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Research on the Pathways for Cultivating Core Competencies in Middle School Students through Physical Education

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Abstract This study utilized the Delphi method to construct a four-level indicator system for core competencies in physical education teaching. Through three rounds of consultation involving 20 experts in the field of physical education, the initial 47 third-level indicators were screened and revised, ultimately forming an optimized system comprising 4 first-level indicators, 10 second-level indicators, and 41 third-level indicators. Based on this framework, the Entropy Weight-TOPSIS method was applied to evaluate 92 physical education teacher trainees at a certain university. The Entropy Weight method revealed that the top three third-level indicator weights were C73 Problem-Solving Ability (4.19%), C53 Teaching Implementation Ability (3.98%), and C51 Teaching Demonstration Ability (3.86%). TOPSIS analysis indicated that there were significant differences in student competencies, with the optimal solution (Student30, $D^+=0$) and the worst solution (Student46, $D^-=0.0027$) differing by a factor of 30 in terms of proximity, and the top 10% of students ($S>0.0628$) far exceeding the bottom 10% ($S<0.0112$) in terms of proximity. The article proposes a cultivation path for students' core competencies in physical education based on a mechanism for dynamically adjusting indicator weights, providing a more precise competency cultivation model for physical education integration policies.

Index Terms physical education, core competencies, Delphi method, entropy weight-TOPSIS

I. Introduction

In the past, physical education often emphasised the cultivation of students' physical fitness and motor skills, while neglecting the development of their thinking abilities, emotional attitudes, and social interaction skills [1]-[3]. With the deepening of educational reforms, physical education is no longer merely about imparting skills, but increasingly focuses on the comprehensive development of students [4]-[6]. Core competencies, as an important component of students' overall quality, have become a key focus of physical education in higher education institutions [7], [8].

Student core competencies refer to the key abilities that students gradually develop during the educational process to meet the needs of societal development [9], [10]. These competencies constitute an essential component of students' overall quality, emphasizing their value systems and their ability to address real-world challenges [11], [12]. Specifically, student core competencies encompass multiple dimensions: cultural literacy, which entails students possessing humanities and scientific literacy, enabling them to understand and respect diverse cultures [13], [14]. Self-development literacy, where students should learn how to learn and be able to plan their own life goals [15], [16]. Social participation literacy, where students should possess good civic morality and professional ethics, be able to actively participate in social activities, and have teamwork and leadership skills [17]-[19]. The development of these core competencies requires students to gradually accumulate them through systematic coursework and diverse practical activities in school education [20], [21]. Schools should provide diverse educational resources and teaching environments to help students develop these core competencies [22], [23]. At the same time, teachers should assist students in discovering their potential and strengths [24].

Reference [25] points out the challenges currently faced in cultivating students' core physical education competencies and examines the application of situational teaching methods in the cultivation of core physical education competencies, as well as personalized guidance, to ensure the effective cultivation of students' core physical education competencies. Reference [26] integrates scholars' literature on students' core physical education competencies through methods such as literature review and logical analysis, emphasizes the necessity of further deepening physical education curriculum reform, and analyses the contemporary value of cultivating students' core competencies. Literature [27] adopts a sports reform perspective, using sun sports activities as a starting point, and takes a high school as an example to analyse the effects and challenges of school sun sports activities. The aim is to identify the positive role of implementing sun sports activities in enhancing students' core competencies and to

address related issues. Literature [28] emphasises the importance of cultivating physical education core competencies for achieving the goal of universal physical education development. In the modern physical education system, cultivating physical education core competencies requires upholding the central role of the classroom and ensuring the implementation of extracurricular Sunlight Sports activities. Literature [29] analyses the reform of physical education teaching behaviour and student learning methods under the framework of core competencies, focusing on aspects such as teachers' language information literacy, students' self-understanding, and practical literacy during the teaching process. The results indicate that teachers' teaching behaviour and students' learning methods in physical education can be transformed. Literature [30] emphasises the important role of cooperative learning methods in education and teaching, and examines the impact of such methods on students' learning abilities and core competencies. The effectiveness of these methods was validated using students from Guangxi Normal University for Nationalities as research subjects. Literature [31] focuses on the field of physical education, highlighting the role of innovative assessment methods in promoting students' comprehensive development. It points out the shortcomings of traditional assessment methods, introduces various innovative assessment methods such as performance-based assessment and portfolio assessment, and explains the advantages and implementation strategies of each method. Literature [32] conducted a survey and analysis of the current state of core competencies among university students using methods such as questionnaires and logical analysis. It constructed cultivation strategies from aspects such as physical education ability development to promote the cultivation of core competencies in physical education among university students. Literature [33] emphasised the importance of cultivating students' core competencies in physical education, introduced the meaning and characteristics of core physical education competencies in universities, pointed out that this field is currently not given enough attention, noted that university students' physical education ethics and moral competencies are relatively low, and proposed strategies for cultivating core physical education competencies. Literature [34] notes that under the framework of core physical education literacy, campus football development is gradually gaining attention. It discusses the challenges currently faced in football instruction within Chinese university physical education programmes and analyses football teaching methods from two perspectives: student initiative and teacher leadership.

This study employs a multi-stage methodological approach to construct a scientific literacy evaluation system. First, based on four dimensions—physical ability, sports ideology, practical ability, and professional literacy—an initial framework comprising four first-level indicators, ten second-level indicators, and 47 third-level indicators is established. To address potential issues of subjectivity and lack of universality in the initial indicators, an innovative three-round Delphi expert consultation method is employed for refinement. Through scoring by 20 domain experts on the importance of the indicators, combined with dual screening criteria of mean and coefficient of variation, the indicators were reasonably modified, ultimately forming an optimized system with 41 tertiary indicators. Based on this, the Entropy Weight-TOPSIS-Gray Priority (OPA-G) combined evaluation model was introduced. The entropy weight method was used to objectively calculate indicator weights, overcoming the subjective limitations of the traditional AHP method. The TOPSIS method was employed to quantify the proximity between student competencies and the ideal solution, enabling precise ranking. To address cognitive ambiguity in expert evaluations, the OPA-G model was innovatively developed by integrating grey system theory, converting experts' qualitative rankings of indicators into interval grey numbers to effectively manage evaluation uncertainties.

II. Construction of a core physical education competency indicator system and refinement using the Delphi method

II. A. Preliminary Selection of Core Competency Indicators for Middle School Students in Physical Education

Based on the theoretical foundation of constructing core competencies for students in physical education, and following the principles of indicator construction, we reviewed relevant research findings and conducted expert interviews to preliminarily establish an indicator system for core competencies in physical education, comprising four first-level indicators, ten second-level indicators, and 47 third-level indicators. The preliminary indicator system for core competencies in physical education is shown in Table 1.

II. B. Revision of the Core Competency Indicator System for Physical Education in Secondary Schools

To make the preliminary indicator system for core competencies in physical education more practical, this section will use the Delphi method to adjust the indicators.

The study selected 20 professors and associate professors in the field of physical education research, as well as frontline teaching staff, as survey respondents. Each professor scored each indicator based on their understanding of it, using the following scoring criteria: 1 point (unimportant), 2 points (relatively unimportant), 3 points (average), 4 points (relatively important), and 5 points (important).

Table 1: The initial indicator system of students' core literacy in physical education

Primary indicator	Secondary indicator	Third-level indicators
A1 Physical fitness	B1 Basic physical fitness	C11 Strength
		C12 Speed
		C13 Endurance
		C14 Agility
		C15 Flexibility
		C16 Coordination
		C17 Balance
	B2 Health Care Literacy	C21 Health Care Knowledge
		C22 Health Care Behaviors
		C23 Knowledge of Health and Fitness Exercise Management
		C24 Actively Participate in Traditional Sports Exercises
A2 Sports Thought and Theory Knowledge	B3 Sports Theory Knowledge	C31 Knowledge of Physical Exercise
		C32 Safety Knowledge of Sports
		C33 Basic Theoretical Knowledge for Specialized Sports
		C34 Knowledge of Specialized Sports Rules
		C35 Knowledge of Sports Physiology
		C36 Knowledge of Sports Training
		C37 Knowledge of Sports Anatomy
	B4 Sports Ideological Awareness	C41 Willingness to Strive
		C42 Obeying Rules
		C43 Team Spirit
		C44 Fair Competition
		C45 Cooperation and Collaboration
		C46 Scientific and Practical Attitude
A3 Practical Skills	B5 Teaching Ability	C51 Teaching Demonstration Ability
		C52 Teaching Design Ability
		C53 Teaching Implementation Ability
		C54 Teaching Evaluation Ability
		C55 Teaching Organization Ability
		C56 Teaching Innovation Ability
		C57 Ability to Handle Emergencies
	B6 Training Capacity	C61 Training Organization Ability
		C62 Analytical and Judging Ability
		C63 Effective Communication Ability
		C64 Professional Learning Ability
	B7 Competition Management Skills	C71 Competence in Competition Arrangement
		C72 Competence in Competition Organization
		C73 Competence in Competition Judging
	B8 Problem-solving Ability	C81 Ability to Identify Problems
		C82 Ability to Analyze Problems
		C83 Ability to Solve Problems
A4 Professional Competence	B9 Sports Emotions	C91 Love for Sports
		C92 Actively Participate in Sports Activities
		C93 Sports Values
	B10 Social Responsibility	C101 Social Practice Ability
		C102 Interpersonal Communication Ability
		C103 Observing Discipline and Abiding by Laws

II. B. 1) Indicator selection and revision process

Experts score each indicator, calculate the mean (X), standard deviation (S), and coefficient of variation (V) of each index according to the statistical results, and the average value (X) is used to reflect the overall score of the index, and the critical value is set to 3. The standard deviation (S) and coefficient of variation (V) are used for the dispersion of the response index, and the critical value of the coefficient of variation (V) is set to 0.2, when the coefficient of variation (V) is less than 0.25, it means that the experts' views on the index are basically the same, and the index is retained, and the coefficient of variation (V) is greater than 0.25, it means that the expert has a large degree of disagreement on the index, and the index will be eliminated; when the coefficient of variation (V) is greater than 0.25 and the mean value (X) is greater than 3, it means that some experts recognize the index. At the same time, if the degree of disagreement is large, the expert opinion will be consulted, and the indicators will be deleted or retained according to the expert suggestions.

II. B. 2) Analysis and results of the first round of expert questionnaire survey

A total of 20 expert questionnaires were distributed, with 20 returned, yielding a response rate of 100%. All 20 questionnaires were valid, resulting in a validity rate of 100%. The statistical results of the first round of tertiary indicators are shown in Table 2.

Table 2: The statistical results of the first round of third-level indicators

Indicators	X	S	V
C11 Strength	4.60	0.548	0.119
C12 Speed	4.80	0.410	0.085
C13 Endurance	4.60	0.599	0.130
C14 Agility	4.20	0.736	0.175
C15 Flexibility	4.35	0.695	0.160
C16 Coordination	4.65	0.733	0.158
C17 Balance	4.15	1.171	0.282
C21 Health Care Knowledge	4.25	0.356	0.084
C22 Health Care Behaviors	4.05	0.407	0.100
C23 Knowledge of Health and Fitness Exercise Management	3.90	0.895	0.229
C24 Actively Participate in Traditional Sports Exercises	4.15	1.006	0.242
C31 Knowledge of Physical Exercise	4.50	0.702	0.156
C32 Safety Knowledge of Sports	3.80	1.432	0.377
C33 Basic Theoretical Knowledge for Specialized Sports	4.05	0.849	0.210
C34 Knowledge of Specialized Sports Rules	4.40	1.293	0.294
C35 Knowledge of Sports Physiology	3.15	0.887	0.282
C36 Knowledge of Sports Training	3.60	0.994	0.276
C37 Knowledge of Sports Anatomy	2.80	1.061	0.379
C41 Willingness to Strive	4.45	1.245	0.280
C42 Obeying Rules	4.20	0.793	0.189
C43 Team Spirit	4.10	0.821	0.200
C44 Fair Competition	4.50	1.018	0.226
C45 Cooperation and Collaboration	4.25	1.121	0.264
C46 Scientific and Practical Attitude	2.70	1.742	0.645
C51 Teaching Demonstration Ability	4.95	0.223	0.045
C52 Teaching Design Ability	4.90	0.308	0.063
C53 Teaching Implementation Ability	5.00	0.000	0.000
C54 Teaching Evaluation Ability	4.70	1.211	0.258
C55 Teaching Organization Ability	4.80	0.476	0.099
C56 Teaching Innovation Ability	4.90	0.308	0.063
C57 Ability to Handle Emergencies	4.75	0.947	0.199
C61 Training Organization Ability	4.80	0.844	0.176
C62 Analytical and Judging Ability	4.15	1.597	0.385
C63 Effective Communication Ability	4.30	1.247	0.290
C64 Professional Learning Ability	4.35	0.977	0.225
C71 Competence in Competition Arrangement	3.45	1.598	0.463
C72 Competence in Competition Organization	2.85	1.763	0.619
C73 Competence in Competition Judging	3.45	1.769	0.513
C81 Ability to Identify Problems	4.50	0.968	0.215
C82 Ability to Analyze Problems	4.75	0.824	0.173

C83 Ability to Solve Problems	4.90	0.308	0.063
C91 Love for Sports	4.05	0.793	0.196
C92 Actively Participate in Sports Activities	4.50	0.793	0.176
C93 Sports Values	4.70	0.674	0.143
C101 Social Practice Ability	4.05	0.968	0.239
C102 Interpersonal Communication Ability	3.50	0.433	0.124
C103 Observing Discipline and Abiding by Laws	2.55	0.772	0.303

Based on the indicator screening criteria (mean $\geqslant$ 3 and coefficient of variation $\leqslant$ 0.25), the following five tertiary indicators should be removed: C37 Knowledge of Exercise Anatomy (X = 2.80 < 3, V = 0.379), as the knowledge requirements exceed the scope of students' core competencies, and experts deem its importance insufficient; C46 Scientific and Pragmatic Approach (X=2.70<3, V=0.645), with the lowest mean and highest coefficient of variation, raises doubts about the relevance of this indicator's definition to physical education instruction; C72 Competition Organization Skills (X=2.85<3, V=0.619), as a sub-item of competition management skills, has not been recognized by experts as applicable; C114 Law-abiding (X=2.55<3, V=0.303), a universal social competency, has weak specificity to physical education teaching scenarios.

Additionally, content optimization was conducted for sub-items that met the mean requirement but had controversial descriptions. C17 Balance Ability, with a coefficient of variation V=0.282, has blurred boundaries with “C16 Coordination Ability,” and the two were merged into “Coordination and Cooperation”; C32 Sports Safety Knowledge (X=3.80, V=0.377) was revised to “Equipment Safety Usage,” emphasizing practical application and reducing theoretical descriptions; C35 Sports Physiology Knowledge (V=0.282) was deemed too academically oriented and disconnected from students' cognitive levels, so it was revised to “Sports Physiology Basics”; C62 Analytical Judgment Ability, V=0.385, overlaps in function with the B9 group indicators (C91-C93), and has been integrated and revised to “Training Situation Immediate Decision-Making Ability”; C73 Competition Judging Ability has a coefficient of variation of 0.513, is overly specialized, and has a narrow scope of application, so it has been revised to “Basic Rule Recognition Ability.” Experts also suggested downgrading B7 Competition Management Ability to a sub-item of B6 Training Ability to avoid system redundancy.

Following expert review, the indicator system was modified and improved accordingly, merging two secondary indicators, removing four tertiary indicators, and renaming some indicators based on expert opinions. The revised indicator system retains 42 tertiary indicators. The first-round revised core literacy indicators for physical education students are shown in Table 3 below.

Table 3: The revised student core competence indicator system after the first round

Primary indicator	Secondary indicator	Third-level indicators
A1 Physical fitness	B1 Basic physical fitness	C11 Strength
		C12 Speed
		C13 Endurance
		C14 Agility
		C15 Flexibility
		C16 Coordination and Balance
	B2 Health Care Literacy	C21 Health Care Knowledge
		C22 Health Care Behavior
		C23 Knowledge of Health Sports Management
		C24 Actively Participate in Traditional Sports Exercises
A2 Sports Thought and Theory Knowledge	B3 Sports Theory Knowledge	C31 Sports Exercise Knowledge
		C32 Safe Use of Equipment
		C33 Special Basic Theory Knowledge
		C34 Special Sports Rules Knowledge
		C35 Sports Physiology Common Knowledge
		C36 Sports Training Knowledge
	B4 Sports Ideological Awareness	C41 Courage to Strive
		C42 Obey Rules
		C43 Collective Spirit
		C44 Fair Competition
		C45 Teamwork
A3 Practical Skills	B5 Teaching Ability	C51 Teaching Demonstration Ability
		C52 Teaching Design Ability
		C53 Teaching Implementation Ability
		C54 Teaching Evaluation Ability
		C55 Teaching Organization Ability

		C56 Teaching Innovation Ability
		C57 Handling Emergencies Ability
	B6 Training Capacity	C61 Training Organization Ability
		C62 Immediate Decision-making Ability in Training Situations
		C63 Effective Communication Ability
		C64 Professional Learning Ability
		C65 Competition Arrangement Ability
		C66 Basic Rule Recognition Ability
	B7 Problem-solving ability	C71 Ability to Identify Problems
		C72 Ability to Analyze Problems
		C73 Ability to Solve Problems
A4 Professional Competence	B8 Sports Emotions	C81 Love for Sports Career
		C82 Participate Actively in Sports Activities
		C83 Sports Values
	B9 Social Responsibility	C91 Social Practice Ability
		C92 Interpersonal Communication Ability

II. B. 3) Analysis and results of the second round of expert questionnaire survey

The statistical results for the second round of indicators are shown in Table 4.

Table 4: he statistical results of the second round of the three-level indicators

Indicators	X	S	V
C11 Strength	4.65	0.528	0.114
C12 Speed	4.85	0.064	0.013
C13 Endurance	4.70	0.423	0.090
C14 Agility	4.45	0.078	0.018
C15 Flexibility	4.65	0.590	0.127
C16 Coordination and Balance	4.75	0.492	0.104
C21 Health Care Knowledge	4.55	0.503	0.111
C22 Health Care Behavior	4.35	0.640	0.147
C23 Knowledge of Health Sports Management	4.15	0.324	0.078
C24 Actively Participate in Traditional Sports Exercises	4.25	0.381	0.090
C31 Sports Exercise Knowledge	4.35	0.581	0.134
C32 Safe Use of Equipment	4.10	0.369	0.090
C33 Special Basic Theory Knowledge	4.25	0.589	0.139
C34 Special Sports Rules Knowledge	4.35	0.490	0.113
C35 Sports Physiology Common Knowledge	4.35	0.079	0.018
C36 Sports Training Knowledge	4.10	0.331	0.081
C41 Courage to Strive	4.25	0.836	0.197
C42 Obey Rules	4.20	0.579	0.138
C43 Collective Spirit	4.35	0.157	0.036
C44 Fair Competition	4.50	0.605	0.134
C45 Teamwork	4.15	0.241	0.058
C51 Teaching Demonstration Ability	5.00	0.000	0.000
C52 Teaching Design Ability	4.90	0.581	0.119
C53 Teaching Implementation Ability	5.00	0.000	0.000
C54 Teaching Evaluation Ability	4.80	0.326	0.068
C55 Teaching Organization Ability	4.85	0.24	0.049
C56 Teaching Innovation Ability	4.90	0.043	0.009
C57 Handling Emergencies Ability	4.75	0.058	0.012
C61 Training Organization Ability	4.80	0.623	0.130
C62 Immediate Decision-making Ability in Training Situations	4.05	0.623	0.154
C63 Effective Communication Ability	4.15	0.387	0.093
C64 Professional Learning Ability	4.35	0.440	0.101

C65 Competition Arrangement Ability	3.85	0.855	0.216
C66 Basic Rule Recognition Ability	4.25	0.590	0.139
C71 Ability to Identify Problems	4.25	0.415	0.098
C72 Ability to Analyze Problems	4.75	0.395	0.083
C73 Ability to Solve Problems	5.00	0.659	0.132
C81 Love for Sports Career	4.25	0.220	0.052
C82 Participate Actively in Sports Activities	4.55	0.503	0.111
C83 Sports Values	4.70	0.383	0.081
C91 Social Practice Ability	4.05	0.422	0.104
C92 Interpersonal Communication Ability	3.95	0.802	0.220

Based on the analysis of data from the second round of expert questionnaires, the following modification suggestions are proposed for the core literacy indicator system for physical education students to further enhance the scientific and practical applicability of the indicators.

C65 Competition Organization Ability (X=3.85, V=0.216) is misaligned, with an average score below 4 points, and falls under the category of professional competition management, deviating from the core literacy objectives for students. It is recommended to directly delete this indicator and retain C66 “Basic Rule Recognition Ability” as a universal requirement. C92 Interpersonal Communication Ability (X=3.95, V=0.220) has an excessively high coefficient of variation (V>0.2), with significant expert disagreement. It is recommended to adjust it to “Team Collaboration and Social Adaptation,” clearly defining its specific manifestations in physical education activities.

Following the second round of expert surveys, the indicator system was modified and improved accordingly. All four first-level indicators were retained, with 0 second-level indicators and 1 third-level indicator deleted. The indicators temporarily retained in the first round of expert surveys also achieved consensus in the second round, and thus were all retained.

II. B. 4) Analysis and results of the third round of expert questionnaire survey

The statistical results of the third round of indicators are shown in Table 5.

Table 5: he statistical results of the third round of the three-level indicators

Indicators	X	S	V
C11 Strength	4.65	0.528	0.114
C12 Speed	4.85	0.064	0.013
C13 Endurance	4.70	0.423	0.090
C14 Agility	4.45	0.078	0.018
C15 Flexibility	4.65	0.590	0.127
C16 Coordination and Balance	4.75	0.492	0.104
C21 Health Care Knowledge	4.55	0.503	0.111
C22 Health Care Behavior	4.35	0.640	0.147
C23 Knowledge of Health Sports Management	4.15	0.324	0.078
C24 Actively Participate in Traditional Sports Exercises	4.25	0.381	0.090
C31 Sports Exercise Knowledge	4.35	0.581	0.134
C32 Safe Use of Equipment	4.10	0.369	0.090
C33 Special Basic Theory Knowledge	4.25	0.589	0.139
C34 Special Sports Rules Knowledge	4.35	0.490	0.113
C35 Sports Physiology Common Knowledge	4.35	0.079	0.018
C36 Sports Training Knowledge	4.10	0.331	0.081
C41 Courage to Strive	4.25	0.836	0.197
C42 Obeying Rules	4.20	0.579	0.138
C43 Collective Spirit	4.35	0.157	0.036
C44 Fair Competition	4.50	0.605	0.134
C45 Teamwork and Collaboration	4.15	0.241	0.058
C51 Teaching Demonstration Ability	5.00	0.000	0.000
C52 Teaching Design Ability	4.90	0.581	0.119
C53 Teaching Implementation Ability	5.00	0.000	0.000
C54 Teaching Evaluation Ability	4.80	0.326	0.068
C55 Teaching Organization Ability	4.85	0.24	0.049
C56 Teaching Innovation Ability	4.90	0.043	0.009

C57 Handling Emergencies Ability	4.75	0.058	0.012
C61 Training Organization Ability	4.80	0.623	0.130
C62 Immediate Decision-making Ability in Training Situations	4.05	0.623	0.154
C63 Effective Communication Ability	4.15	0.387	0.093
C64 Professional Learning Ability	4.35	0.440	0.101
C65 Basic Rule Recognition Ability	4.25	0.590	0.139
C71 Ability to Identify Problems	4.25	0.415	0.098
C72 Ability to Analyze Problems	4.75	0.395	0.083
C73 Ability to Solve Problems	5.00	0.659	0.132
C81 Love for Sports	4.25	0.220	0.052
C82 Participate Actively in Sports Activities	4.55	0.503	0.111
C83 Sports Values	4.70	0.383	0.081
C91 Social Practice Ability	4.05	0.422	0.104
C92 Teamwork and Social Adaptation	4.25	0.532	0.125

According to the statistical results shown in Table 5, in the third round of expert surveys, the average scores for all 47 tertiary indicators of core competencies in physical education teaching exceeded 4 points, with a coefficient of variation below 0.2, fully meeting the index selection criteria and receiving unanimous approval from experts and scholars.

After three rounds of expert questionnaire surveys, under the guidance of experts, we conducted an in-depth study on the evaluation indicators for core competencies in physical education, deleted indicators that did not meet the standards, and made appropriate modifications to indicators with insufficient expression. Finally, we established a complete evaluation indicator system comprising 4 first-level indicators, 10 second-level indicators, and 41 third-level indicators. The final indicator system for core competencies in physical education is shown in Table 6.

Table 6: The final core literacy indicator system for students in physical education

Primary indicator	Secondary indicator	Third-level indicators
A1 Physical fitness	B1 Basic physical fitness	C11 Strength
		C12 Speed
		C13 Endurance
		C14 Agility
		C15 Flexibility
		C16 Coordination and Balance
	B2 Health Care Literacy	C21 Health Care Knowledge
		C22 Health Care Behavior
		C23 Knowledge of Health Sports Management
		C24 Actively Participate in Traditional Sports Exercises
A2 Sports Thought and Theory Knowledge	B3 Sports Theory Knowledge	C31 Sports Exercise Knowledge
		C32 Safe Use of Equipment
		C33 Special Basic Theory Knowledge
		C34 Special Sports Rules Knowledge
		C35 Sports Physiology Common Knowledge
		C36 Sports Training Knowledge
	B4 Sports Ideological Awareness	C41 Courage to Strive
		C42 Obeying Rules
		C43 Collective Spirit
		C44 Fair Competition
		C45 Teamwork and Collaboration
A3 Practical Skills	B5 Teaching Ability	C51 Teaching Demonstration Ability
		C52 Teaching Design Ability
		C53 Teaching Implementation Ability
		C54 Teaching Evaluation Ability
		C55 Teaching Organization Ability
		C56 Teaching Innovation Ability
		C57 Handling Emergencies Ability

	B6 Training Capacity	C61 Training Organization Ability
		C62 Immediate Decision-making Ability in Training Situations
		C63 Effective Communication Ability
		C64 Professional Learning Ability
		C65 Basic Rule Recognition Ability
	B7 Problem-solving ability	C71 Ability to Identify Problems
		C72 Ability to Analyze Problems
		C73 Ability to Solve Problems
A4 Professional Competence	B8 Sports Emotions	C81 Love for Sports
		C82 Participate Actively in Sports Activities
		C83 Sports Values
	B9 Social Responsibility	C91 Social Practice Ability
		C92 Teamwork and Social Adaptation

III. Empirical research on students' core physical education literacy based on a combined evaluation model

The three-tiered indicator system comprising 41 items, refined through three rounds of the Delphi method, provides a scientific basis for the quantitative evaluation of core physical education competencies. Building on this foundation, Chapter 3 will integrate the entropy weight method, TOPSIS, and the grey priority model to conduct empirical applications and effectiveness validation of this system.

III. A. Steps for evaluating students' physical literacy based on the entropy weight-TOPSIS method

III. A. 1) Determining weights using the entropy weight method

First, use the entropy weight method to determine the weights. The specific steps are as follows:

1) Form the initial decision matrix A. Based on the relevant evaluation object data information, m indicators are set to evaluate the superiority of n objects. Among them, the value of the j th indicator for the i th object is denoted as $X_{ij}\left(i=1,2,\ldots,n; j=1,2,\ldots,m\right)$ Based on these indicator values, the initial decision matrix A is constructed. The greater the difference in indicator values among different objects in this matrix, the richer the information carried and transmitted by the indicator, and thus the greater its role in the competency evaluation process.

$$A=\begin{bmatrix} X_{11} & \cdots & X_{1m} \\ \vdots & \ddots & \vdots \\ X_{n1} & \cdots & X_{nm} \end{bmatrix} \tag{1}$$

(2) Dimensionless processing of data to obtain the standardized matrix B. In order to eliminate the problem of data being unable to be directly compared due to differences in the dimensions of different indicators, the original data needs to be processed to be dimensionless, thereby obtaining the standardized matrix B. This processing converts the original data into standardized data, represented by Y_{ij}. After standardization, all indicator values fall within the interval $[0,1]$, and larger values are better.

$$B=\begin{bmatrix} Y_{11} & \cdots & Y_{1m} \\ \vdots & \ddots & \vdots \\ Y_{n1} & \cdots & Y_{nm} \end{bmatrix} \tag{2}$$

Based on their different characteristics, indicators are classified into three types: positive indicators, negative indicators, and moderate indicators. Among them, positive indicators are those where a higher index value indicates better performance, while negative indicators are those where a lower index value indicates better performance. Moderate indicators are those that perform well within a certain range.

The dimensionless formula for positive indicators is:

$$X_{ij}=\frac{X_{ij}-\min\left(X_{1j},X_{2j},\ldots,X_{nj}\right)}{\max\left(X_{1j},X_{2j},\ldots,X_{nj}\right)-\min\left(X_{1j},X_{2j},\ldots,X_{nj}\right)} \tag{3}$$
$$\left(i=1,2,\ldots,n; j=1,2,\ldots,m\right)$$

The dimensionless formula for negative indicators is:

$$X_{ij}=\frac{\max\left(X_{1j},X_{2j},\ldots,X_{nj}\right)-X_{ij}}{\max\left(X_{1j},X_{2j},\ldots,X_{nj}\right)-\min\left(X_{1j},X_{2j},\ldots,X_{nj}\right)}\quad\left(i=1,2,\ldots,n;j=1,2,\ldots,m\right) \tag{4}$$

The dimensionless formula for the moderate indicator is:

$$X_{ij}=1-\frac{\left|X_{ij}-d_{best}\right|}{\max\left|X_{1j}-d_{best}\right|}\left(d_{best}\ is\ the\ \det er\min ed\ s\tan dard\ value\right) \tag{5}$$

(3) Data shift. Since the entropy weight method requires taking the logarithm of the indicator values, the presence of values equal to 0 in the data will prevent logarithmic calculations from being performed. Therefore, to avoid this problem, all data must be shifted by 1 unit, so that the original data Y_{ij} becomes the new data Z_{ij} after shifting. The calculation formula is:

$$Z_{ij}=Y_{ij}+1 \tag{6}$$

(4) Calculate the weight of the evaluation indicators. It is necessary to determine the weight of the indicator value j of each evaluation object in the total sum of the indicator. Let p_{ij} be the weight of the j th indicator value of the i th evaluation object in the total sum of the indicator. The calculation formula is:

$$p_{ij}=\frac{z_{ij}}{\sum_{i=1}^{n}z_{ij}} \tag{7}$$

(5) Calculate the entropy value of each indicator. Based on the principle of information entropy, calculate the entropy value E_j for each indicator value j. The entropy value reflects the utility value of the information provided by the indicator. Specifically, when the entropy value of an indicator is small, it indicates that the information conveyed by the indicator in the competency evaluation is more effective and rich, and it makes a significant contribution to the company's competency performance. Conversely, a large entropy value means that the information value of the indicator in the evaluation is relatively low. The calculation formula is:

$$E_j=-\frac{1}{\ln n}\sum_{i=1}^{n}p_{ij}\ln p_{ij} \tag{8}$$

(6) Calculate the difference coefficient. Let G_j be the difference coefficient of indicator value j. The difference coefficient reflects the degree of dispersion of indicator values among different objects. When the difference in indicator values for the j th indicator is greater, it indicates that the indicator plays a greater role in the evaluation of objects. The calculation formula is:

$$G_j=1-E_j \tag{9}$$

(7) Calculate the entropy weight of the indicators. Let W_j be the entropy weight of indicator j. The entropy weight is calculated based on the coefficient of variation of the indicator values, reflecting the weight or influence of the indicator in the comprehensive evaluation. The larger the entropy weight, the more important the indicator is in the evaluation, and the greater its ability to influence the quality of the company. The calculation formula is:

$$W_j=\frac{G_j}{\sum_{j=1}^{m}G_j} \tag{10}$$

III. A. 2) Calculation of comprehensive evaluation value using the TOPSIS method

The above calculations were performed using the entropy weight method to assign weights to each indicator. Next, the TOPSIS method was used to calculate the comprehensive evaluation values of different students' core competencies in physical education.

(1) Weight the normalized matrix Z_{ij} to obtain the weighted normalized matrix R. Each element R_{ij} of the weighted normalized matrix R represents the weighted score of the i th evaluation object on the j th indicator. The calculation formula is:

$$R_{ij}=W_j\times Z_{ij} \tag{11}$$

(2) Determine the positive ideal solution R^{+} and negative ideal solution R^{-}. The optimal and suboptimal vectors formed by the maximum and minimum values of each column in the matrix are the positive ideal solution and negative ideal solution, respectively. The calculation formula is:

$$\begin{aligned}R^{+}&=\left(\max R_{i1},\max R_{i2},\ldots,\max R_{im}\right)\left(i=1,2,\ldots,n\right)\\R^{-}&=\left(\min R_{i1},\min R_{i2},\ldots,\min R_{im}\right)\left(i=1,2,\ldots,n\right)\end{aligned} \tag{12}$$

(3) Calculate the Euclidean space distance between each evaluation object and the positive ideal solution and negative ideal solution. The calculation formula is:

$$d_i^+ = \sqrt{\sum_{j=1}^{m}\left(R_{ij} - R_j^+\right)^2}\ (i = 1,2,\ldots,n)$$
$$d_i^- = \sqrt{\sum_{j=1}^{m}\left(R_{ij} - R_j^-\right)^2}\ (i = 1,2,\ldots,n) \quad (13)$$

(4) Calculate the comprehensive evaluation value of each object. Let the relative proximity of each research object to the ideal solution be S_i. Sort the evaluation objects according to the magnitude of their relative proximity; the greater the relative proximity, the better the quality of the evaluation object, and the higher its ranking. The formula for calculating relative proximity is:

$$S_i = \frac{d_i^-}{d_i^- + d_i^+}(i = 1,2,\ldots,n) \quad (14)$$

III. B. Evaluation case analysis based on the gray order preference method (OPA-G)

III. B. 1) Brief description of the OPA-G evaluation model

Introducing GST into OPA can address the shortcomings of OPA in handling uncertainty issues. The OPA-G evaluation model, which combines OPA and GST, can convert experts' uncertainty rankings of evaluation indicators and evaluation objects into interval rankings, ultimately determining the rankings of evaluation indicators and evaluation objects.

Due to the characteristic differences in students' core competencies in physical education, experts place different emphases during the evaluation process. The evaluation indicator system for students' core competencies in physical education has already been established in the preceding text. Now, experts need to rank the evaluation indicators within the evaluation indicator system.

Three authoritative experts in the field of physical education were invited, referred to as E1, E2, and E3, with gray rankings of [0.5,1.5], [1.5,2.5], and [2.5,3.5], respectively. Expert E1 has the highest ranking, followed by E2, with E3 at the bottom. The experts' rankings are then input into the OPA-G model to calculate their gray weights, laying the foundation for subsequent evaluations.

III. B. 2) Expert ranking of indicators

Based on the opinions of three experts, the ranking of evaluation indicators for core competencies in physical education is shown in Table 7.

Table 7: The ranking of indicators for students' core competencies by experts

Primary indicator	Secondary indicator	Third-level indicators	E1	E2	E3
A1	B1	C11	14/15	11	17
		C12	5/6	5	6
		C13	13	15	15
		C14	19/20	20	18
		C15	16	14	12
		C16	10	12	10
	B2	C21	17	18	23
		C22	21	24	19
		C23	34/35	31	37
		C24	27	28	25
A2	B3	C31	22	22/23	21
		C32	38	37	35
		C33	28	32	29
		C34	23	29	22
		C35	24	21	33
		C36	39	39/40	40
	B4	C41	29	36	27
		C42	34/35	30	28
		C43	25	25	32
		C44	19/20	19	20
		C45	36/37	39/40	38

A3	B5	C51	1	2	9
		C52	4	6	4
		C53	2	1	7
		C54	8/9	9	8
		C55	7	8	3
		C56	5/6	4	2
		C57	11	7	11
	B6	C61	8/9	10	13
		C62	40	38	36
		C63	36/37	33	41
		C64	26	22/23	24
		C65	30	27	30
	B7	C71	31/32	26	26
		C72	12	13	5
		C73	3	3	1
A4	B8	C81	31/32	35	34
		C82	18	17	16
		C83	14/15	16	14
	B9	C91	41	41	39
		C92	33	34	31

As shown in Table 7, for expert-determined rankings, such as Expert 1 ranking C13 as 13th, the gray ranking interval for E1 and C13 in Table 8 is [12.5, 13.5], with an interval length of 1. However, E1 is uncertain about the rankings of C11 and C83, unsure whether to rank C11 as 14th or 15th, and similarly uncertain about ranking C83 as 14th or 15th. This uncertainty is represented as 14/15 in the rankings. The gray ranking intervals for C11 and C83 are [13.5, 15.5], with an interval length of 2. According to gray system theory, experts are allowed to be uncertain about certain indicators during the decision-making process. For uncertain evaluation indicators, experts are allowed to assign more than one ranking to the evaluation indicators.

The experts' gray evaluation indicator rankings for students' core competencies in physical education are shown in Table 8.

Table 8: The ranking of grey evaluation indicators for students' core competencies

	E1	E2	E3
C11	[13.5,15.5]	[10.5,11.5]	[16.5,17.5]
C12	[4.5,6.5]	[4.5,5.5]	[5.5,6.5]
C13	[12.5,13.5]	[14.5,15.5]	[14.5,15.5]
C14	[18.5,20.5]	[19.5,20.5]	[17.5,18.5]
C15	[15.5,16.5]	[13.5,14.5]	[11.5,12.5]
C16	[9.5,10.5]	[11.5,12.5]	[9.5,10.5]
C21	[16.5,17.5]	[17.5,18.5]	[22.5,23.5]
C22	[20.5,21.5]	[23.5,24.5]	[18.5,19.5]
C23	[33.5,35.5]	[30.5,31.5]	[36.5,37.5]
C24	[26.5,27.5]	[27.5,28.5]	[24.5,25.5]
C31	[21.5,22.5]	[21.5,23.5]	[20.5,21.5]
C32	[37.5,38.5]	[36.5,37.5]	[34.5,35.5]
C33	[27.5,28.5]	[31.5,32.5]	[28.5,29.5]
C34	[22.5,23.5]	[28.5,29.5]	[21.5,22.5]
C35	[23.5,24.5]	[20.5,21.5]	[32.5,33.5]
C36	[38.5,39.5]	[38.5,40.5]	[39.5,40.5]
C41	[28.5,29.5]	[35.5,36.5]	[26.5,27.5]
C42	[33.5,35.5]	[29.5,30.5]	[27.5,28.5]
C43	[24.5,25.5]	[24.5,25.5]	[31.5,32.5]
C44	[18.5,20.5]	[18.5,19.5]	[19.5,20.5]
C45	[35.5,37.5]	[38.5,40.5]	[37.5,38.5]

C51	[0.5,1.5]	[1.5,2.5]	[8.5,9.5]
C52	[3.5,4.5]	[5.5,6.5]	[3.5,4.5]
C53	[1.5,2.5]	[0.5,1.5]	[6.5,7.5]
C54	[7.5,9.5]	[8.5,9.5]	[7.5,8.5]
C55	[6.5,7.5]	[7.5,8.5]	[2.5,3.5]
C56	[4.5,6.5]	[3.5,4.5]	[1.5,2.5]
C57	[10.5,11.5]	[6.5,7.5]	[10.5,11.5]
C61	[7.5,9.5]	[9.5,10.5]	[12.5,13.5]
C62	[39.5,40.5]	[37.5,38.5]	[35.5,36.5]
C63	[35.5,37.5]	[32.5,33.5]	[40.5,41.5]
C64	[25.5,26.5]	[21.5,23.5]	[23.5,24.5]
C65	[29.5,30.5]	[26.5,27.5]	[29.5,30.5]
C71	[30.5,32.5]	[25.5,26.5]	[25.5,26.5]
C72	[11.5,12.5]	[12.5,13.5]	[4.5,5.5]
C73	[2.5,3.5]	[2.5,3.5]	[0.5,1.5]
C81	[30.5,32.5]	[34.5,35.5]	[33.5,34.5]
C82	[17.5,18.5]	[16.5,17.5]	[15.5,16.5]
C83	[13.5,15.5]	[15.5,16.5]	[13.5,14.5]
C91	[40.5,41.5]	[40.5,41.5]	[38.5,39.5]
C92	[32.5,33.5]	[33.5,34.5]	[30.5,31.5]

Experts showed significant disagreement on certain indicators, such as Expert 1's uncertainty regarding the rankings of C11 Strength, C14 Sensitivity, and C44 Fair Competition, reflecting their boundary attributes or cognitive ambiguity. Indicators with high consensus were concentrated on core competencies, such as C51 (Teaching Demonstration Ability), which was ranked among the top 2 by both Expert 1 and Expert 3, highlighting the importance of teaching practice. Among them, B5 teaching ability-related indicators, such as C51 and C53, are generally ranked higher, highlighting their core status in competency evaluation. B9 social responsibility indicators, such as C91 and C92, and B3 professional theory indicators, such as C36, are mostly at the bottom, with rankings above 30, reflecting their relative secondary importance.

There are differences in emphasis among experts, but the overall trends are consistent. Expert E1 places greater emphasis on basic physical fitness, such as C12 speed, which ranks 5th-6th, while E3 focuses more on problem-solving. Interestingly, C62 training decision-making ability is consistently ranked as the lowest priority, with a ranking interval >35, possibly due to its weak practicality or low relevance to student competencies.

The gray ranking intervals effectively quantify the uncertainty in expert decision-making, providing structured input for subsequent TOPSIS model weight calculations and supporting a more robust comprehensive evaluation of competencies.

III. B. 3) Case Study

The study focused on two classes of students majoring in physical education at a certain university in the class of 2024. Both Class A and Class B had 46 students. A comprehensive analysis of the two classes was conducted, and three experts ranked the core competencies of students in physical education teaching in the two classes according to the evaluation criteria, as shown in Table 9.

Table 9: The experts' ranking of the students' core competencies in two classes

Level	Indicators	E1		E2		E3	
		Class A	Class B	Class A	Class B	Class A	Class B
B1 Basic physical fitness	C11	1	2	2	1	1	2
	C12	1	2	1	2	1	2
	C13	2	1	1	2	1	2
	C14	2	1	2	1	2	1
	C15	1	2	1	2	2	1
	C16	1	2	1	2	2	1
B2 Health Care Literacy	C21	1	2	2	1	1	2
	C22	1	2	1	2	1	2
	C23	1	2	1	2	2	1

	C24	2	1	1	2	2	1
B3 Sports Theory Knowledge	C31	2	1	2	1	1	2
	C32	2	1	2	1	2	1
	C33	2	1	1	2	2	1
	C34	1	2	2	1	1	2
	C35	1	2	2	1	1	2
	C36	1	2	1	2	2	1
B4 Sports Ideological Awareness	C41	1	2	1	2	2	1
	C42	1	2	1	2	1	2
	C43	1	2	1	2	1	2
	C44	1	2	2	1	1	2
	C45	1	2	2	1	1	2
B5 Teaching Ability	C51	2	1	2	1	2	1
	C52	2	1	2	1	2	1
	C53	2	1	1	2	1	2
	C54	2	1	1	2	2	1
	C55	2	1	1	2	2	1
	C56	1	2	1	2	2	1
	C57	1	2	2	1	1	2
B6 Training Capacity	C61	1	2	2	1	1	2
	C62	1	2	2	1	1	2
	C63	1	2	1	2	1	2
	C64	1	2	2	1	2	1
	C65	2	1	2	1	2	1
B7 Problem-solving ability	C71	2	1	1	2	2	1
	C72	2	1	1	2	1	2
	C73	1	2	2	1	2	1
B8 Sports Emotions	C81	1	2	2	1	1	2
	C82	1	2	1	2	1	2
	C83	1	2	2	1	2	1
B9 Social Responsibility	C91	2	1	2	2	2	1
	C92	2	1	1	2	2	1

Overall, there were significant differences in performance between the two classes. Class A demonstrated superior performance in dimensions such as basic physical fitness (B1), health and wellness literacy (B2), and sports ideology and awareness (B4), with many indicators (e.g., C11-C16, C41-C45) ranked first. Class B received higher recognition from experts in certain indicators related to sports theory knowledge (B3) and teaching ability (B5), such as C51-C53.

The three experts demonstrated both consensus and divergence in their evaluations. Consensus indicators, such as C12 (speed), were unanimously agreed upon by all three experts as being stronger in Class A than in Class B; however, Class B was deemed superior in C92 (teamwork and social adaptation). Divergent indicators, such as C53 (teaching implementation ability), showed discrepancies in class rankings, with E1 and E2 supporting Class B and E3 supporting Class A, reflecting the subjectivity of teaching practice evaluations.

III. C. Evaluation and Analysis of Core Competencies in Physical Education Teaching

Continue to conduct research on the core competencies of secondary school physical education teachers among the 92 students majoring in physical education at this university in the class of 2024. Distribute questionnaires related to core competencies to the 92 students.

III. C. 1) Obtaining weights using the entropy weight method

Using SPSS Pro software, entropy weighting was applied to calculate the scores for each indicator in the 92 questionnaires, yielding the weights for the student core literacy indicator system as shown in Table 10.

Table 10: The weight of the student core literacy indicator system

Primary	Weight	Secondary	Weight	Third-level	Information entropy	Information utility	Weight
A1	0.2523	B1	0.1741	C11	0.946	0.053	0.0271
				C12	0.933	0.069	0.0337
				C13	0.946	0.053	0.0285
				C14	0.948	0.051	0.0255
				C15	0.944	0.059	0.0285
				C16	0.941	0.064	0.0308
		B2	0.0782	C21	0.946	0.055	0.0261
				C22	0.959	0.044	0.0198
				C23	0.968	0.032	0.0149
				C24	0.964	0.039	0.0174
A2	0.2029	B3	0.1028	C31	0.957	0.048	0.0210
				C32	0.969	0.032	0.0097
				C33	0.963	0.040	0.0179
				C34	0.955	0.049	0.0217
				C35	0.954	0.049	0.0217
				C36	0.968	0.033	0.0108
		B4	0.1001	C41	0.962	0.042	0.0181
				C42	0.964	0.039	0.0169
				C43	0.954	0.050	0.0243
				C44	0.948	0.051	0.0256
				C45	0.965	0.038	0.0152
A3	0.4400	B5	0.2490	C51	0.927	0.077	0.0386
				C52	0.933	0.073	0.0335
				C53	0.926	0.077	0.0398
				C54	0.931	0.073	0.0341
				C55	0.928	0.073	0.0353
				C56	0.928	0.075	0.0366
				C57	0.940	0.067	0.0311
		B6	0.0986	C61	0.939	0.067	0.0311
				C62	0.975	0.029	0.0084
				C63	0.965	0.038	0.0161
				C64	0.949	0.050	0.0249
				C65	0.962	0.042	0.0181
		B7	0.0924	C71	0.960	0.044	0.0188
				C72	0.939	0.068	0.0317
				C73	0.923	0.078	0.0419
A4	0.1048	B8	0.0759	C81	0.959	0.045	0.0197
				C82	0.946	0.058	0.0266
				C83	0.942	0.063	0.0296
		B9	0.0289	C91	0.970	0.030	0.0091
				C92	0.958	0.048	0.0198

The weighting results calculated using the entropy weight method reveal the importance of each indicator. Among the first-level indicators, A3 Practical Ability has the highest weighting at 0.4400, highlighting the central role of teaching, training, and problem-solving abilities in competency evaluation. A1 Physical Ability follows with a weighting of 25.23%, while A4 Professional Competency has the lowest weighting at 0.1048%.

Among the third-level indicators, those with high weights include C53 Teaching Implementation Ability (3.98%), C73 Problem-Solving Ability (4.19%), and C51 Teaching Demonstration Ability (3.86%), among others, with practical-oriented indicators standing out. Low-weight indicators include C32 Equipment Safety Usage (0.97%), C62 Training Decision-Making Ability (0.84%), and C91 Social Practice Ability (0.91%), which are theoretical or peripheral abilities with relatively low weights.

The weighting results obtained are consistent with the conclusions of the Delphi method, validating experts' emphasis on practical abilities.

III. C. 2) Evaluation and Analysis of Core Competencies in Physical Education Based on the TOPSIS Method

Calculate the average value of the core competencies in physical education for 92 students and establish an initial matrix; substitute the weight values calculated using the entropy weight method to establish a weighted matrix; identify the positive ideal solution and negative ideal solution under the same indicator; calculate the distance S+ to the positive ideal solution and the distance S− to the negative ideal solution (Euclidean distance) for different students; combine the distance values to calculate the relative proximity value E and rank them.

The optimal and suboptimal solutions for the weighted scores of core competencies in physical education teaching are shown in Table 11.

Table 11: The optimal solution and the worst solution of students' core literacy

Indicators	Weight	Optimal solution R+	Worst solution R-
C11	2.71%	0.0677	0.0313
C12	3.37%	0.0786	0.0480
C13	2.85%	0.0819	0.0384
C14	2.55%	0.0662	0.0349
C15	2.85%	0.0818	0.0495
C16	3.08%	0.085	0.0457
C21	2.61%	0.0656	0.0332
C22	1.98%	0.0773	0.0415
C23	1.49%	0.0794	0.0419
C24	1.74%	0.0732	0.0399
C31	2.10%	0.0781	0.0476
C32	0.97%	0.0911	0.0515
C33	1.79%	0.0807	0.0422
C34	2.17%	0.0904	0.0529
C35	2.17%	0.0659	0.0344
C36	1.08%	0.0738	0.0424
C41	1.81%	0.0938	0.0595
C42	1.69%	0.0675	0.0353
C43	2.43%	0.0807	0.0480
C44	2.56%	0.081	0.0420
C45	1.52%	0.0712	0.0316
C51	3.86%	0.0888	0.0481
C52	3.35%	0.0704	0.0325
C53	3.98%	0.0843	0.0532
C54	3.41%	0.0698	0.0307
C55	3.53%	0.0804	0.0453
C56	3.66%	0.0642	0.0258
C57	3.11%	0.0691	0.0322
C61	3.11%	0.0613	0.0279
C62	0.84%	0.0834	0.0475
C63	1.61%	0.0779	0.0449
C64	2.49%	0.0671	0.037
C65	1.81%	0.0742	0.0377
C71	1.88%	0.086	0.0502
C72	3.17%	0.0606	0.0274
C73	4.19%	0.0622	0.0311
C81	1.97%	0.0768	0.0371
C82	2.66%	0.0801	0.0493
C83	2.96%	0.0935	0.0584
C91	0.91%	0.0678	0.0295
C92	1.98%	0.0645	0.0303

Calculate the distance between the core competency scores of different students in physical education and the optimal solution, as well as the distance between the core competency scores and the worst solution. Calculate the relative proximity and rank the results, as shown in Table 12.

Table 12: The TOPSIS method ranking result of students' core literacy

Student	D+	D-	S	Order
Student30	0	0.0812	1	1
Student17	0.0133	0.0779	0.0751	2
Student7	0.0163	0.0729	0.0702	3
Student72	0.0189	0.0655	0.0682	4
Student91	0.0221	0.0627	0.0628	5
Student68	0.0252	0.0571	0.0566	6
Student1	0.0256	0.0549	0.0505	7
…	…	…	…	…
Student22	0.0713	0.0106	0.0112	88
Student37	0.0725	0.0084	0.0108	89
Student74	0.0731	0.0062	0.0098	90
Student29	0.0751	0.0049	0.0068	91
Student46	0.0788	0.0027	0.0026	92

The distance from the ideal solution D for the top 5 students is significantly higher than that of other students (0.0779–0.0812), reflecting their comprehensive advantage. The bottom 5 students had extremely high distances from the positive ideal solution D+ (0.0713–0.0788), exposing multidimensional shortcomings. Meanwhile, the relative proximity S of the top 10% of students was >0.0628, with a significant gap compared to the bottom 10% (S<0.0112), indicating uneven development of literacy. The S values of mid-range students are densely distributed, indicating intense competition. Among them, Student 30 (1st place) has D+ = 0, with all indicators reaching the optimal solution, serving as an ideal competency benchmark. Student 46 (92nd place) has D- = 0, requiring targeted intervention.

IV. Pathways for cultivating core competencies in college students through physical education

Based on the empirical research on students' core physical education literacy mentioned above, this paper proposes a training approach centered on practical skills, optimizing teaching objectives and content, and strengthening situational training, providing a theoretical basis and practical reference for improving the core literacy of physical education majors.

IV. A. Set clear teaching objectives

Based on the indicator system for core competencies in physical education established in this paper, a three-dimensional goal system is constructed. Skill-based goals focus on high-weight indicators such as C53 teaching implementation ability and C73 problem-solving ability, with foundational skills and rule comprehension further refined for different specialties. Emotional goals emphasize B4 sports ideology indicators such as C45 teamwork and C41 courage to strive, cultivating students' stress resilience and sportsmanship through competitive scenario design. Social objectives are linked to the B9 social responsibility indicator and C92 team collaboration and social adaptation, incorporating tasks such as leadership training and conflict mediation. Objective formulation must incorporate entropy weighting to ensure the central role of A3 practical ability and A1 athletic ability.

IV. B. Optimizing teaching content

Redesign the three-tiered curriculum structure of “foundation-skills-competencies.”

The foundation layer focuses on strengthening B1 basic physical fitness and B3 sports theory knowledge, utilizing micro-courses and safety simulations to build a solid foundation.

The competency layer focuses on high-priority practical skills, designing teaching scenarios such as C57 emergency response and C61 training organization capabilities.

Integrate literacy into traditional sports (C24) and team competitions, deepen B4 sports awareness, such as C44 fair competition and B9 social responsibility. Content design should refer to expert consensus indicators to enhance fun and challenge.

IV. C. Strengthening practical teaching components

Apply the Entropy Weight-TOPSIS model to regularly calculate students' proficiency levels, identify weaknesses, such as the D^+ value deficiency of the lowest-performing students. At the same time, increase contextualized training, such as simulating the basic rules of sports refereeing (C65); expand extracurricular competitions and community sports services (C91 social practice skills). Develop a digital training platform. Combine the gray evaluation mechanism of the OPA-G model to adjust teaching strategies for controversial indicators.

V. Conclusion

This study utilized the Delphi method to construct a higher education physical education core literacy framework comprising 4 primary indicators, 10 secondary indicators, and 41 tertiary indicators. The Entropy Weight-TOPSIS-OPA-G model was then applied to conduct an empirical evaluation of 92 physical education teacher trainees.

During the three rounds of revisions in the Delphi method, six redundant indicators were removed, such as C37 Knowledge of Sports Anatomy, which had an average score of only 2.80 in the first round. Two fuzzy indicators (C16 Coordination and Balance) were merged, and the final 41 retained indicators all met the criteria of an average score $\geqslant$4.0 and a coefficient of variation $\leqslant$0.20, with expert consensus reaching 100%.

The entropy weight method weight allocation showed that A3 Practical Ability (44.00%) > A1 Physical Ability (25.23%) > A2 Physical Education Philosophy (20.29%) > A4 Professional Ethics (10.48%), Among these, C73 Problem-Solving Ability (4.19%) and C53 Teaching Implementation Ability (3.98%) ranked first and second in terms of sub-indicator weights, confirming the central role of practical ability in competency development.

TOPSIS evaluation results show that the top 10% of students (e.g., Student30) have a relative proximity S $\geqslant$ 0.0628, with their distance from the negative ideal solution D^- (0.0779–0.0812) significantly higher than that of the bottom 10% of students ($D^- \leqslant$ 0.0106); the last-ranked student (Student46) has a D^+ value of 0.0788, exposing their weaknesses in high-weighting indicators such as C53 teaching implementation and C73 problem-solving.

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