easy to regenerate, low sensitivity to water has good industrialization potential, so choose carbon material as carbon dioxide solid adsorbent [6].

In order to solve the problem of environmental pollution, the general selection of biochar or plastic waste as raw materials, by one step or two step method to obtain, one step method is the direct roasting of the mixture of carbon source and activator KOH directly mixed stalk activation, two-step method is the carbonization, activation into two steps roasting [4-5]. The huge amount of polyurethane waste is difficult to degrade, will exist in the environment for decades or even hundreds of years, is bound to bring serious damage to the environment, direct disposal, land landfill, direct incineration and other commonly used treatment methods will cause varying degrees of damage and pollution to the surrounding landscape, water, soil and air [7-11].

In this study, foam polyurethane was used as raw material, nitrogen was doped by mixing different nitrogen sources, and activated by KOH to obtain porous carbon adsorbent. The prepared adsorbent has larger specific surface area and higher carbon dioxide adsorption capacity. It is also environmentally friendly. The CO2 adsorption capacity was measured by BET and fixed bed dynamic adsorption method.

2 EXPERIMENTAL

2.1 Material

Choose waste foam polyurethane as the raw material for preparing activated carbon. The raw material is then crushed in the micro plant crusher to obtain the polyurethane powder. Potassium hydroxide (99%), (C6H11NO4) N (99%), (C3H6N6) (99%), (C2H4N4) (99%) were purchased from China National Pharmaceutical Group Co., LTD. N2 (99.99%) and carbon dioxide (10%) were supplied by Deyi Gas Co., LTD.

2.2 Foam Polyurethane Carbonization

The foam polyurethane is crushed to less than 40 mesh, mixed with urea, melamine, dicyandiamine grinding, screening suitable nitrogen sources, and mixed with the foam polyurethane in different proportions [12-14]. It was put into a quartz boat and carbonized in a tube furnace. Under 100ml/min nitrogen atmosphere, it was heated to the specified temperature at the heating rate of 10℃/min, and kept for 15 minutes to carbonize it. It was recorded as UC-X, where X was the weight ratio of N content in urea.

2.3 Carbon Activation

After carbonizing the foamed polyurethane, it is ground and mixed separately with different proportions of KOH (KOH: C=0.5, 1,1.5, 2,3). It was put into a nickel boat and activated in a tube furnace: under 100ml/min nitrogen atmosphere, it was heated to the specified temperature at the heating rate of 10℃/min, kept for 2 hours to activate it, after activation, it was washed to neutral with 1mol/L hydrochloric acid while ultrasonic, and dried in an oven at 105℃ for 12h after centrifugation [15]. Recorded as UC-X-Y, Y is the ratio of KOH to C.

2.4 Characterization

The structural properties of AC samples were determined by n2 adsorption-desorption isotherm at 77 K using American Micromeritics ASAP 2460. Prior to the measurement, the sample was vacuumed at 150 ° C for 12 hours. Based on the N2 adsorption-desorption isotherm, the specific surface area (SBET) was calculated using the Brunauer-Taylor equation (BET), the total pore volume (Vt) was calculated at P/P0 = 0.99, the micropore volume (Vmi) was calculated using the T-diagram method, and the mean pore width (Dp) was calculated using 4Vt/SBET. Composition and composition of surface elements The properties of the elements have been studied using X-ray photoelectron spectroscopy (XPS) (Skalb 250Xi, Thermo Fisher Science, USA).The static carbon dioxide adsorption capacity of the samples was determined by thermogravimetric analyzer. All AC samples were degassed at 100 ° C for 24 hours and then adsorption measurements were taken

2.5 Adsorption Measurement

The adsorption capacity of the screened sample was preliminarily measured by DSC3+ thermogravimeter. The adsorption capacity of the screened sample was increased from 10℃ /min to 100℃ at 30℃ and maintained for 30min to achieve the purpose of pretreatment.After cooling to 30℃, at 30℃, the adsorption experiment was carried out with 10% carbon dioxide, adsorption for 30min; Then heat up to 100℃ and keep it for 30min to desorption. BET was used to test the adsorption capacity of the sample at 0℃ and pure CO2.

3 RESULT AND DISCUSSIION

3.1 XPS/XRD

Sample UC-5-1.5, for example, contains 90.81wt%C, 0.74wt%N, 8.45wt%O. The properties of N groups on the surface of the absorbent were identified by X-ray photoelectron spectroscopy (XPS). As Figure 1, the selected sample presents two beads centered on 399.2,400.4, and 401.3ev indexed as pyridine-N (N-6), pyrrorole-N (N-5), and pyridine-noxide (N-Q). These nitrogen-rich carbon surface properties can enhance carbon dioxide absorption, and N-5 is more CO2-friendly than N-6. The XRD profile of UC-5-1.5 is shown in the Figure 2. Two wide diffraction peaks were observed near 23° and 43°, corresponding to the (002) and (100) diffraction patterns of amorphous graphite carbon, indicating that the sample is amorphous.

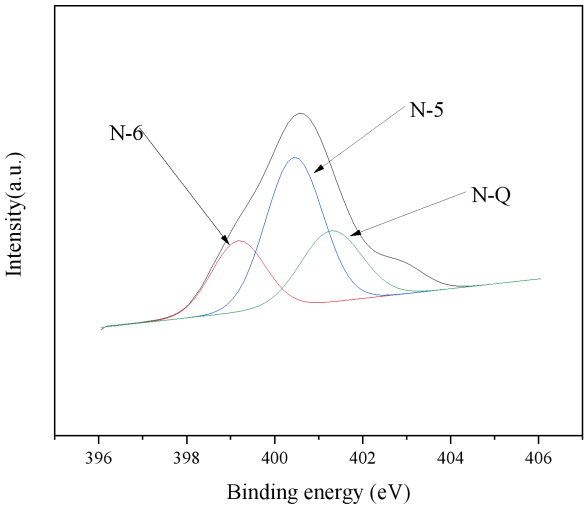

Figure 1 The XPS of UC-5-1.5

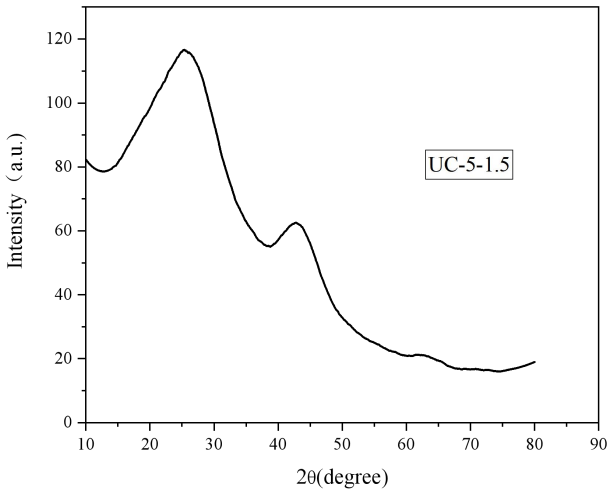

Figure 2 The XRD of UC-5-1.5

3.2 BET

From Table 1, the specific surface area and pore size of the samples were different due to different doped carbon sources and different proportions of doped urea. The specific surface area of doped urea was the largest, reaching 1,742.03m2/g, while the specific surface area of undoped and doped melamine and dicyanodiamine was significantly lower than that of doped urea. Among the doped urea with different contents, the specific surface area of doped 5% urea was the largest. The pore sizes of the two nitrogen sources doped with melamine and dicyanodiamine were smaller than those doped with urea, and even slightly lower than those of the undoped nitrogen source. The results showed that the activated carbon doped with 5% urea had the highest specific surface area of 1,742.03m2/g and the largest pore size of 2.55nm.

Table 1 Textural Parameters and CO2 Adsorption Capacities of the As-Prepared Adsorbents

Sample	SBET (m2 /g)	Dave(nm)	Vt (cm3 /g)
C-1.5	1,340.90	2.18	0.69
UC-1-1.5	1,497.28	2.18	0.67
UC-3-1.5	1,617.62	2.38	0.61
UC-5-1.5	1,742.03	2.55	0.62
UC-7-1.5	1,614.79	2.36	0.82
MC-5-1.5	1,391.39	1.95	0.77
DC-5-1.5	1,493.62	2.10	0.73

3.3 SEM/TEM

Scanning electron microscopy(SEM) was employed to study the morphology of the representative sample UC-5-1.5. As illustrated in Figure 3, the SEM image reveals that UC-5-1.5 possesses.

The porous structure and detail morphology of UC-5-1.5 was further studied using transmission electron microscopy(TEM). As showing in Figure 3 plentiful wormhole-like micropores can be observed. To determine the crystallite structure of UC-5-1.5.

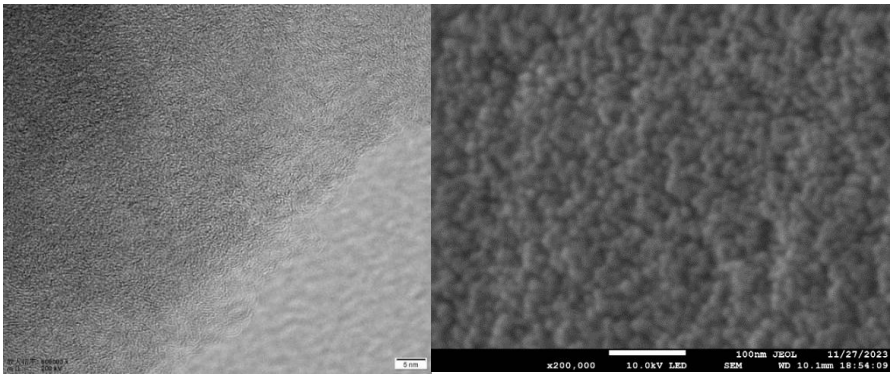

Figure 3 The TEM/SEM of UC-5-1.5

3.4 Adsorption Performance

In order to explore the influence of activated carbon carbonation temperature and activation temperature on CO2 adsorption capacity, the following sets of experiments were done: the carbonation temperature (400-700 ℃) and activation temperature (400-800 ℃) were changed and the adsorption capacity was measured by thermogravimetric adsorption. From Table 2, when the carbonation temperature is 600 ℃, the adsorption capacity is the best, and when the activation temperature is 800 ℃, the adsorption capacity is the best.

Table 2 Effect of Carbonization Temperature and Activation Temperature on Adsorption Capacity

Sample	Adsorption（CO2，mmol/g）	Sample	Adsorption（CO2，mmol/g）
UC-5-400-1.5-800	0.95	UC-5-1.5-400	0.43
UC-5-500-1.5-800	0.61	UC-5-1.5-500	0.79
UC-5-600-1.5-800	1.15	UC-5-1.5-600	0.83
UC-5-700-1.5-800	0.8	UC-5-1.5-700	0.76
		UC-5-1.5-800	1.15

The best adsorbent was screened by the thermo-gravimetric adsorption amount and the static adsorption amount. From Figure 3 and Figure 5, by comparing the static adsorption and thermo-gravimetric adsorption amount of doping different nitrogen sources, the thermo-gravimetric adsorption amount of doped urea can reach 1.15mmol/g is much higher than the adsorption amount of doped melamine and dicyanodiamine. Similarly, the trend of static adsorption is the same. The static adsorption amount of urea doping is 3.2mmol/g much higher than that of doping other types of nitrogen sources

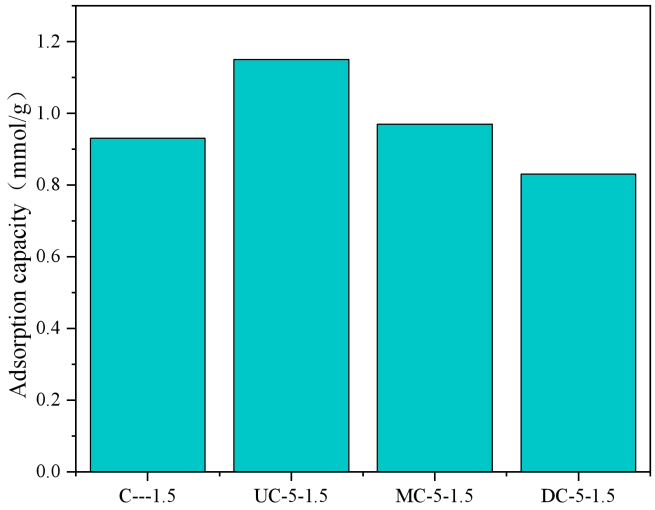

Figure 4 Adsorption Amount of Different Nitrogen Source Doping

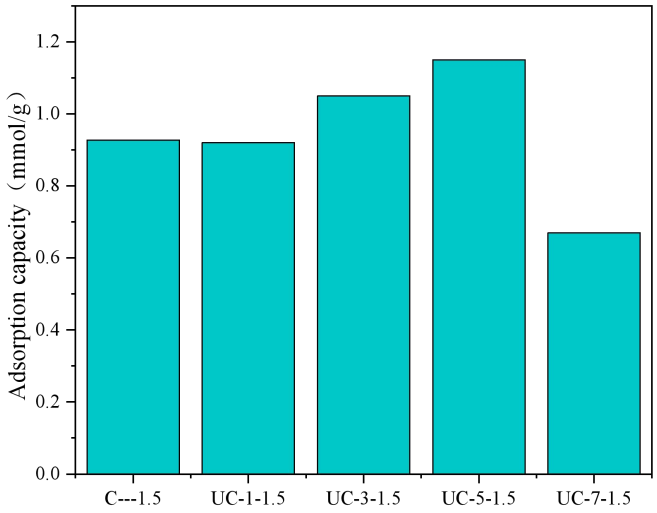

Figure 5 Data Graph of Adsorption Capacity of Different Urea Content

Comparing the influence of different doped urea content on the adsorption capacity, from Figure 4 and Figure 6, it can be seen that whether it is static adsorption or thermogravimetric adsorption, the activated carbon with a doped N content of 5% is higher than that with other N content. Activated carbon, further indicating that the doped 5% activated carbon has the highest adsorption capacity for CO2.

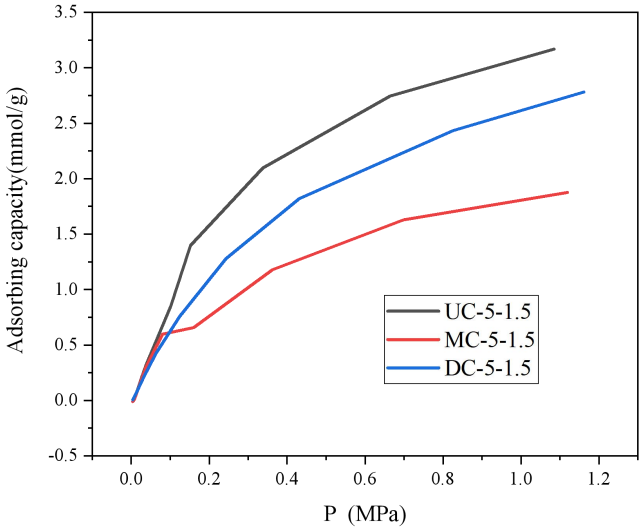

Figure 6 Static Adsorption of Different Nitrogen Sources

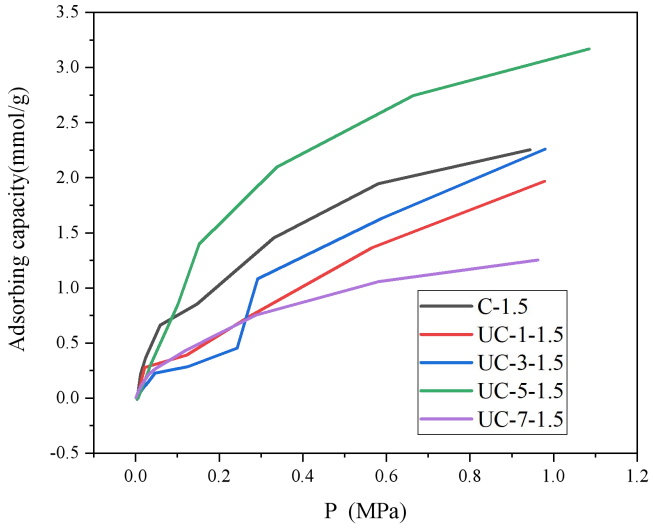

Figure 7 Static Adsorption Data of Different Urea Content

4 CONCLUSION

Using foam polyurethane as raw material, urea, melamine and diammonium dicyanide were mixed to doping nitrogen, and then activated by KOH to obtain porous carbon adsorbent. The prepared adsorbents have larger specific surface area and higher adsorption capacity of carbon dioxide. The adsorption capacity of porous carbon-based adsorbent obtained by urea mixed with foam polyurethane is the best 3.2mmol/g (225℃, 1bar). KOH activation can obtain a larger specific surface area, so that the adsorbent has a larger CO2 diffusion and adsorption capacity. On the other hand, KOH can improve the alkalinity of the adsorbent and further improve the CO2 adsorption performance.

COMPETING INTERESTS

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

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DATA MINING FOR ENHANCING REVENUE GENERATION CAPABILITIES IN THE INSURANCE INDUSTRY

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Abstract: The insurance industry is facing a crisis. Its revenue-generating talent resources are shrinking. As the industries aging population moves closer to retirement, the new young talent is not able to generate equivalent revenue. In this study, a data- mining-based model is proposed for dataset including 521,392 entries with information of insurance agents registered in LIMRA from 2010 to 2016. Bringing the principal component analysis (PCA) model to extract the low-dimensional and efficient feature information. After analyzing the dataset, decision tree model is employed, which proved to be robust to demonstrate the conclusion. It is determined that the industry would be obliged to make changes in distribution channels as well as how to reward employees. As a gesture to retain talents, a strategy to attract millennials is required, as well as some additional evaluations to provide better insights on recruiting future talents. Nothing indicates that the industry has made any significant changes in its business model to appeal to millennials. In addition, subsequent evaluations are recommended. " New Agent Financing " do not correspond to significant retention of agents. Licensing shows significant value in premium values depending on the company types, which indicates that it would be of a certain value to develop the education reimbursement programs for agent licensing. The whole industry ought to invest in technology to enable potential customers to do research and shopping. Geographic location makes a difference in premium totals, from which the strategies based on market penetration are recommended. Finally, moving to a consumer-centric culture is encouraged. The utilization of net promoter scores and a voice of the customer program is proposed to improve revenue with current resources.
Keywords: LIMRA; PCA; Decision tree; Revenue generation; Retention model

1 INTRODUCTION

The study was tasked with identifying areas to assist LIMRA members with talent development and distribution effectiveness strategies. This paper focused on the improvement of the talent pool within the insurance and financial services industry (IFS) and the improvement of revenue generation. Our paper focused specifically on the primary revenue generators and distribution mechanism for insurance policies, the insurance agent and the agencies they work for. To accomplish this, our goal was:Identify means ofpredicting agent retention and premium generation. Identify qualities of a successful agent among various company profiles
Tell a story about the opportunities the IFS industry has to improve its key performance indicators
Improve a balanced scorecard focused on generating stakeholder value within the industry.
The insurance agents' primary role is to create a pool of funds within a community to effectively mitigate the risk of a disaster for their customers. An insurance agent sells policies, which a customer pays a premium into. The customer is then afforded the opportunity to tap into this pool of funds that is generated from the premium that customers pay into in the event of a disaster. In the case of life insurance, this premium enable customer to tap into this pool for the protection of their loved ones in the event of their death. Insurance companies invest this pool of premiums to increase the value within the pool and insurance agencies recruit members of the community to participate in these pools. For insurance agencies to effectively create this pool of members, they must solicit their communities to engage in this pool and prove the value of their participation to their potential customers. They can only accomplish this by engaging agents to market and sell products offered by insurance companies. Insurance agencies, however, must reasonably recruit and enable agents to sell insurance policies to this pool and manage their ability to improve this pool. This whitepaper will explore how agencies can recruit, nurture and retain good agents that are capable of improving these community pools.
The insurance industry is facing a crisis. One in four of its employees is expected to reach retirement age, 59, by the end of 2018 [1]. Based on the Marshberry report the insurance industry will need to hire 3 new producers to make up the difference for older ones retiring out of the industry [1]. Alone this would be cause for concern but combine that with the fact that millennials are not interested in the industry as a whole, this is cause for catastrophe. Since agents are the primary revenue generators for the industry, this poses a problem to many companies' bottom lines if not mitigated. Millennials are expected to make up 70% of the workforce by 2030 and will need to be a consideration for the industries future producers [2]. The issue is that most millennials have little to no interest in becoming part of the insurance industry. The job overall does not appeal to that generation. Millennials differ more so than previous generations in the way they view work and the world. If companies want to continue to stay viable in the industry, they will need to develop a strategy to attract this generation.

2 RETAINING AGENTS

2.1 Qualities of a Top Performing Agent

Insurance agencies are facing a talent pool crisis that is the nightmare of Human Resources (HR) professionals around the world. Millennials consider the insurance industry as "boring" and are not interested in the industry as a whole. Culture and succession planning should be on the top of every HR Professional's mind. With an emerging millennial workforce, HR professionals must begin to consider what impact millennials have in the current workforce and what they need to be successful. HR must work with upper management to define what HR programs will continue to add strategic value with these shifts in workforce generation. HR Analytics will play a crucial role in this evolution.

Retaining good employees and nurturing skilled and satisfied employees is a Darwinian imperative for life insurance agencies and the HR professional as this crisis continues to unfold. HR professional's must use analytics to continuously improve their approaches to hiring. In order to do this they must first identify what good talent is and what value it adds to their organization.

HR professionals tend to acknowledge that good talent is hard to come by and for many organizations, good talent is also the lever that can lift them to greater heights. Talent management is among Human Resources' (HR) most important tasks because high performers not only bring in more revenue, but can decrease costs, teach others, and transform culture. Great talent can be a source of competitive advantage for any company. By being able to identify the characteristics of a good agent, HR can strategically recruit from talent pools that carry characteristics of good agents. For example, talent sourced from industry associations may be much more effective than talent sourced from recruitment advertisements on monster.com. By measuring the effect of their talent pools on employee performance, this will allow HR professionals to make more effective hiring decisions. This will better align their hiring decisions with strategic value generation and thus directly impact stakeholder value and the bottom line. As the Life Insurance industry evolves, so too does the best recruit for the job. Good Insurance agents are customer centric and practice value driven sales [3].

They always put the needs of the customer first and can listen well enough to correctly identify customer needs. By putting a customer's need first and promoting value driven sales, insurance agents reduce clawbacks by ensuring that the policies they sell are in the customers best interests and easy for them to maintain. Agents are able to more effectively identify opportunities to cross sell within their existing business relationships. This allows them to generate more revenue for the company and more value for the customer helping to improve the bottom line and ensure that they maintain customers. In order to be customer centric, a good insurance agent must also be knowledgeable. Good insurance agents are knowledgeable [3]. A good insurance agent must have a broad understanding of their products and the tax and legal considerations of the policies that they are selling. This helps them ensure that they are not only meeting their customers needs but that they are providing the best options for their customers. This allows them to personalize the sale to the customer and give them the best results. Many agents prove their knowledge by obtaining certifications to prove how knowledgeable in specific areas they are. This allows them to get a true understanding of what the product offerings are and what best fits a customer's need. Our primary research supported this notion that knowledgeable agents are more effective. Our studies showed that licensed agents were much more productive on average (Figure 1 and licensed comparison in appendix).

Figure 1 Avg Premium vs License series

It is found that when an agent was licensed they tended to generate significantly more premium than their counterparts on average who were not licensed.Good insurance agents are highly available [3]. They have begun to embrace forms of digital communication allowing customers to reach out to them through websites, chat, instant messages as well as traditional phone and face to face communication. These individuals have embraced the digital age and can market themselves through social media, identify clients needs and use digital communication to better prepare for their clients needs. They have mastered how to market and how to sell through multiple complementary platforms.

2.2 Optimal Agent Profile

While this is heuristic information sourced from industry professionals, this is not to say that this is the optimal agent profile for each type of company. Our research shows that the optimal agent profile may be different for different types of companies.
Optimal Agent Profiles had similar qualities across multiple companies but some qualities stand out as differentiators across company types (Figure 2).

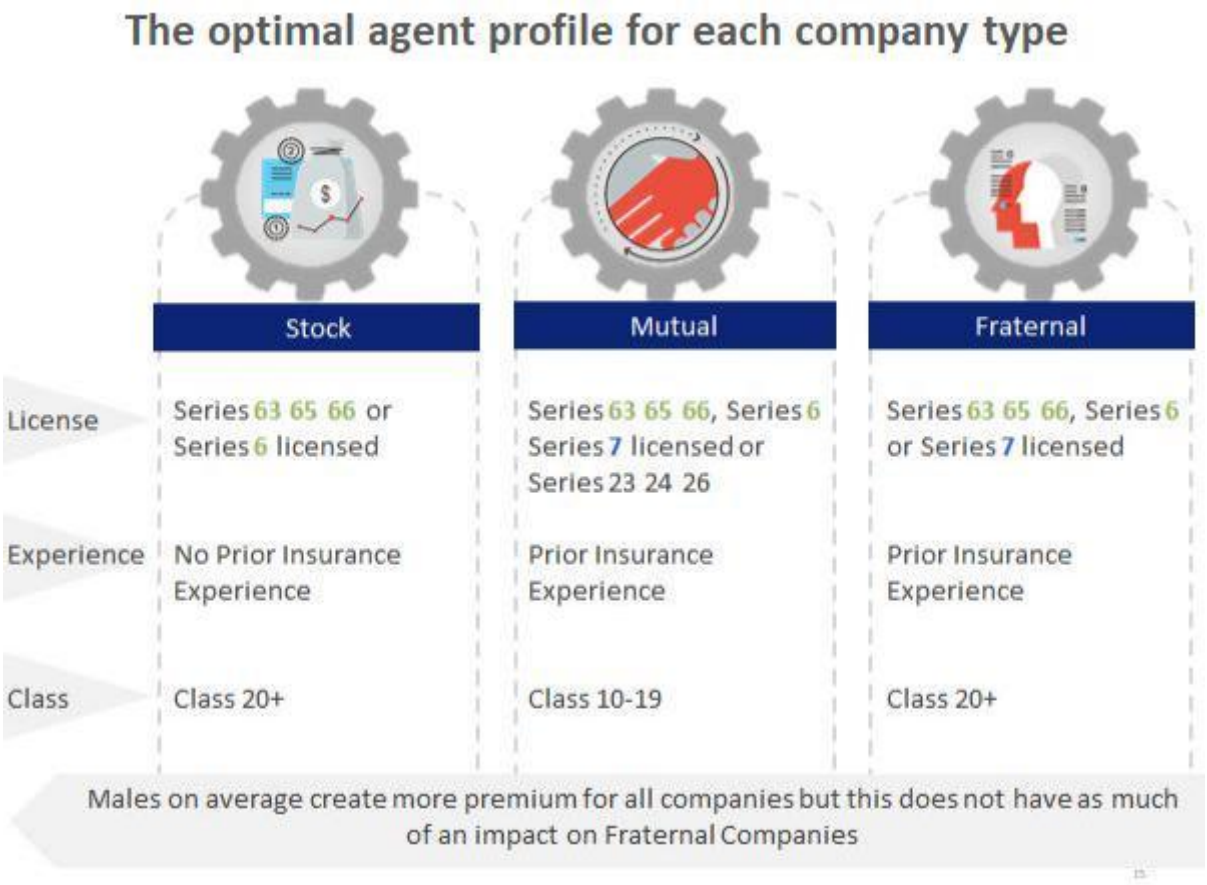

Figure 2 Optimal Agent Profile

The analysis concluded that the optimal profile for an agent differed across companies. While unable to determine why without understanding more about the companies and their strategies, strong correlations were derived between agent characteristics and high performance. At all agencies, it was determined that Series 63, 65, 66 licensing played a major role in sales performance. These licenses collectively focus on investment strategies, regulations, and ethics [4]. Each type of company significantly benefits from agents with these licenses (Figure 3).

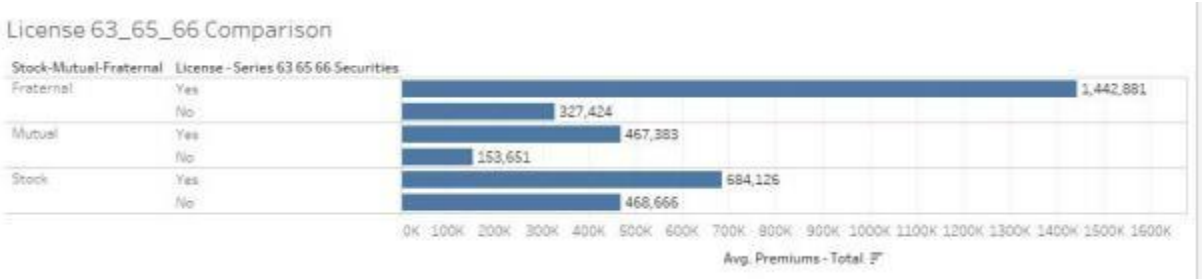

Figure 3 License vs Company Type

Each company also benefited when their employees obtained series 6 securities licenses, which focuses on regulations, securities markets and sales and administration of products. (https://www.financialplannerworld.com/finra-exams/)(Figure 4).

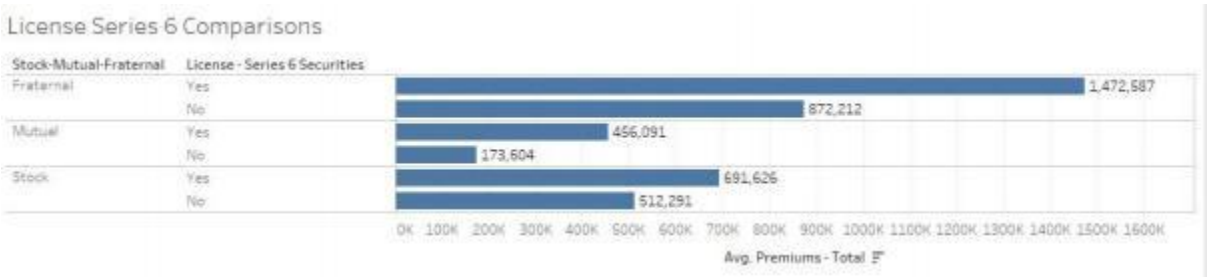

Figure 4 License Series 6 vs Company Type

All companies also enjoyed the perks of tenure as employees who achieved a longer tenure time, typically after 19 years of service, achieved significantly greater premium levels than their less tenured counterparts (Figure 5).

Figure 5 Average Premium – to Total Completed Years

While agents with these licenses were similar across companies some licensing differentiated employees of specific company types greatly. Series 7 licenses contributed enhanced premium sales at all companies on average, however those who held this license at fraternal companies drastically differentiated themselves, earning over 3 times that of their peers on average (Figure 6).

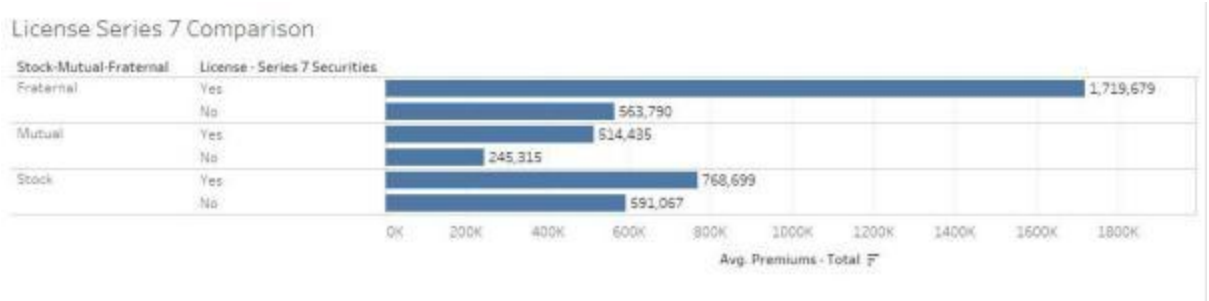

Figure 6 License Series 7 vs Company Type

Series 23, 24, and 26 licenses tended to only positively influence mutual companies with their licensed employees on average making double those who were not licensed (Figure 7).

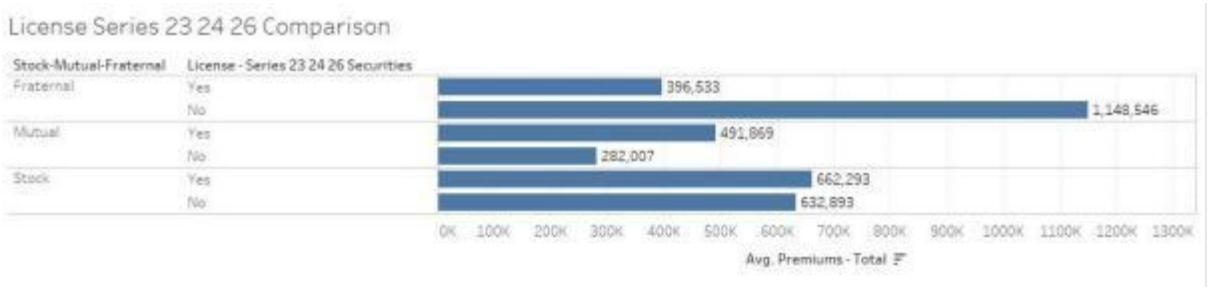

Figure 7 License Series 23_24_25 vs Company Type

Conversely, stock companies saw a negligible raise ofpremium sales for those licensed and fraternal companies actually saw a drastic drop in premium sales for those who had this license on average.
Males overall sold more premium than their female counterparts, however, the significant percentage gaps existed to a lesser extent at fraternal companies (Figure 8).

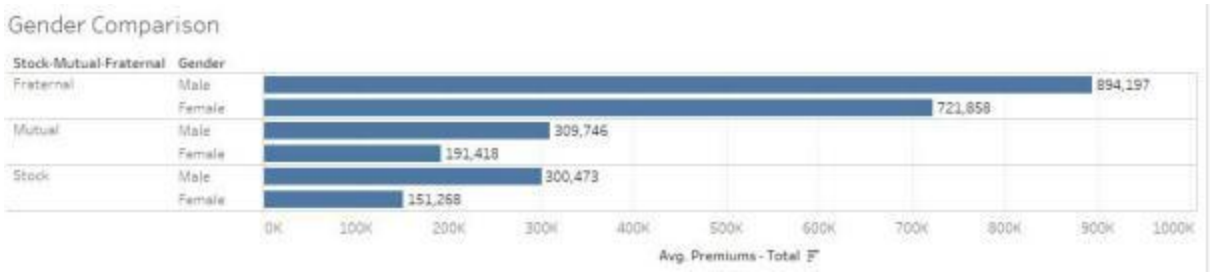

Figure 8 Gender vs Company Type

Prior insurance experience was a major differentiator at Fraternal companies and a minor one at mutual companies. Contrary to what one may believe, at stock companies those with prior insurance experience on average actually generated less premium than their peers without experience (Figure 9).

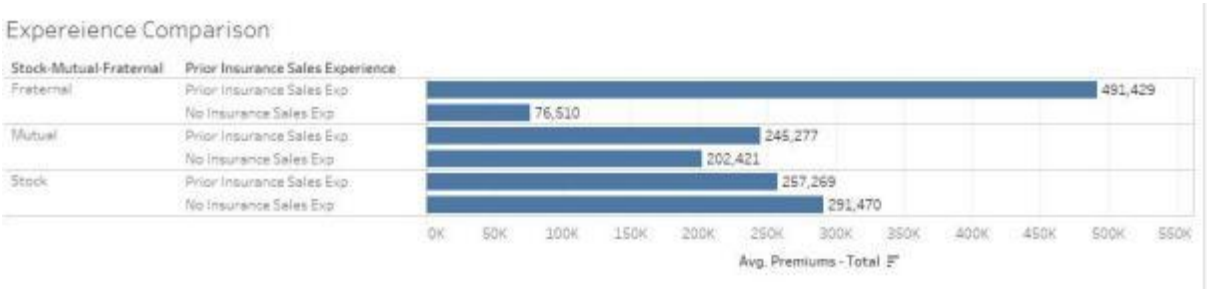

Figure 9 Experience vs Company Type

2.3 Recommendations and Analysis

These differentiators may be key factors in determining the best approaches to training programs within these companies. If companies were to establish educational reimbursement programs to encourage agents to become licensed, they may want to target these programs at those licenses that add the most value for their unique optimal agent profile. In this way, they can maximize their return on investment in these licensing programs and be able to build a business case for the investment in these agents to become licensed. While knowing from the above research that agents who are licensed are able to sell more premium, it can also be seen in (figure 10) that those agents who are licensed also tend to be retained by agencies longer. By influencing agents to become licensed, HR is able to align strategic value with its retention goals.

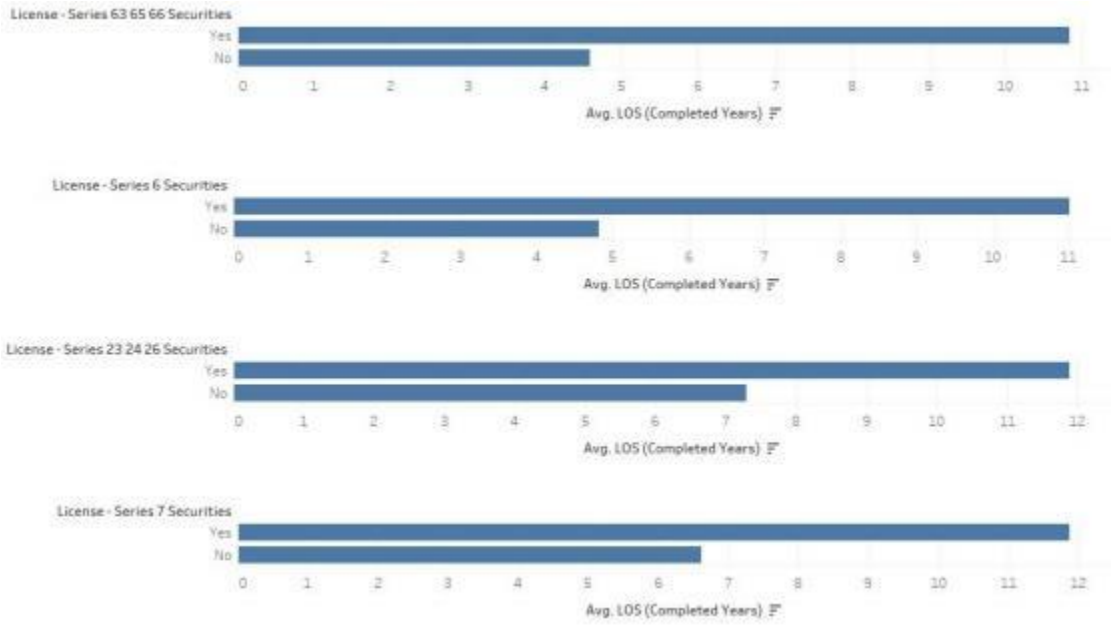

Figure 10 License series vs Completed Years

With a quarter of the workforce expected to retire by 2018, insurance agencies must create strategies to retain their workforce and replace their workforce. If insurance agencies continue to rely on agencies as a primary distribution center and source of revenue generation. Without such a plan they will suffer tremendously as the workforce retires and they find that with the workforce leave many relationships and insights into a customers needs. With eighty-nine percent of insurance agents quitting in three years on average this is even more important that the industry develop a solution to maintain agent relationships and retain their workforce.

While it is clear that people leave often because their commission cannot support their lifestyle, what is less clear is why individuals leave when it is not benefits related. HR experience has taught that onboarding processes must be strengthened, training within the workforce must be facilitated, and employee satisfaction must be increased. Measuring these indicators of success can be difficult. Companies use employee surveys to measure the success of these trainings. While not all data may be reliable, even in surveys that are anonymous, it's important to be able to look for trends and analyze feedback. If a company sees a trend that agents feel they are not being set up for success, or that they were promised great leads but these leads are not as great as advertised, then HR has the opportunity to partner with agency management to generate more effective leads, or set better expectations.

Onboarding must continue to focus on the customer journey, education about insurance carrier policy benefits and risks. Education about the resources that employees have to use to understand the products that they are trying to sell and the needs and experiences of the customers that they are trying to sell to. By training employees, they can be ensured to be extremely knowledgeable and able to align the products they sell with the needs of the customer and by increasing employee satisfaction, employees can be encouraged to stay longer by eliminating concerns that are not typically quantified in the workplace. This could help them to sell more premiums, increase their commission intakes and ensure that they are successful as a long-term agent.

Insurance agencies sit on the cusp of an opportunity to transform the employee experience in order to improve the customer experience, but they must seize it. With millennials positioned to be the largest players in the workforce by 2030, insurance agencies must adopt practices that cater to millennial success in the workforce. The insurance industry is not considered very millennial friendly. Only two percent of graduates want to work in insurance [5]. The reason behind this is because the insurance industry is seen as less technically sophisticated. According to an article published by Forbes “The customer experience is wholly out-of-sync with the ways in which modern consumers wish to buy products and services. Paperwork as well as human brokers and agents are still the norm. Of the $100B in US homeowners insurance, only 6% is sold online, which is a stark contrast to say, the travel industry, where nearly 90% of travel bookings are made online. Self-serve is not an option; websites are barely functional, let alone on mobile [6].”

According to a Salesforce blog, millennials, including millennial employees desire self-service and technical efficiency, which is something they do not see in the insurance world [7]. Insurance agencies must redefine what the employee experience is. While traditionally relying on just domain knowledge and people to deliver effective sales solutions, in today's markets that is not enough. By creating knowledge bases that are easily referenceable and customer-centric solutions that enable agents to select policies that are the best fit for customers, the knowledge gap among new insurance agents can be filled with less training and ensure that they are delivering to customers the best policies that meet their needs. This would enable agents to meet the fiduciary responsibility to their customers as well as allow millennials to have the self-service and technical efficiencies in the processes they so desperately crave within the industry. By embracing technology and allowing millennials to redefine the employee and customer experience, the

millennial talent pool can be more effectively tapped and set up for success. Today, millennials are the most likely to leave an insurance agency and the least likely to be effective agents (Figure 11).

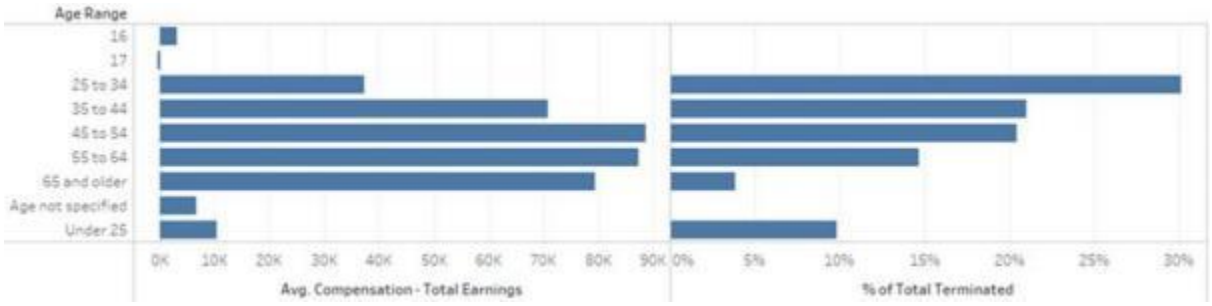

Figure 11 Age vs Earnings vs Attrition Rate

Technology may be the best solution to enable them and allow insurance agencies to meet the desires of their millennial employees. Augmenting human knowledge may be a solution to help millennials. If good agents are knowledgeable, we should provide solutions that enable agents to serve their customers by offering recommendations for offerings that best suit customers needs. This could help bridge the knowledge gap of new agents and help an agency maintain more effective customer relationships, thus allowing agents to sell more, and stay longer. In example, Amazon Web Services (AWS) offers a solution that replaces many of their professional services services called Amazon Trusted Advisor. This tool offers recommendations to customers on how to improve their security, save money that they do not need to spend with Amazon and how to improve their AWS experience. Imagine if agents in insurance had a similar technology at their fingertips. They would be able to tell customers what policies were best for their specific needs, how to meet their financial goals and help explain the single loss expectancy probability and cost for that customer in order to help them make educated financial decisions. While agents would still be expected to be knowledgeable, by bridging the knowledge gap to enable them to perform better, and work on building relationships with the customer. This could also enable them to understand beneficial cross selling opportunities, helping them help customers and themselves. This may fill an unmet need for the millennial agent.

HR leaders within insurance agencies must first understand its employees, assess their needs and understand why they leave the company. Understanding the root cause for employee separation and levels of satisfaction, is the key enabler to accomplish this. Many companies have embraced exit interviews and employee satisfaction surveys in order to accomplish this goal. Employee satisfaction surveys provide employees a means to provide quantitative feedback to management on their general satisfaction with management, company strategy and the holistic work environment. It is important that these surveys are guaranteed to be anonymous to ensure that employees give honest feedback without fear of repercussions.

While some professionals may have doubts about the validity of this data on an individual level, it allows the company to look for trends among their employees' feelings and take action by continuing what they are doing effectively and taking corrective action on trends where their employees are generally dissatisfied. This allows agencies to continuously improve their employee satisfaction and thus improve their companies success. According to a study of employee performance and corporate success in the UK, happier employees drive better corporate results. "On average, the study finds having a 1-star higher rating on Glassdoor predicts about a 1 percent higher annual return on company assets – a statistically significant boost. According to the authors, "firms rated highly by their current employees in terms of satisfaction [on Glassdoor] achieve superior profitability compared to those rated poorly [8]." Exit interviews also allow management to assess the trending root causes of why employees are leaving the company. According to the Harvard Business Review, "The greater goal for any company, of course, is to retain valued employees. Research has shown that high turnover predicts low performance and that an organization with turnover lower than its competitors' can be at a considerable advantage—particularly if it retains its top performers. If people are leaving an organization in ever-increasing numbers, figuring out why is crucial. And the most useful tool for doing so is one that too few leaders pay attention to: exit interviews [9]." For example, if a company sees that agents under one manager are generally leaving because they are dissatisfied with their manager, it may mean an opportunity to train that manager or even that the manager is not a proper fit for his position. Exit interviews thus afford the opportunity for companies to take action to ensure that their good performers do not leave the company and thus enable the company to more effectively keep the relationships and talent that those performers may have left with. By conducting employee satisfaction surveys and exit interviews and analyzing their results, companies will gain a strategic edge to keep their top performers, retain their employees and thus generate better business results.

2.4 Retention Model and Insights

HR leaders within insurance agencies must embrace technology and analytics to improve succession planning and hire more effective agents. This is a practice that is emerging within human resource management to ensure that HR is able to continuously recruit good talent that can help their business meet their strategic goals. To prove this, predictive models are generated based on a de- identified data set provided by LIMRA that would improve HR's capability to plan

when they should recruit new talent. The research derived through the methods described in the "Primary Research Methods" section of the appendix found that the study could predict with 42% improved accuracy from models based on the average retention of an agent how long an agent would stay with an agency. While predictive modeling does not replace the needs for heuristic methods, it would enable HR leaders within agencies to more effectively plan the succession of their agents and recruit and train new talent in an effort to mitigate the cost of their separation from the company. By embracing analytics and improving the data used to predict their retention (Appendix: Improving Data Quality for Analytical models) HR leaders can improve their ability to plan for succession and improve the bottom line for their agencies. Additionally, HR leaders can derive insights from their models that may be worth investigating. From the models, the study derived some interesting insights into what a good agent consists of and what it can be done to improve agent success. It is found that those agents that received new agent financing but made over 6 figures actually tended to separate from the company after shorter tenures of service thena their peers making less. Since new agent financing is typically designed to help agents get acclimated to a new environment and is meant as a retention tool this insight is alarming. While it could be beneficial heuristically for agents, it may not be helping us keep our top performing new agents. Terminated agents who sold greater than or equal to 10806.385 dollars premium and who received new agent financing or did not have report if they had stayed on average 2.4342 years, while their counterparts who did not have new agent financing stayed on average 4.3522 years on average. If new agent financing is meant as a retention tool, these results are counterintuitive to what the investment was designed for. It is believed that LIMRA and the industry should explore this more extensively to see if companies are creating true business value from new agent financing and if it is achieving the goals it was designed for. Our models also confirmed our hypothesis that pay is a significant contributor to retention. It is found that terminated agents tended to stay longer if they earned more. Additionally, older agents typically tended to stay longer. Agents above the age of 47.5 tended to stay longer with 2.3217 years being the average for those above 47.5 and 1.6450 for those younger than 47.5. It is also found that specific groups of companies and states (Figure 12) had vastly higher retention levels than their peers. The study shows why specific states and companies have higher retention rates than their peers with additional information. The only correlation that can seen with the data of this study is that states with higher average compensations for their agents also retain agents longer. While all information in this study points to a link between compensation rates and retention, this may not be the only factor at play. It can, however, be concluded that retention rates are vastly different between states and that compensation may play a role in this. These companies should be investigated and researched to understand if they have retention policies that the rest of the industry could take advantage of and to see why retention may be different across states.

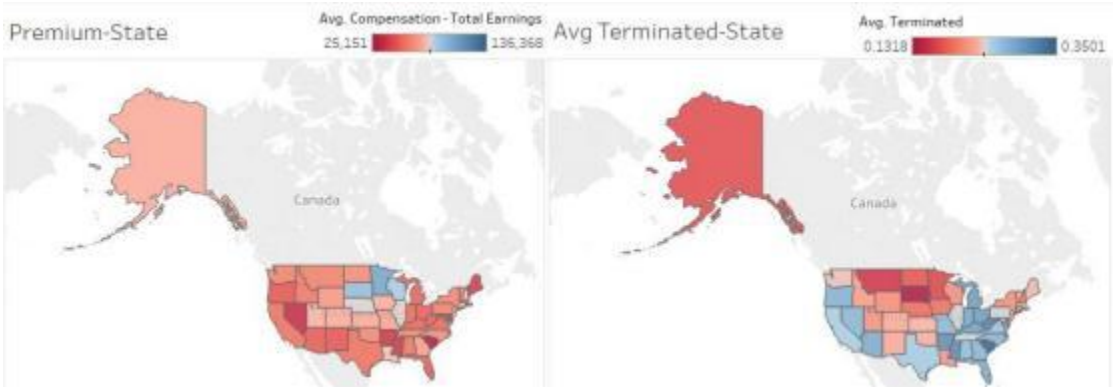

Figure 12 Map: State wise Premium Generation & Termination Rate

3 IMPROVE REVENUE

3.1 Recommendations and Analysis for Revenue Generation

Distribution centers are the primary revenue generators for insurance companies. For our purposes, distribution centers are made up of traditional channels such as agents and newer technologies such as portals. Since the traditional channels as revenue generators are dwindling any insight to increase effectiveness will increase stockholder and stakeholder value. Improving revenue generation strategies and distribution channels will allow companies to improve stakeholder value and overcome the talent crisis to come.

The insurance industry is not known for technology or keeping up with the market expectation. For many of the more complex companies, they are still relying on the traditional distribution channels and their technology may support them but there is no seamless end to end experience for the consumer [10].

The face of the consumer is changing. Not only are millennials going to be the largest population in the workforce, they will also be the majority consumer in the coming years. Millennials view as a consumer is much different than that of the early generations. They have grown up in the digital age having knowledge at their fingertips. They view relationships as very important and are brand loyal. Technology isn't only a tool it's a way of life for them. The industry

as a whole needs to develop technology so potential customers can research and determine their needs online. The following technology will support a move to a better expectation of the market.

Self-service tools provide a place where new potential customers can research and determine what works best for them. The platforms should include the ability to conduct comparison shopping. For innovative companies, it can include what a potential customer would receive from a competitor thus gaining the potential customer's trust. In other words, provide and omni-channel experience.

Automated advisory services are one way to help meet customer's best interests. Based on criteria from a potential customer the robo advisor can steer them to products that work best for them. Robo advisors have already begun to show up in the financial advice industry in places such as Vanguard The traditional agent can be incorporated into this option for those potential customers who may want to finalize with a person.

Utilize social media to identify new business. Tools like facebook graph, and the analytical methods used by social media platforms allow for high lift targeted marketing campaigns. The life insurance industry can take advantage of these platforms to target new consumer bases and engage audiences that they have previously been unable to engage in the past. They can also further target their primary customer demographic profiles to obtain further market penetration.

Many of the technologies are new to this industry and companies are unlikely to have the skill set in house to develop and maintain the technology. In most cases the company would have to go to a vendor possibly outside of the industry. In this regard it will be critical for companies to do their homework and identify vendors that can provide the best value for a given technological need.

Another area that technology can support the effectiveness of agents is technology that supports training. Gamification to support training and productivity has been an inventive way to train companies on subjects that can be tedious or boring. It also can be applied to new hires to help them navigate through behaviors that will increase their ability to sell the right products to customers. Typically badges are earned as part of a gamification training program once criteria or a threshold has been hit.

Besides the effect technology could have on an agents productivity. A comparison across the different states shows certain states sell more premiums then others. As shown in fig 13, there are states that do better than others for selling premiums. A map such as this can be use to develop marketing strategies based on state.

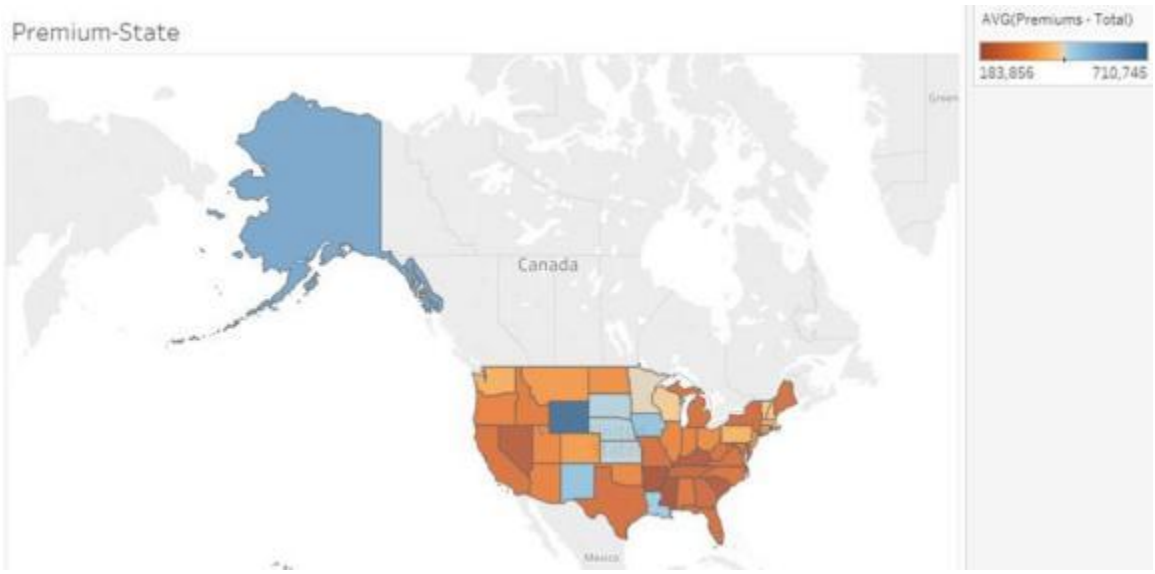

Figure 13 Map State-wise Total Premium Collection

Developing a marketing campaign for states that takes into consideration the penetration into the market as well as the renewal rates can support revenue growth. States that have strong premium showings may be a solid campaign for renewals. States that are at medium levels may be a good place for new business and growth within that state. However, there is no granular detail for why one state does better than another and it is recommended more analysis is conducted on state differences. One concern is for employees that live in states where it is deemed "not worth" putting marketing budget dollars for growth. Those employees may feel that they are being put at a disadvantage to selling in a state that doesn't have a strong marketing brand. In states where the traditional marketing strategies are not worthwhile, it may be worthwhile to test some of the newer avenues to reach new business. Millennials are a great resource for these types of opportunities.

By engaging them in the business plan it keeps them interested in the future of the company. They also will be able to develop and test new ways of marketing products and selling such as a "virtual agent" [2]. Understanding that millennials are brand loyal, it makes sense to understand what a customer's loyalty is to a company (or brand). By developing consumer centric culture companies can improve the loyalty of their consumers and and accelerate their growth in the market. One way of understanding the loyalty to a brand is by analyzing net promoter scores. Net Promoter Score is a way of measuring the percentage of people that would recommend your company to a peer.

Customers are categorized into three buckets based on one question in a survey. “Would you recommend this company to your friends or family?”

(1) Promoters (score 9- 10) are loyal enthusiasts who will keep buying and refer others, fueling growth
(2) Passives (score 7-8) are satisfied but unenthusiastic customers who are vulnerable to competitive offerings
(3) Detractors (score 0-6) are unhappy customers who can damage your brand and impede growth through negative word-of-mouth. The goal of the survey is to keep it simple, so the feedback is quick and actionable.

Frederick Reichheld conducted research that linked survey responses with actual customer behavior and found that companies that focused on improving net promoter score also found significant growth compared to companies in the same industry that did not. In the Figure 14 below you can see a comparison of several airline industries.

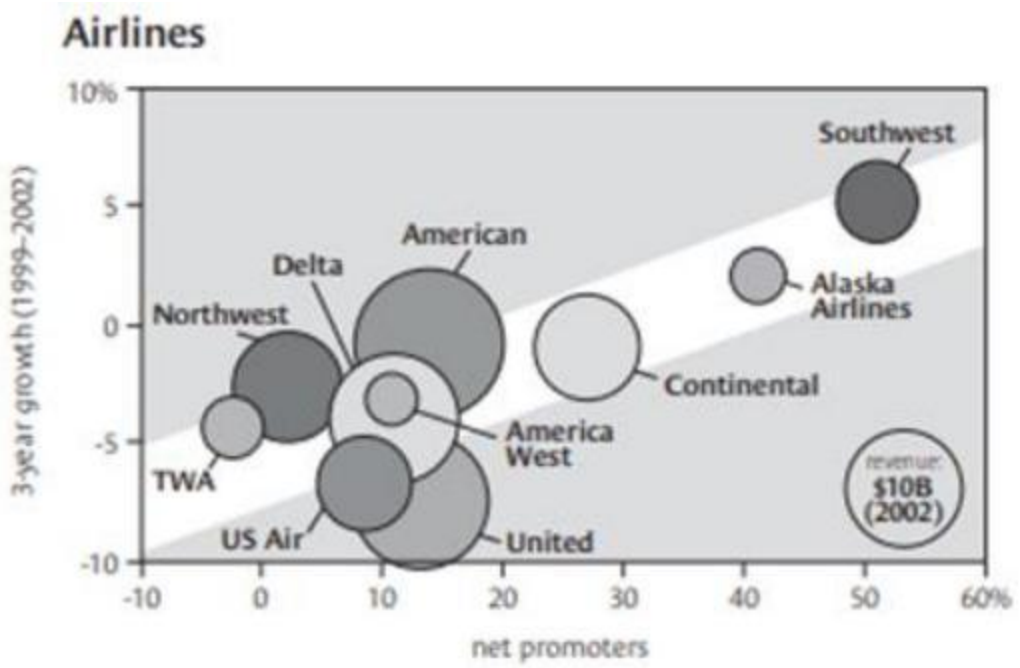

Figure 14 Airlines, Netpromoters vs 3 year growth

Those that have the higher NPS also have significant more growth than others. NPS can be applied to any industry.

In addition to the net promoter score developing a voice of the customer program was recommended. The voice of the customer program is able to develop customer loyalty in two ways. First, responses from customers are resolved immediately, in other words reviewed daily and resolved for an individual consumer. Second, responses are aggregated into process improvement opportunities within the company. Process improvement is not a new concept, it was developed and improved by individuals such as W Edwards Deming, Genichi Taguchi, and Bill Smith.

The idea is a process can be improved upon time and time again which in turns improves quality and reduces the time to get things done. There are several companies today that facilitate the survey questions and provide a dashboard for voice of the customer. The dashboard can measure customer metrics such as customer satisfaction, effort, etc. By aggregating these the company can then identify projects to improve metrics and ultimately improve their net income.

3.2 Super Agents Analysis and Recommendations

During the analysis, a subset of agents were reviewed separately because of their significant yearly premium generation (on average > 10 million for two years or more.) The study dubbed them super agents. In total, twenty five agents met this criteria. Agents whose total premium is over 10 million for only one year were censored as they were most likely outliers. The agents came from the different backgrounds such as company sizes and diversified licenses. The following is a summary of the trends , it is identified within this data set (graphs available to view in the appendix under the super agents’ data analysis):

(1) Gender – Only one of the super agents is Female which is not surprising since in the full data set males tended to generate high premiums on average.
(2) LOS (Completed Years) – The distribution among agents is skewed left. Nearly a half of super agents have 20-30 years experience
(3) Age – Most of the super agents are in the age range of 45-55, consistent with our larger data set that the older generations are finding more success in this industry.
(4) State – Not every state has a super agent most are in California, Michigan, Massachusetts, and Texas. California has the most.
(5) Company – Super agents work for mutual more than stock; They tend to be in management agency (MA) distribution.

Assuming these agents are not crossing any ethical lines, there is an opportunity for companies to leverage them. Here are some recommendations:
Treat them like everyone else- although the first inclination may be to put them on the pedestal and give them special treatment, it could in fact reduce the performance of others on the team. It also will contribute to team divisiveness. Instead get them involved in the success of the team.
Help them represent your company - there's no reason not to share the knowledge and have this group become leaders in the industry. Blogs and conferences is a great way for this group to share what they know. It could in fact be a way to grow new business
Save them time - Find out what activities are wasting their time. Identify opportunities to enhance a process using technology such as mobile apps
Add coaching to their week - one of the best ways to leverage your top performers is for them to help coach others on the team. Unlike putting these folks on a pedestal, this will improve team dynamics. It will also have the added benefit of freeing up a managers time by reducing coaching time.
Keep training them - nothing says I value you more than I'm willing to invest in you. Training is one way that companies can send the message they matter. It keeps their own skills sharp and introduces them to new ways to continually improve their own game.
Use gamification - gamification is a great way to challenge a team to the next level and your top performers can drive significant change. This environment allows for them to share their knowledge in a way that will improve team's overall.

3.3 Premium Model and Insights

The study model the overall agent premium generation per agent, removing super agents from our data set as outliers. Modeling this would allow agencies to more effectively forecast revenue to make better investment decisions. It is found that the model could predict 29% improved accuracy from a baseline model using the average premium generation of an agent. Where you are working and who you are working for for is a significant predictor of how much premium you will sell. This shows that there are not only major differences in state premium opportunities among the market but also that specific companies are able to more effectively reach and sell customers policies. This may speak to the management, specific book of business or the reputation of the company. LIMRA should continue to study different company strategies to understand what is more effective.
It is also found that being licensed plays a significant factor in how much premium you will sell. An agent obtaining a series 6, 7 and especially 63, 65 and 66 series license was a significant predictor in how much premium an agent could sell. This goes to show that more knowledgeable agents are indeed more effective agents as these licenses represented a significant increase in premium sales. Length of service also played a significant role in predicting how much premium an agent would make. Agents with longer tenures typically made much more in premium. While this could speak to an increased knowledge ofproducts and ability to sell with longer tenure, it could also be an indicator as simple as longer tenured agents will have more renewal premium. Furthermore, New agent financing was a predictor that decreases the amount of premium an agent sold for those already selling significant amounts of premium. While this can be expected since this financing is meant as a transition income, it could also be indicative of the investment in agents not being an effective business decision for top performers. Further studies should be done on how this affects top performing new agents as this financing was also indicative of a decrease in retention period among top performers in our retention models. Overall, agencies should invest in predictive models to more effectively forecast the premiums their agents will sell.

3.4 Lifetime Value of an Agent

Agent Lifetime Value represents the total net value over time that an Agent would generate in a company. This value can be utilized to calculate the Return on Investment on a an employee or an agent.
Ability of have the LTV of an agent helps the organization to maximize. Company can achieve this goal by developing and executing programs that impact the outputs (premiums in this case) that drive it.
Building a model to predict the agent's lifetime value would also help a company decide on what set of agents would give a higher overall value to the organization and thus hire better suited talent.
However, with the existing data it's NOT possible to derive an effective model which can predict the lifetime value of an agent.
No predictive model was constructed for arriving at lifetime value. A simplified approach was to calculate Value generated by an average agent by
1. Adding - Cumulative average-premium generated by an agent
2. Removing – Cumulative average-compensation taken up by agent
3. Removing – the cumulative retention cost (Assumed $9,500/ and inflation adjusted at 4%)

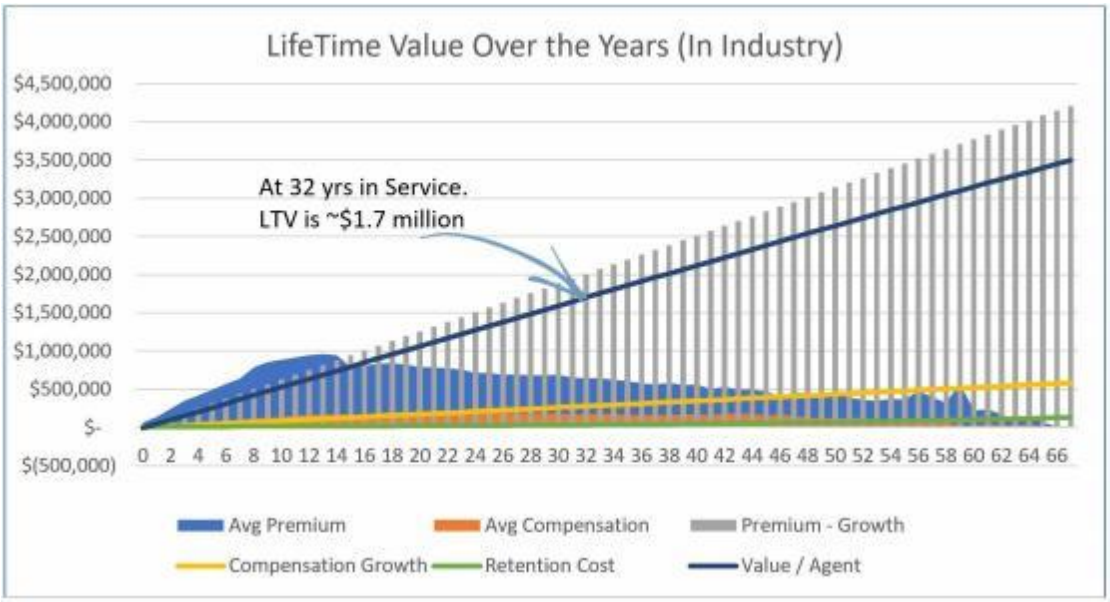

Figure 15 Life-Time Value

The graph -Figure 15 - represents how over the career, an agent would
(1) generate premiums (a)
(2) collect compensation (b)
(3) consume retention costs – beyond commission (c)
(4) generate the value for the company (a-b-c)
With this it can be seen that the upfront cost of hiring and training an agent would be recovered in the first year of the service.
However, as the service life of an agent progresses, the cumulative value generated by the agent would also progress. An agent would have generated ~ 1.7 million in value for the company over a 32-year service.
This visualization which is based only on current dataset shows that longer an
agent stays in the company, higher overall value is generated. With enough information, HR professionals could use lifetime value predictions of agents to more accurately forecast revenue and understand the profit per headcount they can get to make better hiring decisions.

COMPETING INTERESTS

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

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CURRENT STATUS AND INFLUENCING FACTORS OF HEALTH LITERACY AMONG RURAL RESIDENTS IN CHINA--A CROSS-SECTIONAL SURVEY

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Abstract: Objective: Research on the health literacy level of rural residents and its influencing factors can help to improve the health level of rural residents, but also promote the development of rural medical and health care, and provide decision-making references for relevant departments to formulate policies.
Method: The health literacy situation of rural residents in Fengqiu County was investigated by questionnaire star using the Chinese Residents' Health Literacy Questionnaire, and this study is a cross-sectional survey.
Results: The overall health literacy level of rural residents in Fengqiu County, Xinxiang City, Henan Province, was 24.17% in 2024. Those with basic knowledge and conceptual ability accounted for 23.54%, those with lifestyle and behavioral ability accounted for 24.75%, and those with health skills accounted for 18.33%. The knowledge and ability of rural residents in Fengqiu County in six categories of health issues, scientific health concepts accounted for 29.20%, infectious disease prevention, and treatment accounted for 18.25%, chronic disease prevention and treatment accounted for 4.23%, safety, and first aid accounted for 30.17%, basic medical care accounted for 20.19%, and health information accounted for 19.55%, which are all lower than the national level.
Among the 1233 respondents, 200 males had health literacy skills with a health literacy level of 67.23%, and 98 females had health literacy skills with a health literacy level of 32.77%, with a statistically significant difference in health literacy levels between the sexes (χ^2=18.73, P<0.0001). The health literacy level of rural residents under the age of 18 years was the lowest at 12. 96% and the highest in the 18-25 age group was 62.18%, with a statistically significant difference in health literacy levels between different age groups (χ^2=34.39, P<0.0001). and the highest in the 18-25 age group was 62.18%, with a statistically significant difference in health literacy levels of rural residents between different age groups (χ^2=34.39, P<0.0001). Rural residents with primary school education or less, 385 people, accounting for 31.26%, had the lowest health literacy level, 3.67%, and the difference between different education levels was statistically significant (χ^2=284.1, P<0.0001), as the education level increases, the health literacy level of rural residents also increases. Occupation affects the health literacy level, farmers have the lowest health literacy level, 12.11%, and the difference in health literacy level between different occupations is statistically significant (χ^2=61.30, P < 0.0001).
Conclusion: The overall health literacy level of rural residents in Fengqiu County, as well as the results in the three aspects of basic health literacy knowledge and concepts, lifestyle and behavior, and health skills, and the six types of health literacy questions, were lower than the national level. Gender, age, education level, and occupation can affect the health literacy level of rural residents, and relevant departments should take strong measures to promote the improvement of the health literacy level of rural residents.
Keywords: Rural residents; Health literacy; Influencing factors; Education level; Occupation

1 INTRODUCTION

With the development of China's economy and the improvement of people's living standards, people's demand for quality of life is also increasing, and health, as an important part of the quality of life, is receiving more and more attention [1,2], with the expectation of higher health awareness and better health quality [3]. Health literacy, as an important influencing factor in improving the health level of residents, is a key indicator to evaluate the ability of individual residents to acquire, use, and process health information [4-6], and there are significant differences in health literacy between urban and rural areas in China [7-8].
In recent years, the level of residents' health literacy has become the focus of scholars' attention, and related studies and surveys have gradually increased. The Action for a Healthy China (2019-2030)[8] explicitly proposes to carry out health literacy activities, to achieve a health literacy level of at least 22% for the entire population by 2022, and no less than 30% by 2030, and the policy also advocates national campaigns to improve the quality of the people's health through a variety of physical activities, competitions, and campaigns of varying forms. The World Health Organization has emphasized that health literacy is an important predictor of the health status of a population and that an increase in literacy can effectively reduce social costs and mitigate health inequities [9]. Several studies have shown that there is a significant association between health literacy levels and health outcomes. There is a significant association between lower levels of health literacy and poor health outcomes. Leak, C. et al. found that lower health literacy was a significant predictor of incomplete study follow-up [10].McDonald, M. et al. noted that low health literacy is a risk factor for poor health outcomes, including increased hospitalization rates [11]. In addition, health literacy affects

patients' medication adherence and disease control [12]. Whereas, high health literacy contributes to improved health status, fewer medical errors, and higher patient satisfaction [13-14]. Health literacy is particularly important for patients with chronic diseases. Schillinger D et al. showed a significant association between health literacy and diabetes outcomes, with patients with low health literacy more likely to hold health beliefs that interfere with treatment [15]. Similarly, Du, S. et al. found that health literacy was strongly associated with health outcomes in patients with hypertension, and patients with low health literacy were more likely to have poor health outcomes [16].

For the research on the health literacy level of regional residents and its influencing factors, especially for rural residents, Chinese scholars have made some new progress in recent years: a study in Anhui Province in 2022 showed that the overall health literacy level of rural residents was 29.17%, with a low level of health literacy, especially in the prevention and treatment of infectious diseases. Age and literacy were the main factors influencing the level of health literacy [17]. A study in Shandong Province in 2021 found that the health literacy level of rural residents was 21.81% [18]. The level of health literacy is affected by factors such as age, literacy, family income, and whether or not they have chronic diseases. Regional differences are also an important factor, with health literacy levels higher in the eastern region than in the central and western regions. A study in Zhejiang Province from 2016-2021 showed that the health literacy level of rural residents showed an upward trend, with a cumulative increase of 16.32% during the six years [19]. The literacy level of chronic disease prevention and treatment, scientific health concepts, and health information increased year by year, but the health literacy level of the elderly, low-literacy groups, and farmers increased less. A study on grassroots health education in rural Henan Province pointed out that despite a series of health education activities and some improvement in health literacy, there are still problems such as insufficient educational resources and a shortage of health promotion personnel [20]. A health literacy survey of low-income people in rural Henan Province in 2019 found that the literacy level was 20.66%, which was affected by various factors such as gender, age, and literacy level. The study recommended health education based on the characteristics of low-income people, and strengthening health management of chronic diseases [21]. These studies identified the weak points of rural health literacy, which is of great significance in solving these problems.

Although there have been a large number of studies on health literacy, there is still room for improvement. This paper aims to study the health literacy level of rural residents and its influencing factors, which can help improve the health level of rural residents, but also promote the development of rural medical and health care programs, and provide decision-making references for relevant departments to formulate policies.

2 OBJECTS AND METHODS

2.1 Study Population

The study involved a random sample of rural residents, including migrant workers, aged 16 to 59 years in Fengqiu County, Xinxiang City, Henan Province. Health literacy was assessed using a questionnaire distributed between June and July 2024. A total of 1,327 questionnaires were collected, resulting in 1,233 valid responses, yielding a validity rate of 92.9%.

2.2 Measurement Instruments and Evaluation Indicators

The "Chinese Residents' Health Literacy Monitoring Survey Questionnaire" was utilized, which comprises three dimensions: basic knowledge and concepts, healthy lifestyles and behaviors, and health skills. It also addresses six categories of health issues: scientific health concepts; prevention and treatment of infectious diseases; prevention and treatment of chronic diseases; safety and first aid; basic medical care; and health information. Scoring: Each participant receives 1 point for correctly answering judgment, multiple-choice, and scenario questions that align completely with the standard answers. No points are awarded for incorrect responses.

Scoring Criteria: A score of 53 or higher indicates that the individual is considered health literate. Additionally, if a participant's score in a specific area of health literacy (related to a particular health issue) reaches at least 80% of the total points possible for that area, they are regarded as competent in that aspect.

Health Literacy Level Calculation: The health literacy level is calculated using the formula: (Number of individuals with basic health literacy / Total number of respondents) × 100%.

2.3 Statistical Analysis

Statistical analysis was performed using SPSS 26.0. Categorical variables were expressed as percentages, and differences were tested using the chi-squared test, with a significance level of $P < 0.05$.

3 RESULTS

3.1 The basic situation of the research subjects

The survey was conducted by questionnaire star, for the recovery of 1327 questionnaires, of which 1233 were valid questionnaires, with an effective rate of 92.9%. Among them, 685 were male, accounting for 50.55%; 548 were female, accounting for 49.45% (Table 1).

Table 1 Basic Characteristics of the Study Subjects

Variable		n	Composition ratio (%)
Gender	Male	685	50.55
	Female	548	49.45
age (Year)	≥15	182	14.75
	≥18	183	14.82
	≥25	202	16.38
	≥30	209	16.96
	≥40	206	16.73
	50-59	251	20.36
Educational level	Below primary school	385	31.26
	Primary school	313	25.38
	Junior high school	273	22.14
	High school	208	16.89
	University (including college) and above	54	4.33
Occupation	Civil servants or public institution personnel	130	10.54
	Medical staff	96	7.82
	Teacher	108	8.73
	Student	247	20.00
	Enterprise	305	24.72
	Farmer	256	20.73
	Other	92	7.46

3.2 Health Literacy Level of Rural Residents

The survey shows that the overall health literacy level of rural residents in Fengqiu County, Xinxiang City, Henan Province in 2024 was 24.17%, that is, 24 people out of 100 people had knowledge of health literacy. Those with basic knowledge and conceptual ability account for 23.54%, those with lifestyle and behavioral ability account for 24.75%, and those with health skills account for 18.33%. The knowledgeability of rural residents of Fengqiu County in the six categories of health issues possesses 29.20% of scientific health concept knowledge, 18.25% of infectious disease prevention and control knowledge, 4.23% of chronic disease prevention and control knowledge, 30.17% of safety and first aid knowledge, 20.19% of basic medical knowledge, and 19.55% of health information knowledge (Table 2).

Table 2 Rural Residents' Scores on Health Literacy in General, the Three Dimensions, and the Six Categories of Health Problems (n=1233)

Variable		Health literacy (%)		Health literacy level (%)
		Yes	No	
Health literacy level	Availability of health literacy	298 (24.17)	935 (75.83)	24.17
Three Dimensions of Health Literacy	Basic knowledge and concepts	290 (23.54)	943 (76.46)	23.54
	Healthy Lifestyle and Behavior	305 (24.75)	928 (75.25)	24.75
	health skills	226 (18.33)	1007 (81.67)	18.33
Six categories of health literacy issues	scientific concept of health	360 (29.20)	873 (70.80)	29.20
	Prevention and control of infectious diseases	225 (18.25)	1008 (81.75)	18.25
	Prevention and treatment of chronic diseases	52 (4.23)	1181 (95.77)	4.23
	Safety and First Aid	372 (30.17)	861 (69.83)	30.17
	basic medical care	249 (20.19)	984 (79.81)	20.19
	Health Information	241 (19.55)	992 (80.45)	19.55

3.3 Scores and Differential Analysis of Health Literacy by Gender, Age, Occupation, and Education Level

3.3.1 Scores and differential analysis of health literacy among rural residents by gender and age

The study shows that among the 1233 surveyed subjects, 200 males have health literacy ability, with a health literacy level of 67.23%, and 98 females have health literacy ability, with a health literacy level of 32.77%, and the difference in health literacy level among genders is statistically significant (χ^2=18.73, P < 0.0001), indicating that gender is a factor that influences the health literacy level of rural residents in Fengqiu County, with males having higher health literacy level than males, and that gender is a factor that influences the health literacy level of rural residents in Fengqiu County. Literacy level, with males higher than females. In terms of age distribution, the health literacy level of those under 18 years old is the lowest, 12.96%, and the 18-25 age group is the highest, 62.18%, and the difference in the health literacy level of rural residents between different age groups is statistically significant (χ^2=34.39, P < 0.0001) (Table 3).

Table 3 Differential Analysis of Health Literacy Levels of Rural Residents by Gender and Age

Variable		n (%)	Health literacy n (%)		Health literacy level (%)	χ^2	P
			Yes (298)	No (935)			
Gender	Male	685 (50.55)	200(67.23)	485(51.87)	29.20	18.73	< 0.0001
	Female	548 (49.45)	98(32.77)	450(48.13)	17.88		
age (Year)	≥15	108 (8.75)	14(4.75)	94(13.69)	12.96	34.39	
	≥18	121 (9.82)	76(25.37)	45(15.94)	62.81		
	≥25	213 (17.24)	52(17.58)	161(16.47)	24.41		
	≥30	234 (18.96)	53(17.62)	181(17.11)	22.64		
	≥40	257 (20.87)	45(15.21)	212(16.26)	17.51		
	50-59	300 (24.36)	58(19.47)	242(20.53)	19.33		

3.3.2 Scores and differential analysis of rural residents' health literacy in different occupations and educational levels

The study showed that 385 rural residents with elementary school education or below, accounting for 31.26%, had the lowest health literacy level of 3.67%, and the difference between different education levels was statistically significant (χ^2=284.1, P<0.0001), and as the education level rose, the health literacy level of the rural residents also increased. In terms of occupation, farmers had the lowest health literacy level of 12.11%, and the difference in health literacy level between different occupations was statistically significant (χ^2=61.30, P < 0.0001) (Table 4), indicating that occupation is an influential factor affecting health literacy level and that health literacy level of manual labor groups such as farmers and workers is even lower.

Table 4 Differential Analysis of Health Literacy Levels of Rural Residents in Different Occupations and Educational Levels

Variable		n (%)	Health literacy n (%)		Health literacy n (%)	χ^2	P
			Yes (298)	Yes (298)			
Educational level	Below primary school	385 (31.26)	14 (4.84)	371 (39.68)	3.67	284.1	< 0.0001
	Primary school	313 (25.38)	50 (16.73)	263 (28.13)	15.97		
	Junior high school	273 (22.14)	86 (28.75)	187 (20.00)	31.50		
	High school	208 (16.89)	103 (34.58)	105 (11.23)	49.52		
	University (including college) and above	54 (4.33)	45 (15.10)	9 (0.96)	83.33		
Occupation	Civil servants or public institution personnel	130 (10.54)	57 (19.21)	73 (7.81)	43.85	61.30	< 0.0001
	Medical staff	96 (7.82)	31 (10.27)	65 (6.95)	32.29		
	Teacher	108 (8.73)	35 (11.92)	73 (7.81)	32.41		
	Student	247 (20.00)	66 (22.15)	181 (19.36)	26.72		
	Enterprise	305 (24.72)	63 (21.26)	242 (25.88)	20.65		
	Farmer	256 (20.73)	31 (10.25)	225 (24.06)	12.11		
	Other	91 (7.46)	15 (5.04)	77 (8.24)	16.30		

4 DISCUSSION

4.1 Basic health literacy of rural residents in Fengqiu County

According to the survey, the overall health literacy level of rural residents in Fengqiu County, Xinxiang City, Henan Province, in 2024 was 24.17%, i.e, 24 out of every 100 people were health literate, which was lower than the national rural residents' health literacy level of 26.23% in 2023, and lower than the average health literacy level of Chinese residents of 29.70% in 2023, and lower than that of national urban residents' health literacy level of 33.25%. According to “Health Literacy of Chinese Citizens - Basic Knowledge and Skills”, health literacy is divided into 3 aspects, i.e. basic health knowledge and concepts, healthy lifestyle and behavior, and basic skills. Rural residents of Fengqiu County have 23.54% basic knowledge and conceptual ability, 24.75% lifestyle and behavioral ability, and 18.33% health skills, which is also lower than the urban and rural residents' basic knowledge and conceptual literacy level of 42.00%, healthy lifestyle, and behavioral literacy level of 32.21%, and basic skills literacy level of 26.76%. Fengqiu County rural residents of the six categories of health issues knowledge ability to know scientific health concepts accounted for 29.20%, knowledge of infectious disease prevention and control accounted for 18.25%, chronic disease prevention and control knowledge accounted for 4.23%, safety and first aid knowledge accounted for 30.17%, basic medical knowledge accounted for 20.19%, health information knowledge 19.55%, is much lower than the national level of literacy of the six categories of health issues: safety and first aid literacy 59.33%, health information literacy 59.33% and first aid literacy 59.33%. And first aid literacy 59.33%, scientific health concept literacy 54.71%, health information

literacy 41.05%, chronic disease prevention and treatment literacy 30.43%, basic medical care literacy 28.84%, and infectious disease prevention and treatment literacy 28.02% [22].

The health literacy of rural residents in Fengqiu County is lower than the national level mainly because of the following reasons.

First, although Fengqiu County is a place of longevity, it was once a poverty-stricken county at the national level with a relatively low level of economic development. The weak economic foundation of rural Fengqiu County and the limited income of its residents make it difficult to invest in health resources, such as purchasing abundant healthy food, participating in paid fitness activities, or obtaining advanced medical services, which limits the material conditions for improving health literacy [23]. Second, lack of educational resources. Inadequate local educational resources have led to a generally low level of education among residents, and their ability to understand, learn, and apply complex health knowledge is weak, making it difficult for them to deeply understand health concepts and skills [24]. In addition, traditional concepts have far-reaching influence. Some traditional and unscientific health concepts persist in rural areas, such as overreliance on folk remedies and downplaying of preventive health care, which hinders the dissemination and acceptance of modern health knowledge [25]. In addition, the primary health care system is incomplete. Outdated medical facilities and a shortage of specialized medical personnel make it difficult to provide systematic and effective health education, and residents' access to accurate health information is limited [26]. Finally, information dissemination is lagging. Rural residents rely mainly on traditional media, such as television and radio, and underutilize new and informative communication channels, such as the Internet, resulting in untimely and incomplete updates of health knowledge [27].

4.2 Analysis of Differences in Rural Residents' Health Literacy Level by Gender, Age, Education Level, and Occupation

The present study shows that the difference in the health literacy level of rural residents in gender is significant, indicating that gender is a factor affecting the health literacy level of rural residents in Fengqiu County, and males are higher than females; and the difference in health literacy of rural residents between different ages is significant, with the lowest level of health literacy under the age of 18 years old, 12.96%, and the highest level in the age group of 18-25 years old, 62.18%, and with the increase of age, the health literacy level has a decreasing trend, which is consistent with the findings of Wenna Wang et al [28-29]. This may be because in rural areas, the traditional division of gender roles affects the level of health literacy. Men tend to be more involved in social and economic activities and have more access to external resources such as health literacy lectures and training. Women, on the other hand, are mainly responsible for household chores and taking care of the family, so their scope of activities is relatively narrow and their access to health knowledge is limited, resulting in a higher level of health literacy among men than among women. 18-25-year-olds, who grew up in an era of more advanced information dissemination and whose school education included a certain amount of health knowledge education, are more receptive to new knowledge. People under the age of 18 have less accumulated health knowledge. As they grow older, the elderly are influenced by traditional concepts and are less receptive to new health ideas and knowledge, while their ability and channels for acquiring information are not as good as those of young people, leading to a decrease in health literacy with age.

Education level also has an important impact on residents' health literacy, residents with high education levels have significantly higher health literacy levels than those with low education levels, the higher the education level, the higher the health literacy level of the residents, at the same time, occupation also has a significant impact on the level of health literacy, people engaged in certain occupations (e.g, civil servants) have a higher level of health literacy, whereas people engaged in agriculture or manual labor occupations have a lower level. Occupation is an influencing factor on the level of health literacy, and farmers, workers, and other manual labor groups have a lower level of health literacy, which is consistent with the findings of Zhao Y. et al [30-32] and others. This may be because highly educated residents have strong learning ability and knowledge comprehension ability, and can actively acquire health knowledge through a variety of ways, such as reading specialized books and research reports. On the other hand, residents with low educational attainment have difficulties in acquiring and understanding complex health knowledge and lack the awareness and ability to learn health knowledge on their own, thus their health literacy is lower. Civil servants and other professions usually have a better working environment, and their organizations attach importance to the health of their employees and will carry out health-related training and publicity. Farmers and workers, on the other hand, are engaged in long-term physical labor, with high work intensity and working environments that are not conducive to the learning of health knowledge, and they are engaged in occupations that seldom involve health-related training, so the level of health literacy is lower.

5 RECOMMENDATIONS

5.1 Economic Support and Resource Optimization

Relevant departments should increase the economic support for rural areas in Fengqiu County, promote the upgrading and diversification of rural industries, and improve the income level of residents. For example, the development of specialty agricultural products such as honeysuckle and raspberry processing industry extends the agricultural industry chain, and increases the added value of agricultural products, so that farmers can increase their income, and thus have more funds to invest in the field of health. At the same time, the rational allocation of resources increases investment in

rural health infrastructure construction, improves the facilities and equipment of primary medical and health institutions, ensures that residents can conveniently access basic medical services and health checks, and provides material protection for improving health literacy.

5.2 Educational Enhancement and Knowledge Popularization

5.2.1 Strengthen the rural education system and improve the overall quality of education

Increase investment in education, improve school conditions, attract excellent teachers, and provide students with a more comprehensive education, including a systematic health education program, to cultivate health awareness and knowledge from an early age.

5.2.2 For adult residents, carry out various forms of health knowledge popularization activities

Make use of agricultural leisure time to organize health knowledge lectures and trainings, inviting medical professionals to explain the prevention and treatment of common diseases and the adoption of healthy lifestyles. Health knowledge brochures, posters, and other publicity materials are produced and distributed to farm households, with content that is easy to understand and close to the reality of rural life. And make full use of new media platforms, such as the establishment of a public number for rural health knowledge, to regularly push health information suitable for rural residents, and to facilitate residents to learn at any time.

5.3 Conceptual Change and Cultural Guidance

5.3.1 Correct traditional wrong health concepts

Through publicity and case lectures, residents are made to realize the limitations of folk remedies and the importance of scientific preventive health care. For example, carry out health science publicity week activities, focusing on displaying cases comparing scientific health knowledge and misconceptions, and guiding residents to establish correct concepts.

5.3.2 Foster a healthy cultural atmosphere

Organize health-themed cultural activities in rural communities, such as health knowledge contests and healthy lifestyle displays, and reward residents or families with outstanding performance to motivate more people to actively participate, so that health concepts can be deeply rooted in people's minds and a good health culture can be formed.

5.4 Medical Service Improvement and Career Support

5.4.1 Strengthen the construction of the primary medical and healthcare service system

Increase the training of grassroots medical and nursing staff, improve their professionalism and health education capabilities, and encourage medical and nursing staff to go into rural families to provide health guidance. Establishing and improving residents' health records, realizing dynamic management of health information, and providing a basis for personalized health services.

5.4.2 Carry out health literacy promotion work for different occupational groups

For farmers and workers, taking into account their occupational characteristics, training in the prevention and treatment of occupational diseases, labor safety, and health has been carried out, and health bulletin boards have been set up in workplaces to regularly update the content of health knowledge. For occupations such as highly educated groups or civil servants, they are encouraged to play the role of demonstration and leadership, leading those around them to pay attention to their health, and at the same time further provide professional health management training and mental health counseling, etc, to enhance the depth and breadth of their health literacy.

6 CONCLUSION

The overall health literacy level of rural residents in Fengqiu County, as well as the results of the three aspects of basic health literacy knowledge and concepts, lifestyles and behaviors, and health skills, and the six types of health literacy questions, are lower than the national level, gender, age, education level, occupation, etc. can affect the health literacy level of rural residents, and the relevant departments should take strong measures to promote the improvement of the level of health literacy of rural residents.

COMPETING INTERESTS

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THE EFFECT OF FREE NITROUS ACID PRETREATMENT AND AEROBIC DIGESTION ON THE DYNAMICS OF ANTIBIOTIC RESISTANCE GENES IN RESIDUAL SLUDGE

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Abstract: Free Nitrous Acid (FNA) Pretreatment Enhances Organic Matter Hydrolysis in the Digestion Stage, but Its Impact on the Dynamics of Antibiotic Resistance Genes (ARGs) During Aerobic Digestion of Residual Sludge Remains Unexplored.This study employed an orthogonal experimental design to assess the dynamics of ARGs in the aerobic digestion of residual sludge under varying FNA pretreatment sludge ratios, temperatures, and pH levels. The aim was to identify the optimal conditions for ARG reduction and elucidate the underlying mechanisms. Results indicated that the optimal conditions for ARG reduction were a residual sludge to FNA-pretreated sludge ratio of 2:1, a temperature of 45°C, and pH = 10, yielding reductions of 84.13% and 76.03%, respectively. Range analysis revealed that the key environmental factors influencing ARG reduction were pH > temperature > sludge ratio. Under high-temperature and alkaline conditions, concentrations of ammonia nitrogen (NH_3), soluble extracellular polymeric substances (S-EPS), and soluble chemical oxygen demand (SCOD) increased, suggesting that these conditions facilitate cell lysis, thereby promoting ARG reduction. Microbial community analysis showed that the relative abundance of potential ARG-hosting bacteria (e.g., Saccharimonadales, Caldilineaceae, SC-I-84, Ellin6067, unclassified_Blastocatellaceae, Nitrospira, Gemmatimonadaceae, and OLB12) decreased in parallel with ARG reduction, indicating that the high-temperature, alkaline aerobic digestion environment may mitigate ARG dissemination by inhibiting the proliferation of potential host bacteria.
Keywords: Free Nitrous Acid (FNA) pretreatment; Aerobic digestion; High temperature; Strong alkaline conditions; Antibiotic Resistance Genes (ARGs); Microbial community structure

1 INTRODUCTION

Sewage treatment plants (WWTPs) are considered hotspots for the spread of antibiotic resistance genes (ARGs), which can proliferate within the microbial community through the replication of antibiotic-resistant bacteria and horizontal gene transfer mediated by mobile genetic elements (MGEs)[1],This results in the dissemination of multidrug-resistant pathogens into the environment, posing significant threats to public health and ecological safety. The distribution of ARGs in WWTP effluents and sludge varies. Munir et al. investigated the distribution of ARGs in urban WWTPs and found that the abundance of ARGs in sludge was three orders of magnitude higher than in effluent[2]. Therefore, WWTP sludge serves as a major reservoir and source of ARG contamination. Understanding the dynamics of ARGs during sludge treatment is critical for controlling their spread into the natural environment. As a key component of WWTPs, sludge digestion is commonly used to stabilize biosolids. Aerobic digestion, a widely applied sludge treatment technique, enhances the degradation of volatile solids (VS), improves nitrogen and pathogen removal efficiency, and thereby stabilizes the sludge, making it particularly suitable for small-scale sewage treatment systems. However, research on ARG changes during aerobic digestion remains limited and warrants further investigation.

The rate-limiting step in the digestion process is sludge hydrolysis, primarily due to the extracellular polymeric substances (EPS) and cell walls that form stable microbial aggregates, limiting the hydrolysis rate of macromolecular organics. Numerous studies have shown that pretreatment technologies can disrupt cell walls or lyse cells, thereby releasing intracellular organic matter. Research on pretreatment combined with digestion processes is relatively mature in terms of cell disruption and digestion enhancement. Current studies suggest that cell structure degradation is a key factor in ARG removal. Free Nitrous Acid (FNA) pretreatment, characterized by its environmental friendliness, easy accessibility, and strong oxidative properties, has demonstrated excellent performance in promoting cell lysis and improving digestion efficiency, thereby reducing the operational cost of the digestion process. For example, Wang et al. found that FNA treatment at 2.13 mg/L increased the soluble chemical oxygen demand (SCOD) of the sludge sixfold compared to untreated sludge, and after 24 hours of FNA (2.0 mg/L HNO_2-N) pretreatment, followed by 14 days of aerobic digestion, sludge degradation increased from 32% to 50% [3]. Previous studies have shown that alkali, ultrasound, hydrothermal, and ultrasonic pretreatments can enhance anaerobic digestion efficiency while promoting ARG reduction. However, limited research has been conducted on the effect of FNA pretreatment on the reduction of abundant ARGs in aerobic digestion of residual sludge.

This study aims to optimize the FNA pretreatment-aerobic digestion process by regulating environmental factors (such as sludge ratio, temperature, and pH) through orthogonal experimental design. The study will investigate the impact of

these environmental factors on the fate of ARGs by examining changes in ammonia nitrogen (NH_3), SCOD, and EPS. It will systematically analyze the mechanisms of ARGs reduction before and after FNA-aerobic digestion treatment, along with changes in microbial community structure, further elucidating the potential hosts of ARGs and their interactions under different environmental conditions. The findings will provide a theoretical basis for environmental pollution management and ARGs control.

2 MATERIALS AND METHODS

2.1 Source of Activated Sludge

The residual sludge was obtained from the secondary sedimentation tank of a sewage treatment plant in Chengdu, Sichuan Province. The sludge was passed through a 0.5 mm sieve to remove large particles, then left to settle, and the supernatant was discarded to obtain the concentrated sludge

2.2 Pretreatment Conditions

Free Nitrous Acid (FNA) exhibits a strong bactericidal effect, and as the FNA concentration increases, the yield of soluble chemical oxygen demand (SCOD) also increases. Among the influencing factors, pH and nitrite nitrogen (NO_2^--N) concentration are key determinants of FNA concentration. However, neither pH nor NO_2^--N alone has a significant effect on cell lysis, indicating that molecular disruption is primarily caused by FNA rather than by H^+ or NO_2^--N acting independently. Higher FNA concentrations (lower pH and higher NO_2^--N) result in more pronounced cell lysis and better ARG removal from residual sludge [3]. Based on both effectiveness and cost considerations, the FNA pretreatment conditions for residual sludge aerobic digestion in this study were selected as pH 5.3 and NO_2-N 753 mg/L (see Supplementary Table S1).

2.3 Setup and Operation of the Aerobic Digestion System

Aerobic digestion was performed under different conditions using the FNA pretreatment combination. The influence of the pretreatment sludge ratio (residual sludge/treated sludge), temperature, and pH on the abundance of ARGs in the aerobic digestion system was examined. An orthogonal experimental design was used to investigate the changes in ARG concentrations under the influence of these three environmental factors, as shown in Table 1. Sampling was conducted at 0, 4, 8, 12, 16, and 20 days to analyze SCOD, NH_3, and EPS. Samples were also collected at 0, 8, 16, and 24 days to assess ARGs, in order to determine the optimal parameters for ARG reduction during aerobic digestion.

Table 1 Orthogonal Experimental Design of Anaerobic Digestion

Number	Factor 1 (sludge ratio)	Factor 2 (temperature)	factor 3(pH)
E1	1（1:1）	1（25 ℃）	1（6）
E2	1	2（35 ℃）	3（10）
E3	1	3（45 ℃）	2（8）
E4	2（2:1）	1	2
E5	2	2	1
E6	2	3	3
E7	3（3:1）	1	3
E8	3	2	2
E9	3	3	1

2.4 Detection Methods for NH_3, SCOD, and EPS

NH_4^+-N and SCOD were determined using national standard methods. pH was measured using a PH SJ-3F Leici pH meter. EPS in this study was divided into two categories: S-EPS and TB-EPS. The mixed sludge-water suspension was centrifuged at 4000 rpm for 15 minutes. The supernatant was filtered through a 0.45 μm membrane to obtain S-EPS. The remaining sludge sample was rehydrated to the original volume, mixed, and incubated in a 85°C water bath for 10 minutes. It was then subjected to high-speed centrifugation at 12000 rpm for 15 minutes. The supernatant was filtered to obtain TB-EPS. The EPS components mainly include proteins (PN) and polysaccharides (PS), which were measured by the BCA method and the phenol-sulfuric acid method, respectively.

2.5 ARGs High-Throughput Sequencing

DNA extraction was performed using the MoBio Soil Genomic DNA Extraction Kit (DNeasy PowerSoil) to ensure the DNA concentration and purity, with an A260/280 ratio of approximately 1.8. DNA markers and PCR amplification products were loaded into gel wells, and the brightest bands were identified through gel imaging. The brightest bands corresponding to the PCR amplification products were sent for cloning into vectors for the subsequent establishment of

standard curves. Plasmid extraction from bacterial liquid was conducted according to the Plasmid DNA Mini-Prep Kit (SanPrep Column Plasmid Mini-Preps Kit) instructions. The plasmid DNA concentration and purity were determined using a microvolume UV-visible spectrophotometer. The qualified plasmids were used to establish standard curves, and the extracted plasmid DNA was stored at -20°C for future use.

2.6 Microbial Community Structure Analysis

Microbial changes are an important indicator of the aerobic digestion process in sludge treatment. The microbial community structure in the pretreatment phase reflects the survival and death of microbes during the FNA pretreatment process. Changes in microbial community structure can influence ARG abundance. Analyzing the dynamics of microbial community structure during digestion is essential for understanding the fate of ARGs. Correlation analysis between ARGs and microbial community structure was performed to identify potential ARG hosts. Samples were taken on days 0, 8, 16, and 24. The sludge samples from the best FNA pretreatment, anaerobic digestion, and aerobic digestion stages were centrifuged at high speed, and the supernatant was discarded. The remaining sludge samples were frozen at -20°C for preservation. These samples were sent to Shanghai Meiji Biological and Pharmaceutical Technology Co., Ltd., for Illumina MiSeq sequencing analysis. DNA extraction, concentration and purity measurement using a micro-volume UV spectrophotometer, PCR amplification, purification, and quantification using Picogreen dye fluorescence were performed before sequencing. The purified products were then sequenced using the Illumina MiSeq platform.

2.7 Data Analysis

This study used Origin software to analyze the changes in NH_3, SCOD, and EPS during the aerobic digestion process, as well as the abundance of ARGs and MGEs. The relationships between environmental factors, pollutants, ARGs, and MGEs were investigated using Meiji platform and R4.4.1 software. Spearman correlation analysis was performed to assess the correlations between these factors. The changes in microbial communities at the phylum and genus levels during FNA pretreatment and aerobic digestion were also analyzed. Pearson correlation analysis was used to evaluate the relationships between ARGs and MGEs, as well as between bacterial communities, ARGs, and MGEs.

3 MATERIALS AND METHODS

3.1 Changes in Pollutant Indicators, EPS and ARGs

3.1.1 NH_3 and SCOD

As shown in Figure 1(A), aerobic digestion led to the release of NH_3. High-temperature reactors, such as E3, E6, and E9 (45°C), exhibited increases in NH_3 by 14.08, 17.41, and 25.86 times, respectively, compared to day 0, indicating a significant release of NH_3. This suggests that high temperature promotes NH_3 release, and the strong positive correlation between high temperature and NH_3 release is confirmed in Figure 1(F). However, after 12 days of aerobic digestion, the release rate slowed down. High temperature can inhibit nitrification and denitrification, and cell disruption can produce nitrogen in the form of ammonia [4]. Proteins are hydrolyzed into amino acids, which are then converted into NH_3. Therefore, NH_3 release can indirectly reflect microbial cell death. After 12 days, substrate depletion, reduced microbial metabolic activity, weakened endogenous respiration, and the inhibitory effect of high concentrations of NH_3 on microbial activity occurred.

Furthermore, in reactors E4, E5, E7, and E8, NH_3 showed a decreasing trend over time, suggesting that low FNA-treated sludge content and non-alkaline, low-temperature conditions are unfavorable for microbial cell lysis. Conversely, microbial cell disruption aids in the release of organic matter from the sludge into the waste liquid, resulting in an increase in SCOD, as shown in Figure 1(B). Among these, reactors E2 and E6 (pH = 10) exhibited higher SCOD release than the others, indicating that alkalinity facilitates SCOD release. A significant positive correlation between pH and SCOD ($r = 0.59$, $P < 0.01$) is shown in Figure 1(F). However, E7 showed lower SCOD release, which was inhibited by temperature, suggesting that high temperature promotes SCOD growth, a relationship also confirmed by the mental test (Figure 1(F)). Moreover, reactor E6, under high temperature and high alkalinity, displayed the highest SCOD release, consistent with previous research, which concluded that high temperature and strong alkalinity promote SCOD increase during the later stages of aerobic digestion [5].

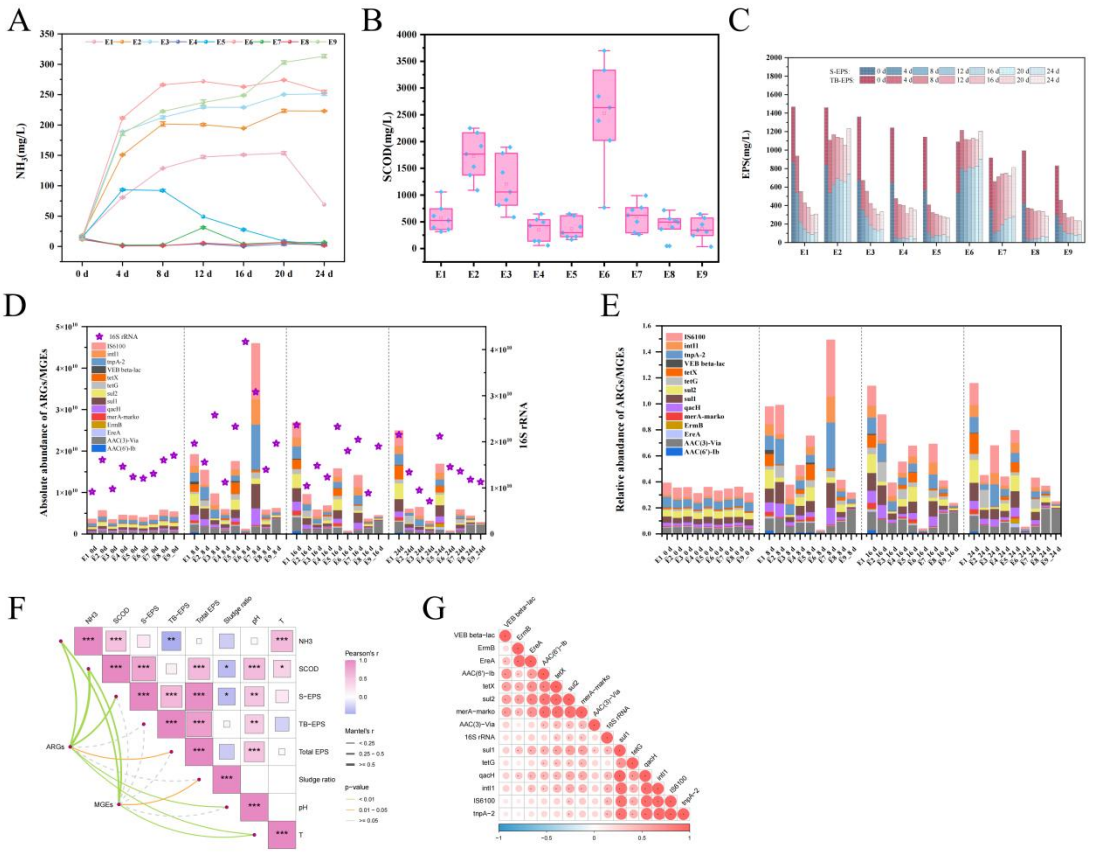

Figure 1 Variations of NH_3(A), SCOD (B), EPS (C), Absolute Abundance of ARGs/MGEs (D), and Relative Abundance of ARGs/MGEs (E) during Aerobic Digestion in Reactors E1–E9. Correlation between ARGs/MGEs and Environmental Factors, NH_3, SCOD, and EPS(F) . Correlation between ARGs and MGEs(G)

3.1.2 Variation of EPS

Figure 1(C) shows the changes in Total EPS during the aerobic digestion process, including the concentrations of S-EPS and TB-EPS. In the initial stage, as the proportion of FNA-pretreated sludge decreased (E1/2/3 sludge ratio = 1; E4/5/6 sludge ratio = 2; E7/8/9 sludge ratio = 3), the S-EPS concentration gradually decreased. This phenomenon suggests that FNA pretreatment helps promote cell rupture, thereby releasing more EPS, which results in an increase in S-EPS concentration. Compared to other reactors, E2/6/7 (pH 10) exhibited consistently higher Total EPS, but analysis of Total EPS at 24 days revealed the following trend: E6 (45°C) > E2 (35°C) > E7 (25°C). Under pH 10 conditions, as the temperature increased, the S-EPS/TB-EPS ratio also increased. Figure 1(F) shows a significant positive correlation between pH and S-EPS, indicating that an alkaline environment (pH 10) facilitates microbial cell rupture and metabolism during aerobic digestion, and high temperature enhances this effect[6]. Except for E6, all other reactors exhibited a decrease in TB-EPS and Total EPS at 24 days. This is because under aerobic conditions, ammonium is generated from the degradation of bacterial cells and their EPS, and with the help of ammonia-oxidizing bacteria (AOB), it is converted into nitrite, which is eventually oxidized to nitrate by nitrite-oxidizing bacteria (NOB)[7], The rate of Total EPS decrease was faster after the first 12 days, which may be related to substrate sufficiency and strong microbial activity in the earlier stages.

3.1.3 Variation of ARGs

Figures 1(D and E) show the trends in the absolute abundance (AA) and relative abundance (RA) of ARGs and MRGs, respectively. During the aerobic digestion process, except for reactor E6, all other reactors exhibited a trend of enrichment followed by removal of ARGs and MRGs. This suggests that the intracellular and extracellular substances released during the pretreatment phase were utilized in the early stage, leading to microbial proliferation. The initial bacterial regrowth is the main reason for the increase in ARGs during the maturation phase [8]. As digestion progressed, in high-temperature environments (E3, E6, and E9 at 45°C), the AA of Total ARGs decreased in all cases. For example, at the end of digestion, the RA of Ermb, tetX, and VEB beta-lactam were almost undetectable, indicating that high-temperature environments not only reduce the AA of ARGs but also reduce the RA of target genes [2]. Notably, E6 exhibited the most significant reduction, with ARGs and MGEs decreasing by 84.13% and 76.03%, respectively. Additionally, when comparing SCOD values, E6 showed significantly higher SCOD than other reactors, suggesting that cell lysis inhibited the transfer of resistance genes and that high alkalinity and high temperature conditions promoted the reduction of ARGs.

Furthermore, a Mantel test correlation analysis was performed on the relationships between resistance genes, environmental factors, and pollutant indicators. The results revealed that both ARGs and MGEs were significantly positively correlated with S-EPS and Total EPS. As reported by Sheng et al. [9], EPS can significantly affect the surface

interactions of microbial cells, such as surface charge, mass transfer, and hydrophilicity/hydrophobicity. These properties influence the interaction between microbial cells and extracellular ARGs, as well as the adsorption of extracellular ARGs by microbial cells, thereby altering the transformation capacity of extracellular ARGs [10] .
SCOD showed a significant positive correlation with S-EPS, indicating that cell lysis not only increased SCOD but also contributed to an increase in S-EPS, which further promoted Total EPS growth. pH exhibited a significant negative correlation with SCOD and EPS reduction, which can be attributed to the continuous cell lysis in an alkaline environment, leading to the sustained increase in EPS and SCOD. According to the range analysis (Table 2), the factors affecting the removal efficiency of resistance genes were ranked as follows: pH > Temperature > Sludge ratio. In the orthogonal experiment, only E6 (sludge ratio = 2; pH = 10; 45°C) demonstrated the highest ARGs reduction rate, due to the strong alkaline and high-temperature environment. Since ARGs are closely related to microbial community composition, further investigation of the microbial community is necessary.

3.2 Microbial Communities

3.2.1 Differences in microbial communities before and after FNA pretreatment and aerobic digestion

The microbial communities of FNA pretreatment and the FNA-based aerobic digestion process exhibited significant differences. The FNA pretreatment stage led to a notable reduction in microbial diversity in the sludge, as evidenced by the Shannon and Simpson indices (Figure 2). During the aerobic digestion phase, both microbial diversity (Shannon and Simpson indices) and richness (Chao 1 and Ace indices) decreased. Additionally, in our study, the diversity index (Shannon index) significantly decreased from 4.78 to 4.05 at the end of the digestion process. The goods coverage index indicated that the major bacterial community types present in each sample were thoroughly explored in this study[2].

Table 2 Range Analysis of ARGs Absolute Abundance Reduction by Aerobic Digestion for 24 days

Number	Sludge ratio	temperature	pH	ARGs cut amount (%)
E1	1:1	25℃	6	-787.20
E2	1:1	35℃	10	-40.88
E3	1:1	45℃	8	0.47
E4	2:1	25℃	8	24.04
E5	2:1	35℃	6	-351.32
E6	2:1	45℃	10	84.13
E7	3:1	25℃	10	-44.34
E8	3:1	35℃	8	-6.22
E9	3:1	45℃	6	15.99
K1	-827.61	-807.52	-1122.53	
K2	-243.15	-398.42	-1.09	
K3	-34.58	100.59	18.8	
R	264.34	302.70	380.28	
The best level of factors	3	45℃	8	
Primary and secondary order of factors	PH> Temperature> Sludge ratio			

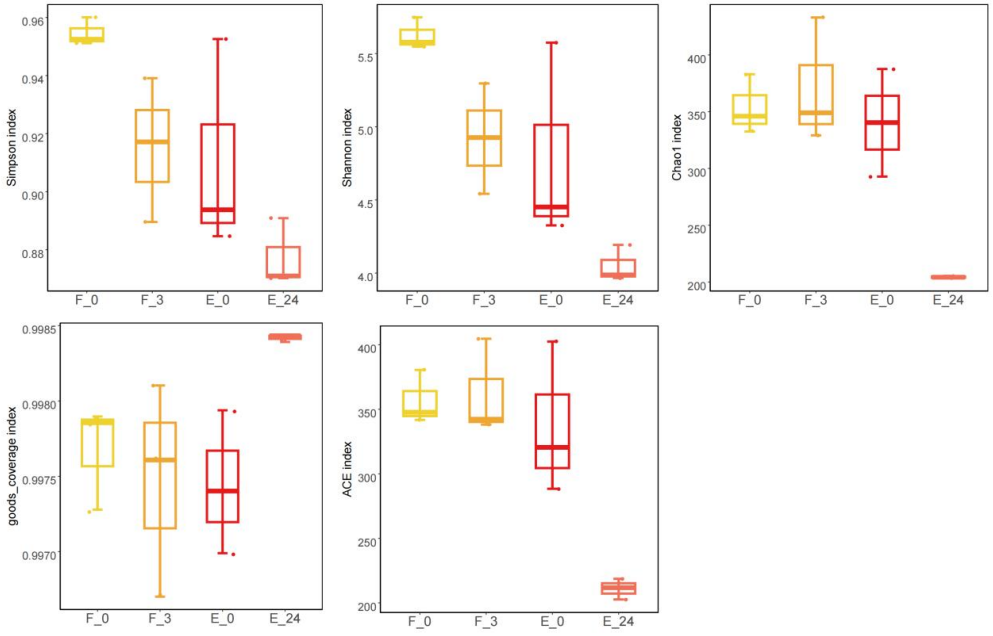

Figure 2 Community Structure Diversity Analysis Before and After FNA-Aerobic Digestion

Before the operation, as shown in Figure 3(A), the relative abundance of the top five dominant phyla were 82.43% and 88%, respectively. At the end of the operation, these values increased to 89.88% and 97.95%, respectively. A comparison reveals that FNA pretreatment and aerobic digestion promoted the accumulation of Actinobacteria and Firmicutes. Previous studies have also reported higher relative abundances of Actinobacteria and Firmicutes during aerobic digestion[11]. During the aerobic digestion process, the relative abundance (RA) of Proteobacteria, Bacteroidetes, and Verrucomicrobia decreased. However, Actinobacteria, as one of the most abundant phyla in the sludge, maintained a stable abundance range of 23.97%–25.09% at both the end of FNA pretreatment and aerobic digestion, indicating its relative stability throughout the pretreatment and digestion phases. After FNA pretreatment, the relative abundance of Chloroflexi (anaerobic bacteria) increased by 10%, possibly because FNA provided nitrate and nitrite as electron acceptors for facultative anaerobes, promoting their metabolic activity. After aerobic digestion, the relative abundance of most dominant phyla decreased, but the growth of Firmicutes (particularly the Bacillales class) was the most significant, reaching 41.69%. This phylum predominantly grows under thermophilic conditions and is associated with antibiotic resistance.[12]

Based on this, a more detailed investigation of the microbial composition at the genus level during aerobic digestion was conducted, followed by Linear Discriminant Analysis (LDA), as shown in Figure 3(C). The aerobic digestion process identified 15 differential microbes, among which 12 genera were included in the dominant microbial communities. The genera Nakamurella and Bacillus exhibited the greatest increases. Nakamurella (increased by 2.24 times) is associated with antibiotic resistance, while Bacillus, a spore-forming bacterium, showed the most significant growth, increasing by 14.19 times, indicating its potential to thrive in extreme environments. At the same time, the relative abundance of Saccharimonadales, SC-I-84, Ellin6067, unclassified_Blastocatellaceae, and Nitrospira decreased. Saccharimonadales is involved in carbon source degradation, SC-I-84 is associated with organic matter degradation, and Nitrospira and Ellin6067 are known for their excellent denitrification capabilities[13]. The unclassified_Blastocatellaceae genus can degrade complex protein compounds, while TM7a, as a symbiont, affects the relative abundance of its host by inhibiting host growth dynamics or directly killing the host. As aerobic digestion progressed, the establishment of a characteristic microbial community in the aerobic digestion tank was observed.

3.2.2 Correlation between ARGs and community structure

Increasing evidence suggests that ARGs and MRGs profiles are significantly correlated with bacterial communities, particularly in the context of wastewater sludge treatment[14-15]. Therefore, Pearson correlation analysis was conducted to assess the relationship between ARGs/MGEs and dominant bacterial genera. The results revealed that 10 out of the 11 ARGs in this study were significantly positively correlated with 10 dominant genera, and 8 out of the 3 MGEs were significantly positively correlated with 8 dominant genera ($p < 0.05$, $r > 0.6$), Figure 3 (D).The common host genera for both MGE and ARGs (8 genera) included *Saccharimonadales, Caldilineaceae, SC-I-84, Ellin6067, unclassified_Blastocatellaceae, Nitrospira, Gemmatimonadaceae,* and *OLB12*. These genera, as hosts for resistance genes, all showed a decrease in relative abundance, as shown in Figure 3(B). The abundance of MGEs was closely related to the abundance of transferred ARGs (Figure 1(G)), suggesting that controlling the abundance of common host bacteria and MGEs could be an effective strategy for controlling the spread of ARGs[16].

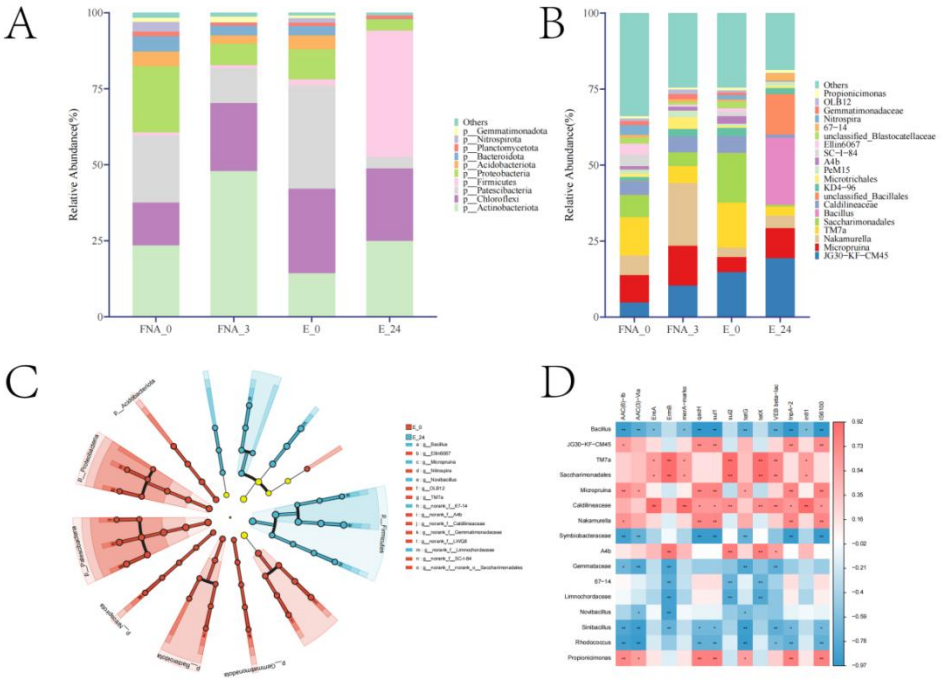

Figure 3 Microbial Community Abundance at the Phylum Level (A)the Genus Level by top 20 (B).LDA Differential Analysis of Microbial Community Composition(C). Heatmap of the Correlation Between ARGs/MGEs and Microbial Community Structure(D)

4 CONCLUSION

This study systematically explored the dynamics of ARGs during the sludge treatment process with FNA pre-treatment combined with aerobic digestion through orthogonal experimental design. The experimental results showed that under the optimal conditions (a sludge ratio of 2:1 for residual sludge to FNA pre-treated sludge, temperature of 45℃, and pH of 10), the removal efficiencies of ARGs and MGEs were significant, with the removal rate of ARGs reaching 84.13% and the removal rate of MGEs at 76.03%. Additionally, the release levels of NH_3, SCOD, and EPS under these conditions were the highest, further demonstrating that the combination of FNA pre-treatment and aerobic digestion significantly enhanced sludge digestion performance. Range analysis revealed that the influence of pH, temperature, and sludge ratio on ARG removal followed the order: pH > temperature > sludge ratio, indicating that high temperature and alkaline conditions facilitate cell disruption, which aids in the removal of ARGs. Further microbial community structure analysis indicated that the reduction of ARGs was closely correlated with the simultaneous reduction of MGEs and potential host bacteria, suggesting that high temperature and alkaline aerobic digestion environments not only remove resistance genes but may also inhibit their transmission. The findings of this study provide new insights into the application of FNA pre-treatment combined with aerobic digestion in sludge treatment, demonstrating that this approach effectively removes resistance genes from sludge and regulates microbial community structure. By properly controlling environmental factors (such as pH, temperature, and sludge ratio), the ARG removal process can be significantly optimized. Future research could further investigate the impact of different types of sludge, FNA concentrations, and directed microbial community regulation on ARG removal, providing deeper theoretical support and technical guidance for ARG control and sludge digestion efficiency enhancement in wastewater treatment.

COMPETING INTERESTS

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

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Appendix

Table S- 1 PH and NO2-N Concentration Gradient Experiments and the Corresponding Reduction Rates of Total ARGs

Gradient experiments	project	T (℃)	pH	NO_2^--N（mg/L)	Total ARGs reduction rate（%）
pH gradient	CK1	25	7.3	0	-20.70
	A1	25	5.3	700	53.67
	A2	25	5.5	700	-107.81
	A3	25	5.8	700	-157.56
	A4	25	6.1	700	41.96
	A5	25	6.4	700	48.60
NO2-N concentration gradient	CK2	25	5.3	0	-6.37
	B2	25	5.3	69	-1.42
	B3	25	5.3	144	-17.56
	B4	25	5.3	294	15.24
	B5	25	5.3	445	15.23
	B6	25	5.3	589	52.48
	B7	25	5.3	753	62.93

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THE DIFFERENCES BETWEEN AUGMENTED REALITY (AR) AND VIRTUAL REALITY (VR) IN LEARNING

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Abstract: As important achievements of modern science and technology, augmented reality (AR) and virtual reality (VR) technologies have shown great application potential in the field of education. They provide rich interactive experiences and teaching resources for the learning process in different ways. AR technology provides a new perspective for education by superimposing virtual information on the real world. For example, in history classes, students can use AR technology to see 3D models of historical figures in textbooks or observe the re-enactment of historical events. In science education, AR can help students visualize complex molecular structures or the internal structure of organisms, making abstract knowledge concrete and intuitive. VR technology allows users to immerse themselves in the virtual world by building a completely virtual environment. In education, VR technology can simulate a real experimental environment, allowing students to conduct virtual experiments, or let students explore in virtual historical scenes and experience immersive historical education. This paper discusses the differences between AR and VR in learning, focusing on their application in history, medicine, music, physics and physical education. By analyzing the performance in terms of content delivery and interactivity in detail, the study found that AR has clear advantages in real-world applications, while VR is more attractive in immersive and simulation-based learning. The article summarizes the best application scenarios of each technology in different disciplines, based on the support of the cited literature.
Keywords: Augmented Reality (AR); Virtual Reality (VR); Learning; Content delivery; Interactivity

1 INTRODUCTION

With the rapid development of education technology, augmented reality (AR) and virtual reality (VR) have become important tools of modern teaching. Both technologies offer entirely new ways to capture students' attention and facilitate learning. AR enhances learners' interaction with their surroundings by overlaying digital elements onto the real world; VR offers the possibility of experiential learning through a fully immersive virtual environment (Al-Ansi et al., 2023). This paper analyzes the application of AR and VR in five disciplines, focusing on their differences in content delivery and interactivity, aiming to provide reference for educational practice. And it is also constantly promoting innovation in education models and improving learning outcomes.

2 APPLICATION COMPARISON AMONG DIFFERENT DISCIPLINES

2.1 History Education: Application, Content and Interactivity

The application of AR and VR technologies in history education provides learners with a new and immersive historical experience, making history education more vivid and intuitive. In history education, AR gives students virtual access to historical sites and artifacts by providing enhanced museum tours. For example, some AR applications allow students to scan historical artifacts to see relevant background information and 3D models. In addition, this technology can present historical scenes directly within the classroom, providing students with an immersive history learning experience.
In contrast, VR immerses students by constructing virtual historical scenarios, such as simulating ancient Roman battles or major historical events. This fully immersive experience enables students to "live" historical situations, resulting in a deeper emotional understanding of historical events [1].
AR is very intuitive in providing historical background information. For example, by overlaying time lines or event details in a real-world environment, AR helps students build a deeper historical background [2]. VR, on the other hand, provides historical content in narrative form, enhancing understanding of the content by allowing students to experience the dynamics of historical events. AR enables direct interaction with real-world artifacts, such as students scanning artifacts through mobile devices to obtain detailed historical information. In contrast, VR further enhances the sense of engagement and immersion in learning by providing a complete virtual interaction scenario that enables students to explore the virtual environment.
VR performs better in immersive learning, while AR is suitable for exploring specific historical context information.

2.2 Medical Education: Application, Content and Interactivity

The application of AR and VR technologies in medical education is gradually changing the traditional teaching mode,

providing a more intuitive, interactive and immersive learning experience. In medical education, AR is widely used for real-time anatomical visualization and guidance of surgical procedures. For example, AR can help students understand the function of organs and their positioning during surgery by superimposing human models. In addition, some augmented reality tools support real-time clinical simulations to help students get immediate feedback on their real-world actions.

Applications of VR in medicine include virtual surgical simulation and emergency medical training. For example, by simulating disaster scenarios in VR, students can practice decision-making and first aid skills in a fully controlled environment [4].

AR provides layered content where students can step by step learn about complex anatomical structures or surgical steps. VR enhances the mastery of medical content by building virtual hands rooms that allow students to practice repeatedly in a safe manner [5]. AR helps students interact with physical models through real-time visual overlay, such as showing key physiological features on an anatomical model. VR, on the other hand, uses high-pressure environment simulations (e.g., emergency room training) to help students improve decision-making skills and respond to sudden events [6].

VR is suitable for high-risk training scenarios, while AR is more suitable for real-time instruction and anatomical learning.

2.3 Music Education

In music education, AR helps students improve their musical instrument learning skills through augmented reality music score applications. For example, certain tools allow students to adjust their fingering and posture with real-time visual guidance [7]. VR, on the other hand, provides students with a virtual performance space, allowing them to perform in a virtual concert or orchestra, thereby increasing confidence and performance ability.

AR superimposes interactive content directly onto the instrument, such as tagging the correct finger position or displaying real-time pitch feedback. In contrast, VR offers complete simulations where students can practice collaboration with other musicians or rehearse in a virtual environment. AR allows students to get corrective feedback in real time during practice, while VR allows students to engage in more complex music scenarios, such as simulated music competitions or collaborative performances [7]. Through the application of these technologies, music education is no longer limited to traditional classroom teaching, but has become more interactive and intuitive. Students can improve their music understanding, performance skills and creative ability through virtual experience. At the same time, these technologies have also brought new teaching methods and innovative experiences to music education.

AR is more suitable for individual skill development, while VR is better for team collaboration and immersive music learning.

2.4 Physics Education: Application, Content and Interactivity

AR helps students better understand physical phenomena by superimposing the visualization of waveforms or electric fields in real-world experiments. VR offers a virtual laboratory where students can explore advanced physics concepts such as optical experiments or quantum mechanics.

AR helps students understand abstract physical concepts by combining theory and experiment, such as real-time observation of the relationship between force and motion. VR allows students to explore complex scientific phenomena, such as simulations of nuclear reactions, through detailed virtual experimental scenarios.

AR allows students to interact with real-world experimental equipment while enhancing realistic visuals. VR provides immersive interactions where students can simulate and test physical hypotheses in a virtual environment.

AR is more effective in combining theory with practice, while VR has advantages in simulating complex and dangerous experiments.

Through the application of AR and VR technologies, physics education becomes more vivid and intuitive, helping students understand physical principles and concepts and improving their experimental skills and scientific inquiry abilities. These technologies provide students with a safe and controllable environment to explore physical phenomena, making the learning experience richer and more effective. With the continuous advancement of technology, the application of AR and VR in physics education will become more and more extensive, helping to cultivate scientific and technological talents in the new era.

2.5 Physical Education: Application, Content and Interactivity

AR promotes physical education through real-time feedback and action correction. For example, augmented reality fitness apps can guide students through movements and provide real-time suggestions for improvement [7]. VR helps students simulate competition scenarios or experience new sports through virtual training environments.

AR analyzes movement data in real time, such as speed, distance and angle of motion, providing students with detailed performance reports. VR allows students to participate in immersive sports training by simulating training scenarios, such as a virtual treadmill or rock climbing experience.AR helps students improve technical performance through visual cues and real-time corrections, while VR improves collaborative and competitive skills through virtual arenas or team

competitions.
AR is more suitable for individual skill optimization, while VR is more prominent in team training and immersive experiences.

3 CONCLUSION

The application of AR and VR technology in the field of education has great potential and advantages, but there are some limitations. In practical application, teachers should choose appropriate technology according to teaching objectives and students' needs, and combine with traditional teaching methods to bring into full play the advantages of these technologies and improve teaching quality.

3.1 Advantages of AR

Lower cost: AR technology can be implemented through smart phones and mobile devices at a lower cost, which makes more schools and educational institutions affordable. For example, in history teaching, students can view the virtual reconstruction of historical scenes through the AR application program on their smart phones, and this low-cost learning method can benefit more students [7].

3.2 Advantages of VR

Immersive Experience Strong: VR technology is able to provide students with a highly realistic virtual environment that completely immerses users as if they were in the real world. This immersive experience allows students to deepen their knowledge and improve their learning. For example, in medical teaching, students can train in surgical simulations through VR devices to experience the surgical process first-hand, and this immersive learning experience can give students a deeper understanding of surgical techniques and operating procedures, while also improving students' surgical skills.

4 CONCLUSION

The differences between augmented reality (AR) and virtual reality (VR) in the learning process are mainly reflected in the degree of immersion, interactive methods, learning scenarios, equipment requirements, and learning experience. VR technology, with its highly immersive characteristics, creates a completely virtual learning environment for learners, which is suitable for complex simulation training and immersive learning, especially for subjects that require in-depth understanding and experience of abstract concepts. AR technology, by superimposing virtual elements in the real world, provides a more intuitive and auxiliary learning experience, which is suitable for explaining complex concepts and immediate applications in the real world.
Overall, AR and VR technologies have important application value in the field of education. AR technology has low cost, strong portability and good interaction, and is suitable for some disciplines that require contextual learning and strong interaction, such as history, geography, language, etc. VR technology has strong immersive experience, good simulation, and rich educational application scenarios, which is suitable for some disciplines that require immersive experience and simulation of real scenes, such as medicine, physics, chemistry and so on. In practical application, teachers should choose appropriate technology according to teaching objectives and students' needs, and combine with traditional teaching methods to bring into full play the advantages of these technologies and improve teaching quality.
The respective advantages of both make them play different roles in education. VR technology is more suitable for those subjects that require a high degree of simulation and immersion, such as medicine, engineering, and architectural design; while AR technology is more suitable for subjects that require direct guidance and information enhancement in the real world, such as natural sciences, history, and art.
In summary, educators should choose appropriate technical means according to specific teaching needs and students' learning characteristics to maximize the advantages of AR and VR technologies and promote the effectiveness and fun of learning. In the future, with the continuous development and maturity of technology, AR and VR technologies are expected to be more deeply integrated into the education system, bringing more possibilities for learning.

COMPETING INTERESTS

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

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EXPLORE THE APPLICATION OF ARTIFICIAL INTELLIGENCE TECHNOLOGY IN ART TEACHING AND CREATION

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Abstract: Artificial intelligence (AI) technology, with its powerful computational and data processing capabilities, offers new possibilities and opportunities for art education and creation. It not only revolutionizes traditional art education but also significantly enriches the methods and forms of artistic expression. By examining recent studies on the application of AI technology in art education and creation, this exploration seeks to discuss its current development, application models, challenges, and future trends. The aim is to provide a reference for further exploration in this field and to offer practical approaches for enabling the digital transformation of aesthetic education through AI technology.
Keywords: Artificial Intelligence (AIGC); Art education; Educational teaching; Applications

1 INTRODUCTION

In the context of this study on the application of artificial intelligence (AI) technology in art education and creation, the term "application" is defined by the author as the process of utilizing theoretical knowledge or technical methods in specific practical contexts to solve real-world problems, enhance productivity, and create value. This process is characterized by its strong precision, relevance, and purposefulness. Researching the application of AI painting technology in art education and creation aligns with the practical needs of societal development. It keeps pace with the new standards introduced in the updated curriculum guidelines for high school art education, making teaching more intelligent and convenient. Furthermore, AI technology is leveraged to strengthen the unique educational functions of art as a discipline, innovate teaching models, improve learning outcomes, cultivate artistic skills, and foster a deep appreciation for art as a field of study.

2 THE ROLE OF ARTIFICIAL INTELLIGENCE IN ADVANCING AESTHETIC EDUCATION

In recent years, artificial intelligence (AI) has gradually become a focal point of attention across various industries and research fields. With its advantages in intelligent technology and continuous updates and iterations, AI has progressively penetrated and transformed numerous sectors, demonstrating vast potential for applications and scenarios.
In the field of education, the State Council's *New Generation Artificial Intelligence Development Plan* proposed that "by 2025, certain AI technologies will reach a world-leading level, and by 2030, China will become a major global AI innovation center. Intelligent technologies should be utilized to accelerate the reform of talent cultivation models and teaching methods, building a new education system that includes intelligent and interactive learning... and promoting the comprehensive application of AI in teaching, management, and resource development [1]."
In 2018, the Ministry of Education issued the *Education Informatization 2.0 Action Plan*, which called for "using emerging technologies such as artificial intelligence, big data, and the Internet of Things as a foundation, relying on various intelligent devices and networks, and actively conducting innovative research and demonstrations on smart education to drive the transformation of education models and the reconstruction of education ecosystems underpinned by new technologies."
With its "intelligent substitution" capabilities and the national policy push for digital transformation in education, AI has become a key focus in both educational practice and theoretical exploration. In the context of art education and creative applications, AI demonstrates immense potential, making it a significant subject in the development of art education.

2.1 Having Revolutionized the Teaching and Learning Model

The current artificial intelligence technology and algorithms of the rapid improvement, through the input of keywords and its per second calculation processing and learning of data volume is increasingly large, AI painting technology development is becoming more and more mature, in the discipline of art teaching in the application of the gradual increase in the teaching mode of teaching and learning to promote the innovation of the teaching mode, for the application of AI technology in the teaching mode of art education, many scholars have carried out the exploration. For example, Yatian Liu (2024) explored the application of AI technology in secondary school art subjects [2], taking the Shanghai area as an example, she pointed out that AI technology provides students with personalized learning resources and feedback in teaching through personalized learning path recommendation and intelligent assessment system, which effectively enhances the students' learning interest and efficiency, and this research provides a practical case for the popularization of AI in art education; Ji Yi et al. (2022) proposed a personalized painting education model based on

artificial intelligence that [3], analyzing students' learning habits and levels through AI technology and providing personalized learning programs, greatly improving the relevance and effectiveness of art teaching; in addition, Dejian L (2019) pointed out in the study [4], artificial intelligence empowers the transformation of talent cultivation in colleges and universities, and realizes the optimal allocation of teaching resources and intelligent management of the learning process through intelligent assisted teaching systems and online learning platforms. The above is a series of technological innovations brought by artificial intelligence in teaching, each with its own characteristics applicable to different teaching environments, AIGC can undoubtedly assist teachers to carry out more accurate teaching assessment and feedback, and provide more flexible and diverse teaching modes and learning experiences for art education.

2.2 Enhancing the Effectiveness of Teaching and Learning

Weiming D (2024) explored the evaluation of the teaching results of painting education and digital aesthetic education in the context of the era of generalized artificial intelligence [4], and he proposed that AI technology can provide a more objective and comprehensive evaluation of the teaching results through the analysis of big data, which can help to improve the quality of teaching; Jing J and Runzhou L (2024) take "elementary school art" as the center of investigation [5], analyze the connotation, hidden worries and transcendence path of art intelligent evaluation, and provide a new perspective and method for the quantitative evaluation of art literacy, they think that although the AI evaluation system can improve the accuracy of evaluation, there are also hidden worries such as neglecting the cultivation of students' creativity, which need to be paid attention to in the use of educators. educators to pay attention to in their use, and this research helps us to assess students' art learning outcomes more scientifically and objectively; Jin L (2024) explored the application of image generation technology in the education of art courses [6], pointing out that the technology can provide students with more intuitive and vivid learning materials, and stimulate students' learning interest and creativity; Lijing X (2024) [7], on the other hand, took Yancheng Early Childhood Normal Higher and Specialized School as an example to study the development of higher vocational art education curriculum based on the influence of artificial intelligence, which further verified the positive effect of technology integration on art education, and that the art teacher's intelligent education literacy is the key to promoting AI technology in art teaching; studied the application of artificial intelligence in elementary school art teaching, and realized interactive teaching, work evaluation and other functions through AI technology, which enhanced students' learning interest and participation.

In summary, we can find that many experts and scholars in the discussion of artificial intelligence and teaching effectiveness are relatively objective and rigorous attitude affirmed that AI has brought a lot of convenience in the improvement of teaching quality, scientific assessment of results, stimulate the interest of learning, integration of technological development, assisting in the design of teaching and learning, etc., but also put forward a higher demand for the coordination of the development of the teacher's knowledge of information technology, instructional design ability, student assessment ability and continuous learning ability and other intelligent literacy. However, it also puts forward higher requirements in coordinating the development of teachers' knowledge of information technology, instructional design ability, student assessment ability and continuous learning ability and other intelligent literacy. It is believed that artificial intelligence can bring breakthroughs in technology in this era, and Chat GPT makes this hope a realityThe emergence of AI technology has enriched art teaching resources. Through digitalization and intelligent means, teachers can obtain more diversified teaching resources, such as AI-generated images, videos and virtual reality scenes, etc., in order to adapt to the needs of teaching in the age of artificial intelligence and to enhance the art teaching ability, and at the same time, these resources can help students to expand their horizons and to enhance their practical and creative abilities.

3 ARTIFICIAL INTELLIGENCE TECHNOLOGY ENABLING THE DEVELOPMENT OF FINE ART CREATION

According to the discussion on the requirements of AI technology in art education in the White Paper on Art Education with Artificial Intelligence in China 2023, and the specific needs of the art discipline for the controllability, ease of use, and popularization of the new technology in teaching design and creative guidance, the establishment of AI disciplinarization system has become the key to the in-depth integration of AI technology in the art teaching of the current colleges and universities.

3.1 Intelligence of Creation Tools

Colleges and universities can help students to obtain information on art theory, creative materials, creative styles and other materials by applying intelligent teaching systems and personalized learning paths. For example, Wei Wei (2024) examines the application of Mid journey in a surrealist fashion photography course [8], showing how AI technology can be used as a creative tool to provide artists with new inspirations and expressive techniques, this study reveals the great potential of AI technology in artistic creation; Zhichao C (2024) studied conceptual art creation based on the background of AIGC technology, pointing out that AI technology can generate rich image materials and creative inspirations, providing new possibilities for art creation [9], demonstrating the great potential of AI technology in the migration and generation of painting styles, and the students can input commands to flexibly create rich and colorful paintings in classroom learning; Fang L et al (2021) [10] further summarizes the new trend of educational evaluation,

and points out the application prospect of intelligent evaluation in art creation, including automatic scoring, sentiment analysis and other functions. The intelligence of the creation tool can analyze a huge amount of art works. Through deep learning, natural language processing and other technologies, the AI tool can understand the user's needs and automatically generate works that meet the requirements, such as articles, paintings, music works, etc., extracting the laws and characteristics of creation and providing inspiration for the artists. At the same time, it can also generate works with market prospects according to market trends and user preferences, seamlessly connect with other software and devices, and work together to improve the efficiency and quality of creation. It not only provides artists with a new creative medium, but also brings about profound changes in creative concepts and art forms, and promotes the diversified and intelligent development of art creation.

3.2 Diversity of Creative Styles

Another major application of artificial intelligence technology in art creation is style migration and generation. Through deep learning algorithms to diversify creative styles, AI can learn and mimic the styles of different artists to create works with unique styles. For example, Wu Qi (2024) proposed a new strategy for art teaching in the context of the rapid development of artificial intelligence [11], which includes the use of AI technology for style migration and creative exploration; Yangxin L (2024) analyzed the online and offline hybrid teaching mode of art class, pointing out that AI technology can optimize the teaching process to improve the efficiency of creation, and through the online platform and intelligent tools [12], it makes the creation styles diversified, so that the students can create anytime and anywhere, and the teachers can provide timely feedback and guidance.

3.3 Innovativeness of Creative Content

Artificial intelligence technology creation tools in the development of art, culture and industry are of great significance, and play a unique charm in aesthetic education. First of all, it breaks the limitations of traditional creation, making the creative content more diversified and rich, AI tools can explore new artistic styles and forms of expression, creating unprecedented works, expanding the boundaries of the arts and analyzing the cultural elements of different regions and nationalities to create works with cross-cultural characteristics, promoting global cultural exchanges and mutual understanding, AI creation tools can quickly generate a large amount of creative content to meet the market demand for fresh and unique content, promoting global cultural exchange and mutual understanding. By analyzing the cultural elements of different regions and nationalities, it creates works with cross-cultural characteristics, which promotes the exchange and mutual understanding of global cultures. AI creation tools can quickly generate a large amount of creative content to meet the market's demand for fresh and unique content, which promotes the development of the cultural industry to a higher level. For example, Qing Z and Yize L et al. (2024) discuss the cross-border application of AIGC technology in animation movie art design [13], showing how AI technology brings a new visual experience and narrative way for animation movies, and demonstrating the advantages of AI technology in enhancing the efficiency and creativity of art design; Guoxing A (2023) argues that AI has a subversive impact on art creation, and that it is not only capable of imitating human creative style [14], but also of imitating human creative style, which is the most important factor in the development of the cultural industry. human creative style, but also show unique innovativeness in the creative process. Jin W and Zhencheng S (2023) further explores artificial intelligence in contemporary art [15], analyzing the multiple roles and possibilities of AI in the creation and application of fine art.

Above all, the application of AI technology in art creation focuses on the intelligentization of creation tools, the diversification of creation styles, and the innovation of creation contents. Artificial intelligence technology can provide artists with the function of assisting creation and inspiration stimulation, and at the same time, it can also analyze a large number of art works and creation data through AI, and provide innovative, diversified and intelligent multi-channel content paths for art education.

4 CHALLENGES AND FUTURE TRENDS OF ARTIFICIAL INTELLIGENCE TECHNOLOGY IN ART EDUCATION AND CREATION

4.1 Challenges Faced

Although AI technology shows great potential and advantages in art education and creation, its development also faces many challenges. First of all, the ethical issues of technology are becoming more and more prominent, and how to ensure that the use of AI technology does not infringe on personal privacy or jeopardize the public interest of the society has become an urgent problem to be solved. Secondly, the conceptual change of educators and artists is also a major challenge, requiring them to actively embrace new technologies and adapt to new changes. Finally, the limitations of the technology itself should not be ignored, such as the lack of emotion and creativity in AI creation, and other issues still need to be further studied and resolved.

Although artificial intelligence technology shows great potential in art education and creation, how it can be better integrated with art is still a problem to be solved. For example, the College of Fine Arts of Guangdong University of Technology Normal has assisted in the design of the course "Landscape Thematic Design" by utilizing the Vineland graphic technology of Mid journey and Stable Diffusion for the course, which greatly It greatly improves students'

creative efficiency, design inspiration and practical ability. In the preliminary stage of teaching preparation, students were organized to collect resources: collect pictures, text descriptions, design cases and other materials related to landscape thematic design as input materials for the text-generated graphic technology; teachers introduced the basic operation and functional characteristics of Mid journey and Stable Diffusion to ensure that they can be skillfully used in the teaching process, designed targeted teaching cases and practical activities, and designed the teaching cases and practical activities to help students to create their own designs. Teachers introduce the basic operation and functional characteristics of Mid journey and Stable Diffusion software to ensure that they can be skillfully used in the teaching process, and design targeted teaching cases and practical activities to let students master the application of Vinnie's diagram technology in practice. Secondly, in the implementation of the teaching process, the basic principles, operation interface, core functions and other basic knowledge of Mid journey and Stable Diffusion are introduced in depth to analyze the application potential and advantages of the two software in landscape thematic design and stimulate the students' interest in learning. And show the existing landscape design cases, combined with Mid journey and Stable Diffusion images generated by the comparative analysis, so that students understand the specific application of the Venn diagram technology in landscape design, guide students to think about how to integrate the Venn diagram technology into their own design works, to enhance the creativity and expressiveness of the design. Teachers guide students to use Mid journey's cloud computing resources to quickly generate multiple styles of landscape design sketches, teach students how to achieve rapid switching and optimization of design styles through simple commands and parameter adjustments, and encourage students to constantly try to refine and improve their own design solutions with artificial intelligence technology. Guide students to download and install Stable Diffusion software (or visit its online platform), familiarize them with its technical and customized operation interface, teach students how to set detailed parameters and options to achieve fine control of landscape design details, and create highly original and artistic landscape design works by using Stable Diffusion's powerful detail control ability. Landscape design works. Finally, the teacher organizes students to discuss and feedback, students share their own design works and the creative process, discuss the advantages and shortcomings of the Vincennes technology in landscape design, the teacher collects students' feedback, and makes timely adjustments and improvements to the problems in the teaching process. The third point is to analyze the summary and reflection of teaching, to evaluate the landscape design works completed by students using Mid journey and Stable Diffusion in the course, to affirm the students' efforts and achievements, to analyze the actual application effect of Venn diagram technology in the landscape thematic design course, to evaluate its effect on the enhancement of the students' design ability and innovation ability, according to the feedback and teaching effect evaluation results of the students. Based on students' feedback and teaching effect evaluation results, we will reflect on and improve the course content and teaching methods, pay attention to the latest development of Vincennes technology, update the teaching content and case materials in time, and ensure that the course is cutting-edge and practical. There are still many challenges and deficiencies in the teaching process of the course "Landscape Thematic Design" to effectively integrate the Venn diagram technology of Mid journey and Stable Diffusion, which needs to enhance the students' design ability and creativity, and at the same time, it also needs to lay a solid foundation for the future practice of landscape design.

4.2 Future Trends

Looking into the future, the application of AI technology in art education and creation will be more extensive and in-depth, with the continuous progress of AI technology, we need to constantly explore new educational modes and methods to meet the needs of the times. On the one hand, with the continuous progress and maturity of technology, AI technology will be more intelligent and personalized to serve art education and creation; on the other hand, interdisciplinary integration will become an important trend, AI technology will be combined with other fields of technology such as Virtual Reality (VR), Augmented Reality (AR), etc., to bring a richer form of expression and experience for art education and creation, and AI intervention will weaken the creativity and depth of art creation. Whether it will weaken the creativity and individuality of art creation is the focus of many scholars. Deng Jing (2023) explored the value and limitations of AI painting as a new art medium [16], pointed out that while utilizing AI technology, we should also pay attention to protecting the creativity and individuality of the creators, and pointed out that the synergistic development of education and technology is the key to realizing the innovation of art education.

5 SHORTCOMINGS AND PROSPECTS

In the future, with the continuous progress of technology and the expansion of application scenarios, AI technology will play a more important role in art education and creation, but AI technology still faces many challenges in art education and creation. For example, how to balance the relationship between AI technology and traditional art education, and how to ensure the originality and value of art works created by AI. It is undeniable that the works created by AI painting are actually based on the results of human wisdom, and the painting content is extracted, decomposed and combined from a large number of works, but this kind of reorganization can not be called emotional art creation, and it is difficult to replicate the highly personal creative activities, the users of the technology are always human beings, and AI painting will become a daily tool, and the initiative should be firmly in the hands of art learners and practitioners. The initiative should be firmly in the hands of art learners and practitioners [17]. AIGC is the inflection point of intelligence from specialization to generalization, a new round of innovation in the paradigm of content production, and a powerful weapon to accelerate the change and high-quality development in the era of digital intelligence, depicting a broad and

promising development prospect. By analyzing the content of relevant policy texts, exploring the educational controversies and ethical risks caused by generative AI, as well as the innovative solutions and promotional methods of generative AI in educational applications, including updating the concept of education, transforming the way of school education, and enhancing the competence of teachers and students, etc., the continuous maturation and development of AI technology will have a broader prospect of its application in art education and creation. In the future, we can look forward to AI technology in the following areas to achieve greater breakthroughs: ① technology integration is more in-depth: AI technology will be integrated with more art teaching and creative tools to form a more complete technical system; ② evaluation system is more scientific: intelligent evaluation system will be continuously improved to provide a more scientific and comprehensive assessment methods for art learning and creation; ③ more balanced educational resources: through the application of AI technology, the application of AI technology, the art education and creativity of teachers and students will be more broad prospects. The application of AI technology, educational resources will be more balanced distribution, and promote educational equity.

In the face of new development requirements in the era of digital economy, how to efficiently utilize AIGC technology to empower high-quality changes in teaching and learning, rationally allocate educational resources, guide students to choose appropriate career paths, and add new vitality to the job market have become important issues that need to be resolved urgently. At the same time, we also need to pay attention to the ethical issues of technology to ensure the healthy development of AI technology in art education and creation, and educators also need to continuously improve their own intelligent education quality to adapt to the new teaching needs and challenges.

6 CONCLUSIONS

In summary, artificial intelligence technology has revolutionized the teaching mode and improved the quality of teaching, making the tools of art creation more intelligent, more diversified styles, more innovative content, and following up the application of artificial intelligence technology in the field of art education and art creation can help integrate art resources with technological innovation, strengthen the unique nurturing function of the art discipline, revolutionize the teaching mode, improve the learning effect, cultivate art skills and accumulate art literacy, injecting the life force of the times with driving force for art education and has achieved remarkable results, and will show a broader and more open development prospect. The application of technology in art education and art creation helps to integrate art resources with technological innovation, strengthen the unique educating function of art discipline, innovate the teaching mode, improve the learning effect, cultivate art skills and build up art disciplinary literacy, and inject the vitality of the times into art education with driving force. However, in the face of challenges such as technological ethics, conceptual changes and technical limitations, we still need to keep a clear mind and a positive attitude, and continue to explore and innovate. We believe that in the near future, AI technology will bring a more brilliant future for art education and creation, and we expect that we should continue to explore the potential of AI technology in the field of fine arts, promote the in-depth fusion of AI technology and traditional art education, inject new vitality into the development of the cause of fine arts, promote the synergistic development of education and technology, and hope to realize the prospect of a better art education and creation.

COMPETING INTERESTS

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IMPACTS OF SCIENCE AND TECH AT ESUT

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Abstract: This research article examines the impacts of science and technology at Enugu State University of Science and Technology (ESUT), focusing on its objectives, methodologies, findings, and conclusions. The primary objective of the study is to evaluate how advancements in science and technology have influenced academic performance, research outputs, and the overall development of the university community. The methodology employed includes both qualitative and quantitative approaches, utilizing surveys, interviews, and case studies to gather data from students, faculty, and administrative staff. The analysis of this data reveals a significant correlation between the integration of modern technology in the curriculum and improvements in student engagement, learning outcomes, and research productivity. Findings indicate that the introduction of state-of-the-art laboratories, access to digital resources, and the promotion of interdisciplinary research have led to a notable increase in the quality of education at ESUT. Furthermore, the study highlights the role of technology in fostering collaboration between departments and enhancing the university's reputation on both national and international platforms. The conclusions drawn from this research underscore the necessity for continued investment in technology and science initiatives to sustain and further amplify the positive impacts observed. By embracing new technological trends and fostering an environment conducive to scientific inquiry, ESUT can position itself as a leading institution in the region, thereby contributing significantly to the socio-economic development of Enugu State and beyond. This study serves as a foundation for future research aimed at exploring specific strategies that can enhance the utilization of science and technology within higher education settings.
Keywords: ESUT; Nigeria; Science; Technology; Career; Students; Learning

1 INTRODUCTION

In the rapidly evolving landscape of modern education, the integration of science and technology has become paramount. The relevance of these fields extends beyond mere academic disciplines; they serve as catalysts for enhancing the quality of education and fostering innovation. As educational institutions strive to prepare students for the complexities of the 21st century, the role of science and technology in shaping curricula, teaching methodologies, and research initiatives cannot be overstated.

Enugu State University of Science and Technology (ESUT) stands out in Nigeria's higher education landscape as a pivotal institution dedicated to advancing scientific knowledge and technological prowess. With its commitment to fostering a conducive environment for learning and research, ESUT plays a crucial role in shaping the educational experience of its students. However, the challenges faced by the university, including resource limitations and the need for updated technological infrastructure, present a significant research problem. Understanding the impact of these challenges on educational outcomes and institutional growth is essential for developing effective strategies to address them.

Key terms for this study include "science," "technology," "higher education," and "educational outcomes." By defining these terms, we establish a framework for analyzing the intricate relationships between them. The scope of this research encompasses an examination of the current state of science and technology at ESUT, while also identifying the barriers to effective implementation. The objectives of the study are to evaluate the effectiveness of existing technological resources, assess the impact on student learning and engagement, and propose actionable recommendations for improvement.

Through this investigation, the study aims to provide valuable insights into how ESUT can leverage science and technology to enhance its educational offerings and better prepare its students for future challenges [1].

2 LITERATURE REVIEW

The integration of science and technology in educational institutions has been extensively studied, particularly in the context of Nigerian universities. Previous research underscores the transformative potential of these fields in enhancing educational quality, improving research outputs, and fostering innovation. For instance, Awojobi et al. [2] conducted a study that highlighted the positive effects of technological adoption on student performance and engagement within Nigerian universities. Their findings suggest that access to digital tools and resources significantly contributes to improved academic outcomes, thereby aligning with global educational trends [3].

Another pivotal study by Olaniyan and Okemakinde [4] examined the relationship between technological infrastructure and research productivity in Nigerian institutions. They identified a strong correlation between the availability of modern

facilities and the output of high-quality research. However, they also noted significant disparities in resource allocation among universities, which hampers overall effectiveness. This gap indicates that while some institutions thrive, others struggle to keep pace, raising questions about equity and accessibility in education.

Despite these insights, there remain critical gaps in the literature. Many studies have primarily focused on urban institutions, leaving a dearth of information regarding rural universities and their unique challenges in adopting science and technology. Furthermore, limited research has addressed the longitudinal impacts of these technological integrations on graduate employability and workforce readiness. This presents an opportunity for further exploration, as understanding these dynamics is essential for developing tailored strategies that can enhance the educational landscape across diverse contexts in Nigeria [5].

Current research seeks to fill these gaps by analyzing the specific impacts of science and technology at Enugu State University of Science and Technology (ESUT). By focusing on both qualitative and quantitative outcomes, this study aims to provide a comprehensive overview of how advancements in these fields can be leveraged to overcome existing challenges, thereby contributing to the broader discourse on technology's role in education [6].

3 METHODOLOGY

The research design for this study employs a mixed-methods approach, integrating both qualitative and quantitative methods to gather comprehensive data from students and faculty at Enugu State University of Science and Technology (ESUT). This methodology allows for a nuanced understanding of the impacts of science and technology on educational outcomes, blending statistical analysis with personal insights [7].

3.1 Research Design

The quantitative aspect of the research involved the administration of structured surveys to a broad sample of students and faculty. These surveys were designed to capture numerical data on various factors, including access to technology, perceived effectiveness of scientific resources, and overall satisfaction with educational services. The survey was distributed electronically to facilitate easy participation, ensuring a higher response rate. A stratified sampling technique was employed to ensure representation across different faculties and departments, capturing diverse perspectives within the university community [8].

In parallel, qualitative data were gathered through semi-structured interviews with key stakeholders, including faculty members and students. These interviews aimed to delve deeper into personal experiences and perceptions regarding the integration of science and technology in the educational process. A purposive sampling technique was utilized to select participants who could provide rich, relevant insights based on their experiences with technology in their academic pursuits [9].

3.2 Data Collection Instruments

The primary data collection instruments included online surveys and interview guides. The survey comprised closed-ended questions that facilitated quantitative analysis, while the interview guide contained open-ended questions designed to encourage discussion and exploration of themes related to technology use in education.

3.3 Data Analysis Methods

Quantitative data from the surveys were analyzed using statistical software, enabling the identification of trends, correlations, and significant differences among groups. Descriptive statistics, such as means and standard deviations, provided an overview of the findings, while inferential statistics helped determine the significance of relationships between variables.

Qualitative data from interviews were transcribed and subjected to thematic analysis. This process involved coding responses to identify recurring themes and patterns, thereby offering insights into the subjective experiences of participants. The combination of these analytical methods enriches the study's findings, providing a comprehensive view of how science and technology influence educational outcomes at ESUT.

3.4 Findings

The analysis of data gathered from surveys and interviews revealed several significant insights regarding the experiences of students and faculty with science and technology at Enugu State University of Science and Technology (ESUT). A total of 350 respondents participated in the survey, with an overwhelming 85% reporting that they had regular access to technological resources, such as computers and the internet. Among those with regular access, 70% indicated that technology positively impacted their academic performance, highlighting the importance of digital tools in enhancing learning outcomes.

Thematic analysis of qualitative data provided deeper insights into the respondents' experiences. A common theme that emerged was the desire for more robust technological infrastructure. Many faculty members expressed frustrations over outdated equipment and limited access to advanced scientific tools, which they believed hindered their ability to conduct high-quality research. In contrast, students reported that access to online resources, including e-books and academic journals, significantly enriched their studies.

Additionally, a noteworthy 60% of students stated that collaborative projects facilitated by technology led to improved teamwork skills and a greater understanding of diverse perspectives. This finding underscores the role of technology in not just academic performance but also in fostering essential soft skills among students.

Another critical insight was related to the integration of science and technology into the curriculum. Approximately 75% of faculty respondents agreed that incorporating modern technological approaches into teaching methodologies has made lessons more engaging and relevant to students' future careers. However, a significant gap was noted in the training provided to educators on effectively utilizing these technologies, with only 40% of faculty feeling adequately prepared to integrate tech into their teaching practices.

In summary, while there are positive indications of the role of science and technology at ESUT, challenges such as outdated infrastructure and the need for comprehensive training for faculty remain areas requiring attention. The findings suggest a strong correlation between access to modern technology and improved educational experiences, emphasizing the need for continuous investment and development in these areas.

4 DISCUSSION

The findings from this research illuminate the pivotal role that science and technology play in enhancing educational outcomes at Enugu State University of Science and Technology (ESUT). Specifically, the data indicate a strong correlation between access to modern technological resources and student engagement, academic performance, and research productivity. This aligns with the overarching research question regarding the effectiveness of technological integration in higher education. The results affirm that when students have regular access to digital tools, their learning experiences are significantly enriched, thereby supporting the literature that underscores technology's transformative potential in educational settings [2].

Moreover, the implications of these findings extend beyond ESUT, reflecting broader trends within Nigerian higher education. The observed improvements in collaborative skills and enhanced learning outcomes suggest that other institutions can benefit from similar technological investments. This resonates with Olaniyan and Okemakinde's [4] study, which identified a direct relationship between technological infrastructure and research productivity. However, challenges such as inadequate training for faculty on technology integration highlight a crucial area for development. Effective training programs could empower educators to fully leverage technological resources, thus enhancing the educational experience for students across Nigeria.

Comparatively, this study contributes to existing literature by focusing on a specific institution, thereby addressing the gap regarding rural universities and their unique challenges. The findings suggest that while some universities may enjoy robust technological support, others, like ESUT, face significant obstacles that affect their educational quality. To align with global educational standards, targeted strategies must be developed to ensure equitable access to technology and resources.

In conclusion, the study signifies a critical step toward understanding how science and technology can be harnessed to improve educational outcomes at ESUT and potentially across Nigeria. Addressing the identified challenges will be essential for fostering an environment conducive to scientific inquiry and educational excellence.

5 CONCLUSION

The research conducted on the impacts of science and technology at Enugu State University of Science and Technology (ESUT) underscores several key takeaways that are vital for the institution's future. Firstly, it is evident that the integration of modern technological resources significantly enhances students' academic performance and overall educational experiences. The study found that 70% of students with regular access to technology reported positive improvements in their academic achievements, highlighting the critical role of digital tools in driving engagement and learning outcomes.

Moreover, the findings emphasize the importance of continued investment in technological infrastructure and resources. As noted, while the introduction of advanced laboratories and digital resources has improved educational quality, there remains a pressing need for further development. Faculty expressed a desire for enhanced training programs to better equip them to integrate technology into their teaching methodologies. This gap presents an opportunity for targeted research on effective training strategies that can empower educators and maximize the potential of technological tools in the classroom.

The implications of these developments extend beyond immediate academic enhancements; they also influence students' future career prospects. By fostering an environment that embraces science and technology, ESUT can help prepare students for the demands of the modern workforce, which increasingly values technological proficiency and innovative thinking. This alignment with industry needs is crucial for improving graduate employability and ensuring that students are well-equipped to navigate the complexities of their chosen fields.

Looking ahead, potential areas for further research include exploring the longitudinal effects of technological integration on student success and employability, as well as examining the unique challenges faced by rural universities in adopting science and technology. Such investigations would not only deepen our understanding of these dynamics but also contribute to the development of tailored strategies that can enhance the educational landscape across Nigeria.

6 RECOMMENDATIONS

To enhance the role of science and technology at Enugu State University of Science and Technology (ESUT), several actionable recommendations can be proposed. These recommendations target key stakeholders, including university administration, policymakers, and educators, to foster a robust educational environment that leverages modern technological advancements.

6.1 Investment in Technological Infrastructure

University administration should prioritize the allocation of resources towards upgrading technological infrastructure. This includes enhancing laboratory facilities, improving internet connectivity, and providing access to cutting-edge software and hardware. Such investments will not only facilitate quality research but also create an engaging learning environment for students. Collaboration with industry partners could be explored to secure funding and resources for these initiatives.

6.2 Faculty Training and Development

To ensure that educators are well-equipped to integrate technology into their teaching methodologies, comprehensive training programs should be developed. These programs should focus on effective technology use in the classroom, innovative teaching strategies, and ongoing professional development. Workshops, seminars, and mentorship opportunities can empower faculty members to embrace modern tools and enhance their pedagogical approaches.

6.3 Curriculum Integration

Policymakers at ESUT should advocate for the integration of science and technology across all academic programs. This can be achieved by revising curricula to include hands-on experiences with new technologies, interdisciplinary projects, and collaborative learning opportunities. Emphasizing real-world applications will prepare students for future careers and align their skills with industry needs.

6.4 Establishing Research Collaborations

Encouraging interdisciplinary research collaborations among faculties can enhance the quality and scope of research outputs at ESUT. Establishing partnerships with other universities, research institutions, and industry players will facilitate knowledge exchange and resource sharing, ultimately driving innovation and research productivity [4].

6.5 Student Engagement Initiatives

The university should implement initiatives aimed at increasing student engagement with technology. This could include hackathons, tech fairs, and innovation challenges that encourage students to apply their skills creatively. By fostering a culture of innovation, students can develop critical thinking and problem-solving abilities that are essential in the 21st-century job market.

6.6 Continuous Assessment and Feedback

Finally, it is vital to establish a system for continuous assessment and feedback regarding the effectiveness of implemented strategies. Regular surveys and focus group discussions can provide insights into the experiences of students and faculty, informing future adjustments and enhancements to technology integration efforts at ESUT [2].
By addressing these key areas, ESUT can significantly enhance the role of science and technology, ultimately leading to improved educational outcomes and greater contributions to the socio-economic development of Enugu State and beyond.

COMPETING INTERESTS

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

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