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Article

The study on the intelligent transformation of ice and snow sports curriculum under the perspective of innovation and entrepreneurship education in biomechanics

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Abstract: The necessity for an effective and sustainable curriculum reform has grown in importance since ice and snow sports have advanced so quickly. In order to maximize the development and delivery of ice and snow sports curriculum, this study investigates the integration of innovation and entrepreneurship education within the biomechanics framework. The study suggests using intelligent systems, like fuzzy c-means (FCM) and optimal clustering algorithms, to improve the assessment and advancement of ice and snow sports instruction from the perspective of biomechanics. This study promotes a comprehensive, data-driven approach to curriculum design that places a high priority on sustainable growth by assessing the state of information technology in ice and snow sports schools today and looking at the influence of biomechanical factors on athletic performance and injury prevention. For example, through advanced sensor technologies, coaches can precisely measure parameters like the force exerted on skis or skates, the angular velocities of joints during turns, and the balance dynamics of athletes. This data, when integrated with biomechanical principles, enables the customization of training programs. By implementing the suggested intelligent transformation model in Shenyang's ice and snow physical education programs, the study further assesses its effectiveness and shows notable gains in both athlete performance and the instructional framework. In order to promote long-term growth and sustainability in the sector, this research combines cutting-edge technologies, biological principles, and creative teaching methodologies related to ice and snow sports education. It focuses on how biomechanical insights can drive curriculum innovation, ensuring that athletes not only master the skills but also minimize the risk of overuse injuries and enhance overall athletic efficiency in the challenging environment of ice and snow sports.

Keywords: intelligent transformation; ice and snow sports; biomechanical education; innovation and entrepreneurship; curriculum optimization

1. Introduction

The rapid growth of ice and snow sports underscores the need to optimize educational curricula to meet the evolving demands of both competitive athletes and recreational participants [1,2]. As nations invest in infrastructure and training programs for these sports, the role of specialized schools and tailored curricula becomes increasingly vital for sustainable athletic development. This investment is not merely about building facilities; it encompasses a holistic approach that integrates training, education, and community engagement to foster a culture of excellence in winter sports. However, existing curricula face several challenges, including fragmented course structures, inadequate teaching resources, and the lack of standardized evaluation methods. These challenges can hinder the development of athletes, making it essential to address them systematically. Furthermore, the integration of advanced technologies and biological principles—key to enhancing athletic performance and promoting sustainability—remains insufficient [3,4]. While many educational institutions recognize the importance of technology in sports training, few have effectively incorporated these tools into their curricula.

Biology, particularly the study of human physiology and performance optimization, is foundational to sports education. Understanding the biological responses to physical exertion, training, and recovery is crucial for designing curricula that address the physiological needs of athletes. For instance, athletes engaged in high-intensity training require specific nutritional support and recovery strategies to optimize their performance and health. This biological perspective not only facilitates individual performance enhancement but also supports injury prevention, well-being, and sustainable training practices. Incorporating biological principles into the curriculum can lead to more informed training regimens that consider individual athlete differences, such as age, gender, and genetic predispositions. Additionally, the concept of sustainable development in the context of biological systems highlights the importance of incorporating environmental, health, and technological considerations into educational models. This means that curricula should not only focus on physical training but also address the broader implications of sports on health and the environment. Such integration ensures the long-term viability of ice and snow sports [5–8].

In recent years, the inclusion of innovation and entrepreneurship education within ice and snow sports curricula has emerged as a promising solution to address these challenges. This shift recognizes that the future of sports will require not only skilled athletes but also innovative thinkers who can adapt to changing circumstances and create new opportunities. By fostering creativity and entrepreneurial thinking, educators can equip students to envision the future of these sports and develop innovative solutions to existing barriers. For example, students might be encouraged to design new training programs, develop sustainable practices for sports events, or create technology that enhances athlete performance. Advanced intelligent systems, including clustering algorithms and fuzzy c-means (FCM) models, offer powerful tools for evaluating and improving sports education programs by providing data-driven insights into curriculum effectiveness [9,10]. These systems can analyze large datasets from various sources, such as athlete performance metrics and educational outcomes, to identify trends and areas for improvement.

This study explores the intelligent transformation of ice and snow sports curricula through the lens of innovation and entrepreneurship education in biology. By integrating biological principles with cutting-edge technology, this research aims to create a robust educational framework that not only enhances athletic performance but also prepares students for careers in the evolving landscape of sports. By leveraging biological principles alongside advanced algorithmic models, the research aims to optimize curriculum design, assessment, and educational outcomes. For instance, using FCM models, educators can categorize athletes based on their performance data, allowing for more personalized training approaches that cater to individual strengths and weaknesses [11,12]. The application of intelligent, data-driven, and biologically informed approaches seeks to create a sustainable and innovative framework for ice and snow sports education. This model emphasizes continuous improvement, where feedback loops allow for real-time adjustments to training programs based on athlete performance and recovery data. This approach not only enhances the learning experience for students but also contributes to the overall development of ice and snow sports as a discipline.

2. Methods

2.1. Optimized clustering algorithm

When dealing with numerical data, the similarity measurement method presented in the following table prove to be quite useful. Among them, Minkowski distance is LP norm ($P \geq 1$), while Manhattan distance, Euclidean distance and Chebyshev distance correspond to the case when $p = 1$ or 2 respectively, as clearly shown in **Table 1**.

Table 1. similarity measurement criteria function table.

Similarity measurement criteria	Similarity measure function
Euclidean distance	$d(x,y) = \sqrt{\sum_{i=1}^{n}(x_i - y_i)^2}$
Manhattan distance	$d(x,y) = \sum_{i=1}^{n}\lVert x_i - y_i \rVert$
Chebyshev distance	$d(x,y) = \max_{i=1,2,\ldots,n}^{n} \lVert x_i - y_i \rVert$
Minkowski distance	$d(x,y) = \left[\sum_{i=1}^{n}(x_i - y_i)^p\right]^{\frac{1}{p}}$

The integration of multiple algorithms in hybrid approaches inevitably increases algorithmic complexity. Thus, achieving a balance between algorithmic complexity and solution effectiveness remains a critical focus in the study of hybrid heuristic algorithms. To address this, a hybrid meta-heuristic algorithm, m-ils-spp, is proposed [13].

This algorithm leverages a multi-start mechanism and incorporates four neighborhood search operators designed to explore the neighborhood space, thereby enhancing partition quality. Additionally, a Set Partition Problem (SPP) model is established to improve the algorithm's global optimization capability. As a result, the proposed algorithm demonstrates strong optimization performance and reliable convergence [14,15].

However, some limitations exist. The algorithm requires significant computational time to construct the initial solution, and the convergence speed of the designed neighborhood search operators is relatively slow when applied to single calibration slicing. The dimensional representation of the algorithm is illustrated in **Figure 1** below.

This research aims to refine these aspects while maintaining a balance between complexity and efficiency, ensuring the algorithm's practical applicability in solving complex optimization problems.

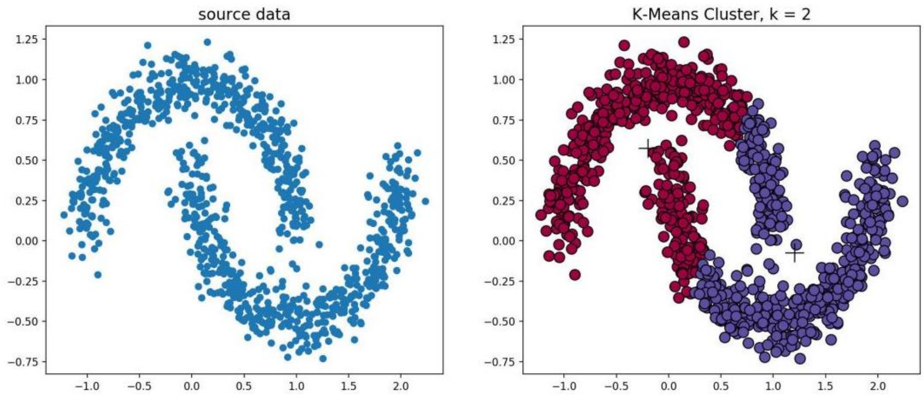

Figure 1. Dimension code diagram.

With the strategy of "school grouping first, students then assigning", the k-medoids model is used to group the schools, and the hybrid heuristic algorithm is used to slice the single school and multiple schools respectively, and finally the optimal partition scheme is obtained. Therefore, by analyzing the framework, characteristics, advantages and disadvantages of heuristic algorithm, combined with the idea of hybrid algorithm, this chapter proposes three hybrid heuristic algorithms to solve the school district division problem under the multi start and random mechanism [16]. The heuristic algorithm combined in each hybrid heuristic algorithm can make up for their respective defects, enhance the search ability of the algorithm, ensure that the algorithm does not fall into the limitation of local optimization, and realize the diversification of the algorithm. The basic structures of the three hybrid heuristic algorithms are: Constructing the initial solution, hybrid heuristic algorithm optimization and optimal solution. The construction of the initial solution is the same in the three algorithms.

2.2. Optimize clustering algorithm to build ice and snow characteristic teaching model

The effect of the original K-means source code test data is shown in **Figure 2** below.

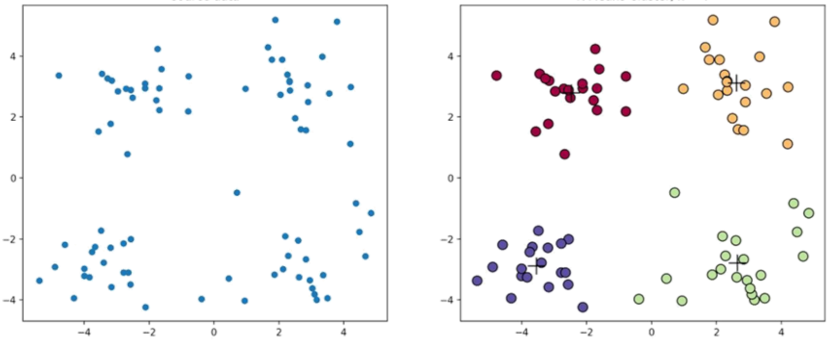

Figure 2. K-means source code dataset.

The main algorithm used in the teaching of ice and snow characteristics is the optimized fuzzy clustering algorithm. And there is no sudden change. Bezdek combines Fuzziness with the concept of mathematics and puts forward fuzzy set theory. Fuzzy theory is mainly used to explain some fuzzy information concepts in language. Based on this, fuzzy set theory has been widely developed, Ruspini proposed fuzzy partition [17]. On this basis, the objective function can be written as the following Equation (1):

$$\min \sum_{i=1}^{n} \min_{j=1,2,\ldots,k} \left\| x_i - \mu_j \right\|^2 \tag{1}$$

This function is a non convex optimization function and will converge to the local optimal solution, as shown in Equation (2):

$$z = \min_{j=1,2} \left\| x_i - \mu_j \right\|^2 \tag{2}$$

The data of the optimized clustering algorithm should be classified into one category, while the data above should be classified into two categories, which is caused by the unreasonable selection of the initial centroid. Similarly, take the data set in the above figure, and take *k* = 2, 3, and 4 to get the following clustering results, as shown in **Figure 3**.

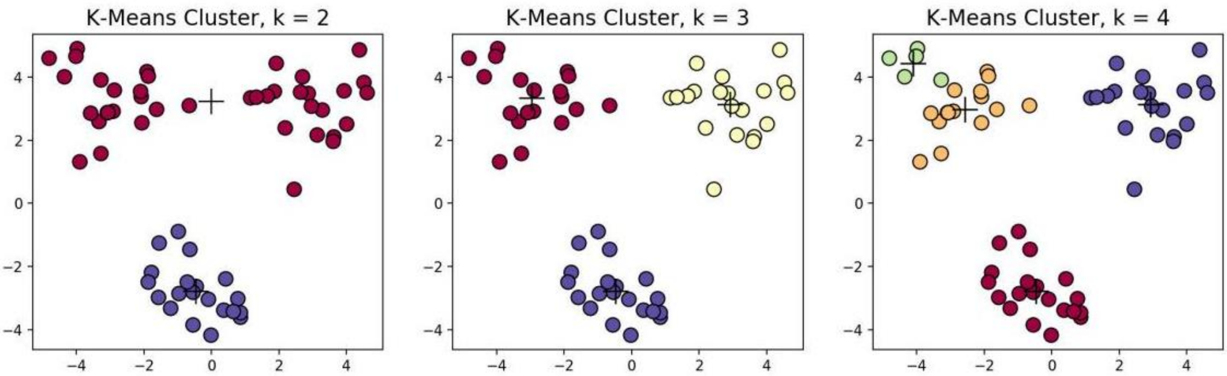

Figure 3. Optimized source code data set 4 case study.

Data cleaning and data standardization are the two primary components of this chapter, which primarily examines the data pretreatment involved in building the ice and snow characteristic school model. Based on the degree of information application development in ice and snow characteristic teaching schools, an online questionnaire survey although the questionnaire system data was exported, and the original data of the development of the informatization application level of ice and snow characteristic teaching schools was gathered and sorted out, some errors occurred during the manual filling out of the questionnaire, which could result in data errors and input data that is not in accordance with common sense. As a result, the initial data collected can be insufficient, inconsistent, or even partially erroneous.

3. Improve data cleaning efficiency

After exporting the required original data through the questionnaire system, this data is usually not directly used as the specific data for data analysis. It is necessary to process some invalid or missing data in the original questionnaire data of the type or format in the questionnaire data. In addition, it is also necessary to de duplicate the questionnaire data according to the actual situation. For example, this research is based level in ice teaching schools [18,19]. Therefore, in the questionnaire survey, the ice and snow characteristic teaching school is the main body to understand some specific application index data about information application of its ice and snow characteristic teaching school, each ice and snow characteristic teaching school only needs the school leader or the chief teacher of the information office to fill in a questionnaire, of the informatization application of ice and snow characteristic teaching schools.

As shown in **Figure 4**, it is the data cleaning module of orthogonal matching pursuit.

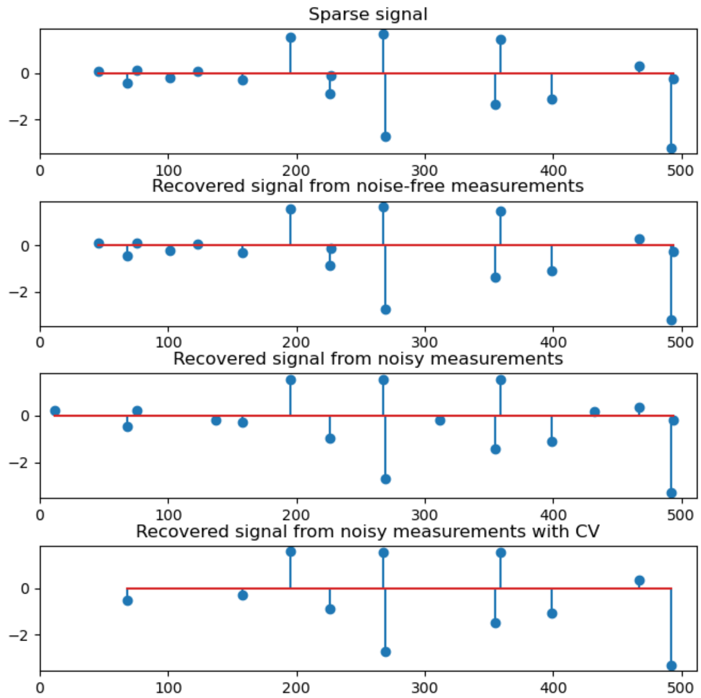

Figure 4. Data cleaning module of orthogonal matching pursuit.

3.1. Strengthen the application of data standardization

In the multiple informatization application index system of optimized clustering algorithm, due to the different nature of each informatization application index, there are different dimensions and orders of magnitude of informatization application index data. The standardized processing of information application index data of ice and snow characteristic teaching schools can quantify the specific application index data. Before cluster analysis and processing of data, it is a common processing method to standardize the original data [20]. Common data standardization methods include min MA (standardization, log function conversion, etc.). In this paper, the data standardization processing adopts the min max standardization method, and the dimensionless expression scalar is finally formed by converting the dimensionless expression.

The transformation formula is:

$$X_n = \frac{X - X_{\min}}{X_{\max} - X_{\min}} \tag{3}$$

3.2. K-means clustering analysis to improve the informatization application

The K-means method's optimization dimensions are more varied when analyzing the improved clustering algorithm. The K-means clustering technique classifies information application index data based on distance. The internal properties of various application indicators are more similar the closer their data objects are near one another. **Figure 5** illustrates the main steps involved in implementing the K-meam clustering method, which is a hard clustering technique in expression.

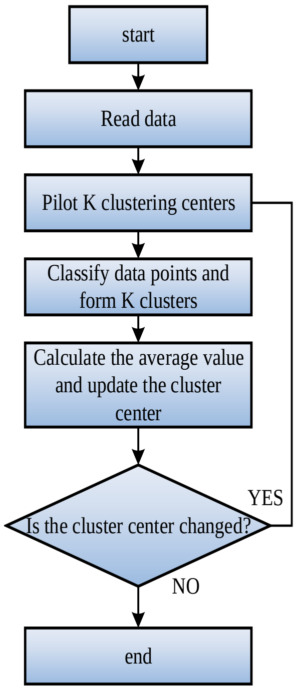

Figure 5. Implementation flow chart of K-means clustering analysis algorithm.

3.2.1. K-means clustering results provide multidimensional indicators for ice and snow characteristic teaching

The data for this experiment was sourced from a questionnaire survey system assessing informatization applications in schools specializing in ice and snow sports education. The dataset includes 13 informatization application indicators. To facilitate visualization of the clustering results generated by the clustering algorithm, dimensionality reduction was performed [21].

A commonly used dimensionality reduction technique across various data contexts is Principal Component Analysis (PCA). The core idea of PCA is to map the original high-dimensional data onto a lower-dimensional space while retaining the most significant features. Specifically, the initial data with NN dimensions is transformed into a reduced space of mm dimensions, where mm represents a simplified set of new orthogonal feature dimensions, also referred to as the *principal components*. For visualization purposes, mm is typically set to 2, enabling the creation of a two-dimensional representation that effectively summarizes the original data's key features.

In determining the optimal number of clusters (K), the quality of clustering is evaluated using the Silhouette Coefficient (SC). The SC ranges from −1 to 1, with values closer to 1 indicating better-defined clusters. In this study, when K = 3, the SC value is approximately 0.95, suggesting that the clustering algorithm effectively categorized the informatization application levels of the ice and snow education schools into three distinct groups.

The clustering visualization results obtained using the K-means algorithm are presented in **Figure 6**, highlighting the successful classification of informatization development levels within the dataset.

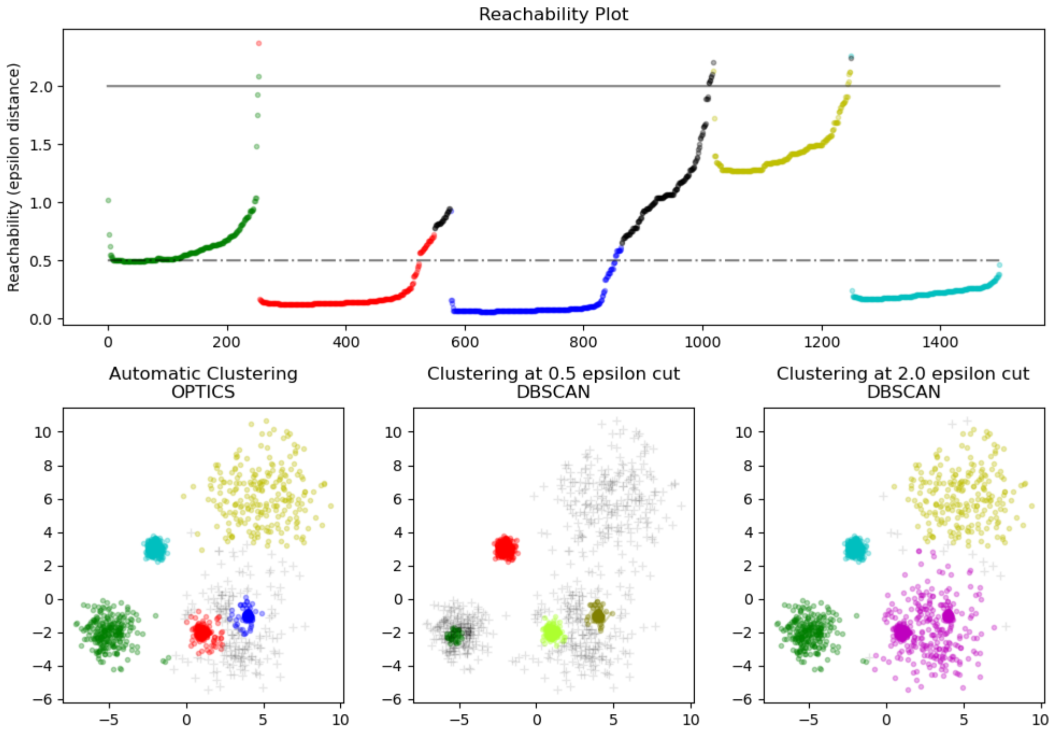

Figure 6. K—clustering visualization effect of means clustering algorithm.

3.2.2. optimized K-means

In algorithm, the number of ice and snow characteristic teaching schools divided into category 2 is the largest. In order to better describe the informatization application level of three different categories and the differences of informatization application among different categories of schools, the development level of each category of ice and snow featured teaching schools under 13 informatization application indicators is shown in **Figure 7** in detail.

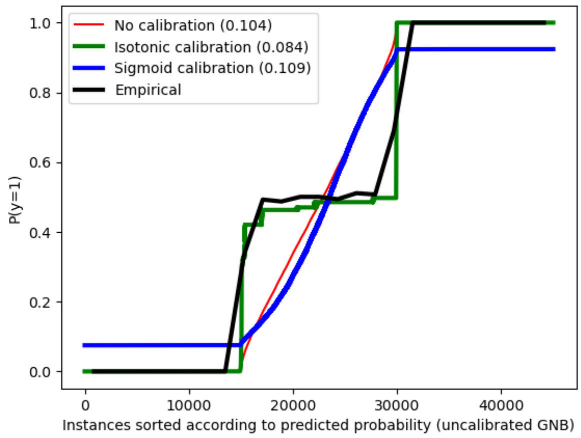

Figure 7. K—development level under the informatization application index of means clustering.

Table 2. analysis results informatization application of different types of schools under K-means clustering.

		Sum of squares	df	mean square	F inspection	Scheffe(c)
Common functions of school online learning space	Intergroup	6.241	2	3.211	59.318	3 > 1
	In group	17.862	330	0.054		3 > 2
	total	24.284	332			1 > 2
Common functions of school teaching information system	Intergroup	7.934	2	3.967	71.182	1 > 2
	In group	18.391	330	0.056		1 > 3
	total	26.325	332			3 > 2
Proportion of teachers who open real name online learning space	Intergroup	56.887	2	28.444	808.012	1 > 2
	In group	11.617	330	0.035		1 > 3
	total	68.504	332			3 > 2
Proportion of subject teachers who can use information technology to teach	Intergroup	4.202	2	2.101	31.786	1 > 2
	In group	21.810	330	0.066		3 > 2
	total	26.011	332			
Functions of management information system commonly used in schools	Intergroup	16.876	2	8.438	25.200	3 > 1
	In group	24.471	330	0.074		3 > 2
	total	41.347	332			

As shown in **Figure 6**, A1–A3 are three specific application indicators for the application of information infrastructure in ice and snow characteristic teaching schools, B1–B7 are seven specific application indicators of informatization teaching application in ice and snow characteristic teaching schools, and C1–C3 are three specific application indicators of informatization management application in ice and snow characteristic teaching schools. The development of the application level of the three + similar ice and snow characteristic teaching schools under the application dimension of information infrastructure is roughly similar. Compared with the application of information infrastructure, the utilization rate of multimedia equipment in the multimedia classroom of ice and snow characteristic teaching school is as high as 80%, The average class scheduling of each computer classroom in the ice and snow characteristic teaching school and the number of multi-functional classrooms commonly used in the school in the ice and snow characteristic teaching equipment are less than 40%, Ice and snow characteristic teaching schools more multi-functional classrooms, which for ice and snow characteristic teaching, It is also the foundation to ensure that children have good ice and snow characteristic teaching. As shown in **Table 2**.

4. Discussion

The rapid advancement of ice and snow sports has necessitated a robust and sustainable curriculum reform that aligns with contemporary educational and athletic needs. This study highlights the integration of innovation and entrepreneurship education within the biological biomechanics framework as a critical step towards enhancing the curriculum for ice and snow sports. The findings emphasize that a data-driven approach, underpinned by intelligent systems such as fuzzy c-means (FCM) and optimal clustering algorithms, can significantly improve the assessment and advancement of ice and snow sports instruction.

The necessity for curriculum reform in ice and snow sports education cannot be overstated. As the popularity of these sports grows, so does the complexity of the skills required to excel in them. Traditional teaching methods may not adequately address the diverse needs of athletes, particularly in terms of skill acquisition and injury prevention. By integrating biological biomechanics into the curriculum, educators can provide a more holistic approach that not only focuses on performance but also on the physiological aspects of athletic development. This integration ensures that athletes are not only mastering the required skills but are also equipped with the knowledge to prevent injuries, thus promoting long-term participation in these sports.

The study proposes the use of intelligent systems, particularly FCM and optimal clustering algorithms, to enhance the assessment of ice and snow sports instruction. These systems allow for a nuanced analysis of data collected from various sources, including advanced sensor technologies. For instance, coaches can gather precise measurements of forces exerted on skis or skates, joint angular velocities during maneuvers, and balance dynamics. By analyzing this data through the lens of biomechanical principles, training programs can be customized to meet the specific needs of each athlete. This personalized approach not only optimizes performance but also minimizes the risk of overuse injuries, which are prevalent in high-intensity sports like skiing and snowboarding.

The comprehensive data-driven approach to curriculum design advocated in this study is paramount for sustainable growth in ice and snow sports education. By assessing the current state of information technology in ice and snow sports schools, the research identifies gaps and opportunities for improvement. The emphasis on biomechanical factors and their influence on athletic performance provides a solid foundation for developing effective training regimens. Moreover, the incorporation of innovative teaching methodologies ensures that athletes are engaged and motivated to learn.

The findings reveal that integrating advanced technologies into the curriculum not only enhances the learning experience but also prepares athletes for the demands of competitive sports. For example, the use of real-time feedback from sensor technologies can help athletes make immediate adjustments to their technique, leading to improved performance outcomes.

The application of the intelligent transformation model in Shenyang's ice and snow physical education programs serves as a case study for the effectiveness of this approach. The notable gains in athlete performance and the instructional framework underscore the potential benefits of adopting a data-driven, biomechanically-informed curriculum. By focusing on the unique characteristics of ice and snow sports, this model fosters an environment where athletes can thrive, both in terms of skill development and injury prevention.

Furthermore, the study's findings suggest that the implementation of such models can lead to significant improvements in the overall quality of ice and snow sports education. The ability to tailor educational experiences to the specific needs of athletes not only enhances individual performance but also contributes to the development of a more competent and knowledgeable coaching staff.

Building on expert research and findings regarding educational informatization, this study refined the informatization application index system tailored to the unique needs of China's ice and snow education schools. The establishment of this index system is a crucial step in understanding the current levels of informatization within these schools. By utilizing a questionnaire survey system, the study collected data that reflect the informatization application levels, providing a comprehensive overview of how technology is being integrated into ice and snow sports education.

The application of K-means and FCM clustering algorithms to analyze this data reveals significant insights into the characteristics of school informatization applications. The identification of distinct levels—high, low, and intermediate—allows for targeted interventions and resource allocation. Schools categorized within the high level can serve as models for best practices, while those in the low and intermediate categories can benefit from tailored support and training to enhance their informatization efforts.

The variance analysis conducted to test for significant differences in school informatization levels further emphasizes the utility of FCM clustering. This method provides a more precise depiction of the unique informatization application levels within ice and snow characteristic education schools. By capturing the personalized and nuanced features of these applications, educators and administrators can better understand the specific needs of their institutions.

The findings suggest that the FCM clustering algorithm is particularly effective in analyzing differences in personalized teaching applications. This capability is essential for developing educational strategies that cater to the diverse needs of students and athletes. By understanding the developmental characteristics at each level of informatization, schools can implement targeted initiatives that promote growth and enhance educational outcomes.

5. Conclusion

Building on expert research and findings regarding educational informatization and its development in schools with ice and snow characteristics, this study further refined the informatization application index system through comprehensive questionnaires and expert interviews. This process involved gathering insights from educators, administrators, and technology specialists to ensure that the index system accurately reflects the unique context of ice and snow sports education. Ultimately, an index system tailored to the unique needs of China's ice and snow education schools was established. This customized index serves as a foundational tool for assessing the current state of informatization and guiding future enhancements in educational practices. Data on the informatization application levels of these schools were collected using a questionnaire survey system. The survey was designed to capture a wide range of factors, including the availability of technological resources, the integration of digital tools in teaching, and the overall digital literacy of educators and students. This comprehensive approach ensured that the collected data provided a holistic view of how informatization is being implemented in these specialized educational settings

By applying the K-means and fuzzy c-means (FCM) clustering algorithms, the study identified key characteristics of school informatization applications in ice and snow education. These algorithms allowed for the grouping of schools based on their informatization levels, providing insights into patterns and trends that may not have been evident through traditional analysis methods. A significant difference test for school informatization levels was conducted using variance analysis. This statistical approach enabled the researchers to determine whether the differences observed between groups were statistically significant, thereby validating the findings. The results demonstrated that the FCM clustering algorithm is particularly effective for analyzing differences in the personalized teaching applications of ice and snow characteristic education schools. This effectiveness can be attributed to FCM's ability to handle uncertainty and variability in data, making it well-suited for educational contexts where individual needs and circumstances can vary widely. It provides a more precise depiction of the unique informatization application levels within these schools.

Using FCM clustering, the development levels of informatization applications were categorized into three groups: High, low, and intermediate. This categorization not only simplifies the analysis but also helps stakeholders understand where each school stands in terms of their technological integration and use. Additionally, a difference analysis was conducted to explore the developmental characteristics at each level. For instance, schools in the high category may exhibit advanced digital teaching methods and robust infrastructure, while those in the low category may struggle with basic technological integration. This approach underscores the utility of FCM clustering in capturing the personalized and nuanced features of informatization applications in ice and snow characteristic education schools.

Overall, this study highlights the importance of tailored educational frameworks that consider the specific needs and contexts of ice and snow sports education. By leveraging advanced analytical techniques like FCM clustering, educators and policymakers can make informed decisions that enhance the effectiveness of informatization efforts, ultimately benefiting students and the broader educational landscape.

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References

1. Wang N, Jiang Y, Xu H, et al. A pre-game evaluation of the tourism legacy of the Beijing 2022 Winter Olympic Games. Journal of Resources and Ecology. 2022; 13(4): 578–591.
2. Tang C, Rui Z, Yang Y, et al. High-quality development paths of ice-snow tourism in China from the perspective of the Winter Olympics. Journal of Resources and Ecology. 2022; 13(4): 552–563.
3. Wang J, Sun Y. Relationships between tourist experiential value and ice-snow tourism loyalty in Zhangjiakou City, and the moderating effects of travel companions. Journal of Resources and Ecology. 2022; 13(4): 646–654.
4. Lourdusamy A, Dhivviyanandam I, Mathew L. NDC Pebbling Number for Some Class of Graphs. Journal of Combinatorial Mathematics and Combinatorial Computing. 2024; 119: 121–128.
5. Wu L, Xu J, Yan Z, et al. The Spatio-Temporal Evolution of Ski Resorts in the Beijing-Tianjin-Hebei Region: Characteristics and Influencing Factors. Journal of Resources and Ecology. 2022; 13(4): 592–602.
6. Costamagna F, Lind R, Stjernström O. Livability of urban public spaces in northern Swedish cities: The case of Umeå. Planning Practice & Research. 2019; 34(2): 131–148.
7. Shaktawat A, Vadhera S. Risk management of hydropower projects for sustainable development: A review. Environment, Development and Sustainability. 2021; 23(1): 45–76.
8. Warner K, Zommers Z, Wreford A, et al. Characteristics of transformational adaptation in climate-land-society interactions. Sustainability. 2019; 11(2): 356.
9. Li D. The Comprehensive Training Effect of Translation Ability of College English Majors Based on Machine Learning. Journal of Combinatorial Mathematics and Combinatorial Computing. 2024; 120: 399–410.
10. Pang B, Qian J, Zhang Y, et al. 5S multifunctional intelligent coating with superdurable, superhydrophobic, self-monitoring, self-heating, and self-healing properties for existing construction application. ACS applied materials & interfaces. 2019; 11(32): 29242–29254.
11. Guo L, Sun Y. Economic Forecasting Analysis of High-Dimensional Multifractal Action Based on Financial Time Series. International Journal for Housing Science and Its Applications. 2024; 45(1): 11–19.
12. Altay A, Mirici İH. Efl Instructors' Implementations of 21st Century Skills in Their Classes. International Journal for Housing Science and Its Applications. 2024; 45(2): 37–46.
13. Wu Y. Exploration of the Integration and Application of the Modern New Chinese Style Interior Design. International Journal for Housing Science and Its Applications. 2024; 45(2): 28–36.
14. Fu L, Liu Y, Yang Z. Influence of ice and snow sports participation experience on participation constraints among residents in southern China: A quantitative analysis based on propensity score matching. Journal of Resources and Ecology. 2022; 13(4): 624–634.
15. Ramadan MASM, El-Halaby M. Integrative Relationship Between Environmental Architecture and Interior Design Towards Sustainability. International Journal of Architectural Engineering and Urban Research. 2020; 3(2): 38–46.
16. Huang H, Li Q, Zhang Y. Urban residential land suitability analysis combining remote sensing and social sensing data: A case study in Beijing, China. Sustainability. 2019; 11(8): 2255.
17. Bang SD, Cecil DJ. Constructing a multifrequency passive microwave hail retrieval and climatology in the GPM domain. Journal of Applied Meteorology and Climatology. 2019; 58(9): 1889–1904.
18. Yan Y, Huang K, Shao D, et al. Monitoring the characteristics of the Bohai Sea ice using high-resolution geostationary ocean color imager (GOCI) data. Sustainability. 2019; 11(3): 777.

19. Zhang K, Kevern J. Review of porous asphalt pavements in cold regions: The state of practice and case study repository in design, construction, and maintenance. Journal of Infrastructure Preservation and Resilience. 2021; 2(1): 1–17.
20. Ford JD, Clark D, Pearce T, et al. Changing access to ice, land and water in Arctic communities. Nature Climate Change. 2019; 9(4): 335–339.
21. Cramer W, Guiot J, Fader M, et al. Climate change and interconnected risks to sustainable development in the Mediterranean. Nature Climate Change. 2018; 8(11): 972–980.