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Research on the Evaluation of College Students' Information Literacy Under the Background of Sustainable Development: A Case Study of Yancheng Institute of Technology

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Abstract

In the era of digital intelligence, information literacy (IL) competency has become a critical indicator for measuring the comprehensive quality and sustainable development potential of university's education. Using Yancheng Institute of Technology as a case study, this study systematically elucidates the connotation and current development status of college students' IL within the framework of sustainable development. An evaluation index system is constructed, comprising four dimensions: information awareness and attitude, information ethics, law and security, information knowledge and skills, and information integration and innovation. The study employs the Analytic Hierarchy Process (AHP) to determine the weights of indicators at various levels and integrates the Fuzzy Comprehensive Evaluation Method (FCEM) to establish a quantitative assessment model for IL competency. Empirical research demonstrates that the proposed model effectively enables a multidimensional and quantitative evaluation of students' IL, with results that exhibit sound scientific validity and applicability. Based on the analysis, specific strategies are proposed to enhance students' IL from the perspectives of curriculum design, teaching models, and library services, thereby providing theoretical references and practical pathways for advancing informatization and sustainable development in higher education.

Keywords: sustainable development; college students; IL; AHP; FCEM; evaluation system

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1. Introduction

In 2019, International Federation of Library Associations and Institutions (IFLA) released the 2019 Development and Access to Information Report [1] against the backdrop of the United Nations 2030 Agenda for Sustainable Development (hereinafter referred to as the Development Agenda). The report focused on the 17 goals of the Development Agenda and pointed out the importance of information access in the new era, and the skills people need to master in using information, targeting the different effects of each dimension of information access. It also proposed that libraries will play a big role in achieving these goals in the future [2], especially in information literacy (IL) education.

Today, the world is in a new era of digitalization and intelligence driven by data analytics. The widespread application of advanced technologies, such as big data, artificial intelligence, and the Internet of Things, has not only revolutionized society's production and lifestyles but has also had a profound impact on education. As core institutions for cultivating high-level professionals, universities shoulder the important mission of providing

exceptional talent across all sectors of society. Against this backdrop, IL is considered a key competency for university students to adapt to the development of a modern digital and intelligent society and has garnered widespread attention and significant attention from both academic and educational communities.

IL is the comprehensive ability of individuals to acquire, understand, evaluate, apply, and innovate information in an information society. It encompasses not only basic computer skills but also multifaceted skills such as information retrieval, data analysis, and information security. High levels of IL help college students achieve better outcomes in academic research, career development, and lifelong learning [3]. However, with the continuous advancement of information technology, the information environment and information behavior are also evolving, posing more severe challenges and raising higher standards for the IL of college students.

Compared to international standards, Chinese university students' IL still shows an overall gap in the literature. Firstly, some students lack the initiative and purpose to identify and use information, leading to unsystematic information behavior. Secondly, although information retrieval courses are commonly offered, their content is often disconnected from specialized academic needs, making it difficult for students to obtain high-quality information efficiently for real tasks. Thirdly, students struggle to integrate and critically process fragmented information into structured knowledge, which limits their ability to think independently and innovate. Additionally, in terms of information ethics and security, many students have a weak capacity to identify and resist misinformation and have inadequate awareness of cybersecurity and legal norms [4,5].

Additionally, China still lacks a systematic and scientific evaluation system and measurement criteria for assessing IL competency. The university-level IL evaluation system serves as both the objective of IL education in higher education institutions and the basis for judging students' competency levels [6]. Network surveys reveal that universities currently cannot accurately determine whether students' IL competency meets required standards during the educational process; meanwhile, college students themselves cannot properly plan their IL enhancement pathways and have yet to develop lifelong learning capabilities.

Therefore, based on the current status of college students' IL, the author attempts to establish an evaluation system for college students' IL and conducts empirical research to test the rationality and effectiveness of the system. After analyzing the results of the empirical research, the author proposes measures for college students to further improve their IL and strives to provide a theoretical and practical basis for IL education in Chinese universities.

2. Literature Review

2.1. Current Status of Research on IL and IL Education

With the continuous development of computer technology and the increasing demand for information, Paul Zurkowski, president of the Information Industry Association (IIA), proposed the concept of IL in 1974, which refers to the skill of using information tools to retrieve information and solve problems. Sheila Webber et al. [7] clarified the definition of IL, provided methods to improve IL, pointed out the limitations of viewing IL as a skill, and advocated that the academic community expand IL research to a wider range of fields. In subsequent research and practice, combined with the corresponding information environment, the concept of IL has been continuously developed and refined. In 1989, the American Library Association stated that People with IL can judge when information is needed and know how to obtain, evaluate and effectively use the required information [8]. In the 1990s, with the development of network and communication technology, IL can be understood as: various information qualities possessed by individual members of the

information society, including information awareness, information ability, information ethics, information psychology, etc.

The development of the connotation of IL can be divided into three stages: the early stage, the middle stage and the late stages. The IL in the early stage mainly emphasized the traditional manual document retrieval skills of librarians, which is called library literacy. In the middle stage, with the background of the rapid development of computer information technology, emphasis began to be placed on the skills of using computers to retrieve information and the skills of evaluating the retrieved information, and the importance of people's information awareness began to be emphasized. IL during this period can be referred to as computer literacy. With the development and popularization of computer technology, network technology, multimedia, and AI technologies, the connotation of IL began to emphasize the social attributes of people in IL (the ability to communicate and transmit information), fully valued people's critical thinking ability and ability to evaluate information, and emphasized that IL is an inevitable requirement for lifelong learning [9].

In today's society, experts and scholars from all over the world attach great importance to the research on IL education, and have conducted multi-level and multi-faceted research, and have achieved constructive research results [10]. The United States is at the forefront of the world in terms of informationization. One of the most fundamental reasons is that it has invested a lot of effort in IL education. Since the second half of the 1980s, under the strong advocacy and reasonable planning of the American Library Association and the education department, the IL education program has been included in the national education curriculum. Various universities have also conducted many IL project activities to promote the formation of national IL awareness. In 1990, the United States established the IL Forum Organization, which comprises 75 educational departments. Its purpose is to improve global and national IL awareness and to encourage various IL activities. Simultaneously, online IL education with the help of network computer technology has become one of the main ways of IL education for the American people. In 1988, the British education reform included information technology courses in the national unified curriculum, requiring the creation of a good environment for IL for students in the educational practice of all subjects. At the same time, it also vigorously conducted online distance education to carry out IL education more widely and improve the overall information quality of the whole people. Simultaneously, Japan, France, Australia and other countries also proposed the necessity of IL education, carried out information technology teaching in primary and secondary schools, and later provided different IL education for students at all levels. European scholars Repanovici A and Salcă Rotaru C. [11] have made a new interpretation of the connotation of IL based on the concept of sustainable development and proposed the concept of sustainable information behavior ability. They pointed out that IL education in university libraries can cultivate students' sustainable thinking and sustainable information behavior ability by introducing the impact of information technology on the environment.

China's research on IL and IL education started relatively late, but has developed rapidly in recent years, showing multi-dimensional and interdisciplinary characteristics. With the promotion of policies such as the "Education Informatization 2.0 Action Plan" and the "Regulations on Libraries in General Colleges and Universities", IL has been incorporated into the national education development strategy, and colleges and universities, as well as primary and secondary schools, have gradually attached importance to IL education. IL has expanded from the early "information skills" to comprehensive abilities such as critical thinking, data literacy, media literacy, and digital citizenship. Lu Maoying defines IL as: the ability required for people to recognize, understand, and use information and communicate with the outside world in the information society. It includes not only various information technologies and skills, but also the attitudes and understandings of

individual members of society towards information, as well as the cultivation of students' adaptability and adaptability to the information environment [12]. Gu Yulin proposed that IL is a constantly evolving concept for college students. IL is formed and developed through information activities. It represents a student's capacity, both as a personality trait and a practical skill, through which they independently apply scientific information strategies to find, obtain, process, and use information for analyzing and solving practical problems [13]. Xiao summarizes the essence of IL into four levels: information awareness, information thinking, information skills, and related knowledge and moral cultivation. It is concluded that IL is an intelligent architecture, not a simple technical operation [14]. Some scholars also focus on the meaning of IL in other fields. Liu Chunyan et al. believe that IL is a comprehensive information capability, including information wisdom, information ethics, information awareness, information consciousness, information concepts, information potential, and information psychology, etc. It is a knowledge structure for understanding, collecting, evaluating, and utilizing information, which requires the use of information technology, relies on perfect investigation methods, and involves identification and reasoning [15].

China's IL education activities began in the 1980s and have since expanded. In 1984, the former State Education Commission issued the "Opinions on the Establishment of Document Retrieval and Utilization Courses in Colleges and Universities", which pioneered IL education. In December 2004, a seminar on IL education for colleges and universities in some cities was conducted in Guangzhou. The conference comprehensively and in-depth discussed basic issues such as the construction of IL education curriculum resources in colleges and universities, the research on modern teaching models for information retrieval, and new ideas for IL education in colleges and universities in the network environment. In 2018, the Ministry of Education of China issued the "Guiding Opinions on Further Strengthening IL Education in Colleges and Universities", which included five aspects: IL education content, education form, education conditions, evaluation, and implementation suggestions [16]. In terms of education form, it innovatively proposed to "integrate online and offline education methods" and encourage the development of diversified course forms, especially the new concept of embedded teaching and the emergence of Massive Open Online Courses (MOOCs), which injected new vitality into the development of IL education in colleges and universities. For example, on the "China University MOOC" platform, Professor Huang Ruhua of Wuhan University opened the course "Information Retrieval" [17], and the team led by Zhou Jianfang of Sichuan Normal University launched the course "IL: A New Engine for Efficiency Improvement and Lifelong Learning". The 2019 China University Information Culture and IL Education Seminar discussed the concepts, models, practices, and innovations of IL education in university libraries from the perspective of a new information culture [18]. With the application of artificial intelligence technologies such as deep-seek big models in IL education, a new type of library learning space that supports innovative experiences, creative activities, and interdisciplinary exchanges has been obtained [19].

Based on the explanations and interpretations of IL and IL education by experts and scholars at home and abroad, and combined with the characteristics of college students themselves, IL can be defined as: college students in the digital age should have an awareness of IL; master the knowledge of the nature, characteristics, dynamic laws, composition of information system processes and their principles, technologies, methods, etc.; have a certain ability to acquire, process, store, handle, use and communicate information, correctly identify information and strictly abide by information ethics and relevant laws and regulations, and maintain information security; have the basic ability to learn independently

and throughout life, and rely on their own information knowledge system to develop and innovate research content.

Compared with other countries, China is still lagging in IL education research, with the primary focus on schools, particularly universities. While China has developed online teaching platforms, most users lack IL knowledge. The monotonous teaching content, outdated models, and insufficient interdisciplinary integration hinder students' ability to utilize information technology to address professional issues. Furthermore, a lack of personalized instruction tailored to individual needs has resulted in relatively low practical and innovative capability. The lack of effective oversight mechanisms and information ethics regulations has also hindered the rapid development of IL education in China. IL education in the digital age requires a long-term, planned development process. Therefore, IL education topics should be comprehensively planned, stratified, and targeted to cultivate IL among the public. University libraries, in particular, should play a crucial role in IL education and in fostering students' IL skills.

While these challenges at the national level—such as monotonous teaching content, insufficient interdisciplinary integration, and the lack of personalized instruction—are widely acknowledged, there remains a significant gap in translating these macro-level critiques into actionable, micro-level evaluation and improvement frameworks. The existing literature predominantly calls for generalized reforms but offers few empirically grounded tools to diagnose the specific deficiencies in students' IL structures or to guide targeted interventions at the institutional level. This study addresses this gap by constructing a quantitative evaluation model tailored to the context of a typical Chinese university (Yancheng Institute of Technology). By developing a multi-dimensional index system and applying the Analytic Hierarchy Process (AHP) and Fuzzy Comprehensive Evaluation (FCEM) methods, this research aims to move beyond descriptive criticism and provide a measurable, data-driven approach to assess and enhance IL capabilities, thereby offering a concrete pathway to address the very problems of outdated models and insufficient personalization highlighted above.

2.2. Current Status of Research on IL and Its Evaluation at Home and Abroad

The development of college students' IL shows that the focus of IL is on the scope of "ability". IL pays particular attention to students' abilities and refines them in various fields. In the context of global informatization, everyone needs to have IL capabilities, including the ability to obtain effective information, make judgments, communicate, process information, and recreate. In the era of big data, it is necessary to be able to use the resources at hand to solve problems and innovate [20].

With information technology and digitalization pervading every aspect of society, IL has become a fundamental survival skill. Countries around the world are devoting increasing attention to IL education. In 1998, the United Kingdom's Society of National and University Libraries (SCONUL) published the "IL Competency Model." In 2000, the Association of College and Research Libraries (ACRL) in the United States developed the "IL Competency Standards for Higher Education." In 2004, the Australia and New Zealand Joint Working Group on IL (ANZIIL) issued the "IL Competency Indicator System for Higher Education." In 2015, the Association of College and Research Libraries (ACRL) in the United States released a new version of the "IL Framework for Higher Education." These standards and indicator systems generally consist of several primary indicators, as well as several secondary and tertiary indicators, covering areas such as information needs, information acquisition, information evaluation, information organization and management, information innovation, and information ethics.

Foreign scholars have conducted academic discussions on IL competency standards at the practical application and teaching evaluation levels. Davidson et al. [21] discussed how the teaching and guidance departments of Oregon State University used the "ACRL Higher Education IL Competency Standards" document to carry out IL education, and pointed out that university library teachers should apply the standards to specific teaching practices based on their initial self-study, to expand the concept of IL and determine the main competencies of IL. Lorrie A. Knight [22] surveyed the IL learning outcomes of first-year undergraduates in academic research and writing courses and pointed out that academic work ability is an important indicator for evaluating the results of college students' IL education. This provides a reference for university libraries to use the ACRL standards to evaluate the effectiveness of IL education and guide their implementation of IL education. Lynn Cameron [23] and other scholars developed an IL test tool (ILT) to measure the degree to which college students master the specific indicators of ACRL standards. This test tool can be used to help university libraries evaluate the results of IL education and ensure effective implementation of teaching plans.

IL assessment is a knowledge framework for examining students' information application capabilities and levels. As an important component of IL education research, it has gradually been valued by the academic community. A relatively complete information evaluation system has been developed abroad, and its assessment is completed by professional institutions. The more famous one is the "Nine IL Standards for Student Learning" jointly developed by the American Association of School Libraries and the Association for Educational Communications and Technology in 1998. In 1999, the Association of National and University Libraries in the United Kingdom proposed the British IL Standards. In 2000, the United States and Australia also developed the "American College IL Standards" and the "Australia and New Zealand IL Assessment Framework", respectively. Among them, the "American College IL Standards" issued by the Association of College and University Libraries (ACRL) in the United States is a relatively authoritative IL evaluation indicator system that is widely accepted and applied. This standard starts from both macro and micro aspects, emphasizes the combination of theory and practice, and highlights the cultivation of students' IL capabilities, especially innovation capabilities. It is operational, scientific, forward-looking and popular [24]. In 2015, ACRL revised and published the Framework for IL in Higher Education, based on this framework, which proposed six threshold concepts for IL in higher education [25]. Many colleges and regions in the United States have established some regional indicators that are consistent with the characteristics of local students.

Based on relevant research results from abroad, China has proposed a series of plans for IL. On 8 May 2006, the General Office of the CPC Central Committee and the General Office of the State Council issued the "National Informatization Development Strategy 2006–2020". As the strategic focus of China's informatization development, it emphasizes the implementation of various forms of informatization knowledge and skills popularization activities to improve the national education level and information capabilities. On January 15, 2007, the Beijing Municipal Informatization Leading Group Office issued the "Beijing Action Plan for Improving the National Information Capacity" during the "Eleventh Five-Year Plan". In 2005, Tsinghua University Library and Beijing University of Aeronautics and Astronautics Library jointly undertook the research and formulated the "IL Capacity Index System for Colleges and Universities in Beijing". As an important indicator for the IL assessment of college students in Beijing, the standard is divided into 7 dimensions, 19 standards, and 61 specific indicator items. This is China's first relatively systematic and complete IL capacity index system. Internet IL education has become the biggest feature of IL education in colleges and universities during this period [26].

Chinese experts and scholars have conducted extensive research on this topic. Zhong [27] proposed that Chinese IL is mainly manifested in the following eight aspects: using information tools, obtaining information; processing information, generating information, creating information, exerting information benefits, information collaboration, and information immunity. Huang [28], with information ability as the core evaluation standard, proposed to use information knowledge, information ability, and information ethics to evaluate the IL of Chinese college students in the "Study on the Evaluation Standard of IL of Chinese College Students". Ma and Yang Guimei used a method that combined static analysis with dynamic analysis and vertical with horizontal comparative analysis to conduct a relatively detailed analysis of the current situation of college students' IL education, constructed an evaluation index system for college students' IL, designed an evaluation system, and found new ways and rules to follow in strengthening college students' IL education in the construction of soft and hard environments [29,30]. Zeng and other scholars used the Delphi method, inviting several IL education experts from university libraries to conduct a multi-faceted review of the preliminary university IL capability indicator system. Ultimately, the university's IL capability indicator system was formed [31,32]. Based on the historical scope and logic of IL in the context of the artificial intelligence era, Liu and Bai evaluated the IL of contemporary college students from three aspects: information skill operation ability, information thinking training evaluation, and information humanistic care evaluation [33]. In the practice of building an IL assessment system, Peking University Library has built an "IL Capacity Assessment Platform" to provide a solution for establishing a more complete and targeted IL education development [34].

In summary, a review of the existing evaluation systems reveals two critical limitations that this study directly aims to overcome. First, as noted, many evaluation standards are either regional (e.g., the Beijing Index System) or tailored to a specific developmental stage, resulting in a pronounced lack of a universally applicable framework that can be adapted for general assessment across diverse institutional contexts in China. Second, and more critically, many influential standards were formulated in the early stages of IL research (e.g., ACRL 2000, ANZIIL 2004 [35,36]) and have not been sufficiently updated to reflect the transformative impact of big data and artificial intelligence on information behaviors and competencies. It is precisely these gaps—the need for a more adaptable, scalable evaluation tool and the imperative to modernize assessment criteria for the contemporary digital intelligence era—that the present research aims to fill. The evaluation model proposed in this study, with its core four-dimensional structure (information awareness and attitude, information ethics, law and security, information knowledge and skills, and information integration and innovation), is constructed not only based on established theories but also explicitly incorporates considerations for the modern AI-driven information landscape. Furthermore, the methodological combination of AHP and FCEM provides a flexible weighting mechanism, allowing the model to be calibrated for different contexts while maintaining a core universal standard, thereby directly addressing the identified shortcomings of existing methods.

3. Methodology

This paper uses a literature research method to collate the literature on IL among university students, analyze the components of IL among university students, and construct a framework for evaluating IL among Chinese university students. This framework is then revised and improved based on expert advice. Through questionnaire surveys and the AHP, an evaluation index system for IL among Chinese university students is established. Employing empirical research methods and employing an FCEM, this paper quantitatively

evaluates IL among university students, laying the foundation for developing strategies to improve their IL.

3.1. Ideas for Constructing an IL Evaluation System

Based on the concepts of college students' IL and IL ability and referring to existing standards and relevant literature at home and abroad, several evaluation indicators were sorted out. After analyzing the relationship between each indicator, a primary evaluation indicator system was developed. The opinions of experts, scholars, and teachers were gathered through telephone, Internet, and interviews. As well as online and on-site explanations and surveys among college students, some indicators were adjusted, indicators with weak attribute characteristics were deleted, similar indicators were merged, and indicator factors were rearranged to ensure the systematic, logical, and practical nature of the indicator system. Finally, the indicator system was improved based on the Delphi method to obtain an evaluation index system for college students' IL ability.

3.2. Determine the Weight of Evaluation Indicators

The weight is the relative importance of a specific indicator in the entire evaluation standard system. Based on the determination of indicators at all levels of the evaluation system, the weights of the evaluation indicators were determined using the AHP method, because the AHP can structure and quantify fuzzy subjective judgments and ensure the logical rationality of the weights through consistency testing [37–39].

The steps of the AHP are as follows:

(1) Construct a hierarchical structure model of the evaluation index system for college students' IL ability, which consists of the goal layer, the criterion layer, and the indicator layer, and then construct a judgment matrix at each layer. The hierarchical model is shown in Figure 1.

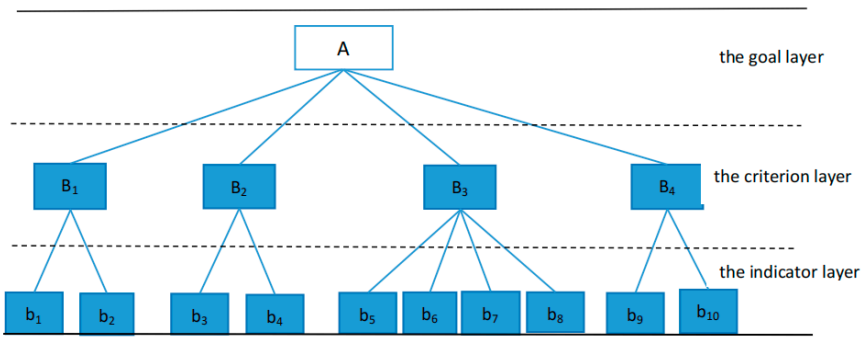


Figure 1. Schematic diagram of the hierarchical structure model.

(2) Design the judgment matrix of the evaluation index system based on the hierarchical structure model.

After establishing a hierarchical structure model for the evaluation index system of college students' IL, experts compared the scale values of indicators at the same level and obtained a matrix through a comprehensive analysis, as follows:

$$A = (a_{pq})_{n \times n} \quad (1)$$

where n is the number of first-level indicators or second-level indicators.

After comparing the indicators at the same level, we obtain judgment matrices for the evaluation index system of college students' IL ability. The judgment matrix formula meets the following conditions:

$$a_{pq} = 1/a_{pq}, p, q = 1, 2, 3 \cdots \cdots, n, \text{ where } p \neq q,\ a_{pq} \geq 0;\ p \neq q,\ a_{pq} = 1 \tag{2}$$

(3) Use the expert scoring judgment matrix to check the consistency of the matrix and calculate the indicator weights with the help of the SPSSAU (https://spssau.com) software tool.

3.3. Fuzzy Comprehensive Evaluation of the Empirical Method

The FCEM incorporates the concept of membership from fuzzy mathematics into the evaluation process, transforming qualitative factors that are difficult to quantify into quantitative evaluations using membership functions. It constructs a set of factors, a set of comments, a set of weights, and a fuzzy relationship matrix, and applies fuzzy synthesis operations to obtain a comprehensive evaluation result, thereby addressing the inherent ambiguity and uncertainty of the evaluation object. The FCEM has the advantages of combining quantitative and qualitative evaluation, is suitable for multi-level factor evaluation, and can provide a comprehensive and integrated assessment of matters. The evaluation of college students' IL involves a comprehensive evaluation of multiple levels, dimensions, and factors. Therefore, the fuzzy comprehensive analysis method is suitable for the quantitative evaluation of college students' IL [40,41].

The specific steps of the FCEM are as follows:

(1) Determine the evaluation factor set and comment set.

Let $U = \{u_1, u_2, \ldots, u_m\}$ be the m factors that characterize the evaluated object, that is, the evaluation index; and $V = \{v_1, v_2, \ldots, v_n\}$ be the n decisions that characterize the state of each factor, that is, the evaluation level of U. Here, m is the number of evaluation factors, and n is the number of comments.

(2) Construct the evaluation matrix.

First, perform a single factor evaluation on the single factor u_i (i = 1, 2, …, m) in the factor set. Based on the factor u_i, the membership degree of the object to the decision level v_j (j = 1, 2, …, n) is r_{ij}. Thus, the single factor evaluation set of the i-th factor u_i is obtained as follows:

$$r_i = (r_{i1}, r_{i2}, \cdots, r_{in}) \tag{3}$$

In this way, the evaluation set of m factors constructs a total evaluation matrix R. That is, each evaluated object determines the fuzzy relationship R from U to V, which is represented as a matrix:

$$R = (r_{ij})_{m \times n} = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix} i = 1, 2, \cdots, m; j = 1, 2, \cdots, n \tag{4}$$

where r_{ij} represents the degree of membership of the evaluation object to be rated as v_j based on factor u_i. Specifically, r_{ij} represents the frequency distribution of the i-th factor u_i on the j-th comment v_j, which is generally normalized to satisfy $\sum r_{ij} = 1$.

(3) Determine the weights of the evaluation factors.

The fuzzy relationship matrix is insufficient for object evaluation. Each factor in the evaluation factor set has a different status and role in the evaluation target, that is, each

evaluation factor has a different proportion in the comprehensive evaluation. It is proposed to introduce a fuzzy subset w on U, called the weight set, $w = (w_1, w_2, \ldots, w_n)$, where $w_i > 0$ and $\sum w_i = 1$. By combining different rows with the fuzzy weight vector w, we can obtain the degree of membership of the evaluated object to each level of fuzzy subset from an overall perspective, that is, the fuzzy comprehensive evaluation result vector. This study uses factor analysis to determine the weight coefficient of each indicator, calculate the weight vector $w = (w_1, w_2, \ldots, w_n)$ of each indicator, and perform normalization processing as follows:

$$\sum_{i=1}^{n} w_i, i = 1, 2, 3, \cdots, n \tag{5}$$

(4) Synthesis of fuzzy comprehensive evaluation result vector.

After determining the fuzzy comprehensive evaluation membership matrix R and the weight coefficients of each indicator, the weighted average fuzzy operator is used to combine the fuzzy comprehensive evaluation membership matrix R and the weight vector w of the evaluated object to obtain the synthesized fuzzy comprehensive evaluation result vector S.

$$S = w * R = (w_1, w_2, \cdots, w_n) \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix} = (b_1, b_2, \cdots, b_n) \tag{6}$$

Among them, b_i represents the degree of membership of the evaluated indicator u_i relative to the evaluation level v_j.

(5) Calculation of fuzzy comprehensive evaluation results.

Calculation of the final results of fuzzy comprehensive evaluation:

$$G = S * V^T \tag{7}$$

4. Results and Discussions

4.1. Constructing an IL Evaluation System

4.1.1. Selecting and Designing Evaluation Indicators for College Students' IL Competency

To ensure the rationality, completeness, and authority of the selected indicators, we reviewed the literature on IL evaluation indicators for Chinese and foreign university students [9–31] and analyzed existing evaluation indicators. We concluded that the connotation of university students' IL mainly includes five aspects: information awareness and attitude, information ethics and security, information knowledge and skills, information management and evaluation, and information integration and innovation. This preliminary construction of an evaluation indicator system for university students' IL includes five primary indicators and 20 secondary indicators, as shown in Table 1.

Table 1. Preliminary construction of evaluation indicators for college students' IL competency.

First-Level Indicators	Second-Level Indicators	Detailed Description
information awareness and attitude	information sensitivity	the ability to capture information in life on time and discover important information that others have overlooked
	awareness of information value	the ability to realize the importance of information to social life

Table 1. *Cont.*

First-Level Indicators	Second-Level Indicators	Detailed Description
information awareness and attitude	information needs	the ability to clearly express one's information needs and describe the key words of information needs
	information attitude	the willingness and habit to learn and use information technology
information ethics and security	information ethics	complying with information ethics and related regulations when using information
	information law	complying with relevant laws and regulations when using information
	information security awareness	being aware of information security precautions when dealing with information issues
	information security standards	ensuring information security and preventing information leakage when using information
information knowledge and skills	basic information knowledge	mastering information-related concepts, basic computer functions and operating knowledge
	information operation skills	mastering basic computer hardware and software operations, including the operation of common software such as Office components
	information acquisition methods	mastering information acquisition methods and strategies, and retrieving required information through various channels
	information utilization	being able to fully utilize information to solve problems in life, study, and work
information management and evaluation	information extraction and storage	mastering strategies for extracting and storing information
	information organization and combination	mastering methods for organizing and reorganizing information
	information authenticity evaluation	being able to distinguish the authenticity of information
	information value evaluation	being able to evaluate the value of information
information integration and innovation	information integration and presentation	integrating information from multiple sources to make decisions, forming systematic cognition, and appropriately presenting information in an information environment
	information exchange and collaboration	interacting and sharing information in an information environment, collaboratively creating content, checking problems, and completing tasks through information channels
	problem solving	making decisions or solving problems independently or collaboratively in an information environment
	innovation and creation	generating new information and integrating it into one's own knowledge system, being able to discover problems and propose new solutions based on information technology

4.1.2. Determination of the Evaluation Index System of College Students' IL Competency Based on the Delphi Method

Based on the initial screening of evaluation indicators for university students' IL, the final indicators were determined using the Delphi expert consultation method. Considering that IL involves knowledge related to basic computer education and library information management in higher education, the authors invited 30 university experts with backgrounds in library science, education, and computer science between 5 January and 28 April 2025. These experts were identified through methods such as academic search engine recommendations and contacts established during conferences. The consultation involved 12 telephone surveys, 10 online surveys, and 8 face-to-face interviews. Basic information, including professional titles and teaching experience, was collected through the survey, as shown in Table 2.

Table 2. Expert Information Statistics.

Professional Title	Number	Percentage	Teaching Experience	Number	Percentage
Intermediate (Lecturer/Librarian)	4	13%	10–15 years	6	20%
Deputy Senior (Associate Professor/ Associate Research Librarian)	9	30%	15–20 years	5	17%
Senior (Professor/Research Librarian)	17	57%	More than 20 years	19	63%

Based on the consulting experts' opinions on the modification of the indicator settings (Table 3), each indicator was modified and supplemented to form a revised indicator system for evaluating college students' IL capabilities. It was adjusted to 4 first-level indicators and 10 second-level indicators. See Table 4 for details.

Table 3. Expert consultation and revision opinions on the evaluation indicators of college students' IL competency.

First-Level Indicators	Second-Level Indicators	Modification Suggestions
information awareness and attitude	information sensitivity	This assessment primarily examines students' awareness of information technology, their willingness and habit for learning it, and their understanding of the impact of information technology. Information sensitivity is encompassed within information awareness, and information needs are also reflected in both information awareness and attitudes. It is recommended that "information sensitivity" and "information needs" be deleted, and "information value awareness" be replaced with "information awareness," while retaining "information attitude."
	awareness of information value	
	information needs	
	information attitude	
information ethics and security	information ethics	1. Experts believe that both "Information Security Awareness" and "Information Security Standards" fall under the umbrella of information security, making the two secondary indicators somewhat redundant. Students with information awareness also possess certain security standards to prevent information security incidents. Based on expert opinion, these indicators should be combined into "Information Security." 2. Information ethics and information law both constrain information stakeholders and can be combined into "Information Ethics and Law."
	information law	
	information security awareness	
	information security standards	

Table 3. *Cont.*

First-Level Indicators	Second-Level Indicators	Modification Suggestions
information knowledge and skills	basic information knowledge	1. Experts believe that information management is related to information operation. Corresponding software must be used in the organization to combine information. Therefore, information management and operation skills can be classified as information skills. Being able to evaluate information means that a certain information knowledge base is already possessed. The classification of the two first-level indicators "information knowledge and skills" and "information management and evaluation" and the second-level indicators within the first-level indicators are interconnected and integrated. According to the opinions of experts, they will be modified and merged into one first-level indicator "information knowledge and skills"; 2. The second-level indicators "information authenticity evaluation" and "information value evaluation" are both information evaluations. They are merged with "information utilization" and it is recommended to be uniformly adjusted to "information evaluation and utilization". Adjust "information extraction and storage" and "information organization and combination" to "information management", and adjust "information basic knowledge" and "information operation skills" to "information basics and operation"
	information operation skills	
	information acquisition methods	
	information utilization	
information management and evaluation	information extraction and storage	
	information organization and combination	
	information authenticity evaluation	
	information value evaluation	
information integration and innovation	information integration and presentation	Experts point out that the primary indicator assesses students' information exchange and collaboration, problem-solving and computational thinking, and creativity and innovation. They suggest adjusting "information integration and presentation" and "information exchange and collaboration" to "information fusion and collaboration." They also suggest merging "problem solving" and "innovation and creation" into "problem solving and innovation and creation," which would be more concise and integrated.
	information exchange and collaboration	
	problem solving	
	innovation and creation	

(1) Questionnaire survey results

After expert consultation, the preliminary evaluation indicators for college students' IL were revised to produce the final evaluation indicators. An expert questionnaire survey (Appendix A) was conducted using a five-point Likert scale to assess the rationality of the revised evaluation indicators. Thirty valid expert questionnaires were received, and the results of the expert consultation are shown in Table 5. The weighted average scores of the expert evaluations were all above 4, demonstrating that each indicator has been recognized by the experts.

Table 4. Evaluation index system for college students' IL competency.

First-Level Indicators	Second-Level Indicators	Indicator Meaning
information awareness and attitude	information awareness	Correctly understand the impact of information technology and be able to identify and express information needs
	information attitude	Have the willingness and habit to learn and use information technology
information ethics, law and security	information ethics and Law	Understand and comply with information ethics and legal and regulatory requirements
	information security	Have information security awareness and be able to protect information security

Table 4. *Cont.*

First-Level Indicators	Second-Level Indicators	Indicator Meaning
information knowledge and skills	information foundation and operation	Master the relevant concepts of information and basic computer functions, and master the basic operating skills of computer software and hardware.
	information acquisition methods	Conceive and implement effective information retrieval strategies and excel at discovering information
	information management	Use information means to store, extract, organize and reorganize information
	information evaluation and utilization	Accurately evaluate information, verify and diagnose things based on the information, and integrate software and hardware knowledge to solve problems in life, study, and work
information integration and innovation	information integration and collaboration	Integrate, analyze, communicate and share information resources from multiple sources, and collaborate to create content, check problems and complete tasks through information channels
	problem solving, innovation and creation	Make decisions or solve problems independently or collaboratively in an information environment, generate new information and integrate it into one's own knowledge system, and be able to discover problems and propose new solutions based on information technology

Table 5. Weighted average of expert consultation results.

Second-Level Indicators	Very Unimportant (1 Point)	Unimportant (2 Points)	Average (3 Points)	Important (4 Points)	Very Important (5 Points)	Weighted Average
information awareness	0	0	2	7	21	4.633
information attitude	0	1	2	7	20	4.533
information ethics and Law	0	0	0	4	26	4.867
information security	0	0	0	5	25	4.833
information foundation and operation	0	0	2	4	24	4.733
information acquisition methods	0	0	3	5	22	4.633
information management	0	0	4	12	14	4.333
information evaluation and utilization	0	0	0	7	23	4.767
information integration and collaboration	0	0	2	15	13	4.367
problem solving and innovation and creation	0	0	6	10	14	4.267

(2) Reliability Analysis of Evaluation Indicators.

This reliability study focused on confirming the internal consistency of the evaluation index. Cronbach's alpha factor was used, and it is generally considered that if the value of this factor exceeds 0.7, the reliability of the survey report is high. Based on the data collected from the 30 questionnaires, a statistical analysis of the consistency and reliability of the college students' IL evaluation indicators was performed. The consistency reliability

analysis result was 0.757 (greater than 0.7), as shown in Table 6. This shows that the consistency results of the questionnaire are acceptable.

Table 6. Reliability analysis results of expert questionnaire.

Reliability Statistics	
Cronbach's α coefficient	0.757
number of items	10

4.1.3. Contribution of IL Competency Indicators to the Sustainable Development Goals

By cultivating "information awareness and attitudes", college students can gain a keen insight into the intrinsic connection between global issues and the Sustainable Development Goals (SDGs), and stimulate their initiative and sense of responsibility to use information to solve social and environmental challenges. "Information Ethics, Law and Security" literacy ensures that students adhere to ethics, respect intellectual property rights and privacy in information activities, lays the foundation for building a fair, inclusive and secure global digital social environment, and directly supports the realization of SDG16 (peace, justice and strong institutions). Mastering solid "information knowledge and skills" enables students to acquire, evaluate and use information efficiently and critically, providing them with core tools to become lifelong learners and promote technological innovation and capacity building advocated by the SDGs in all walks of life. Ultimately, the "information integration and innovation" capability encourages college students to integrate multi-source information across disciplines, giving rise to new ideas, new solutions and new knowledge for solving complex sustainable development problems. It is a key innovation engine driving the realization of goals such as a green economy and sustainable cities and communities (SDG11).

In summary, these four major IL indicators jointly empower contemporary college students, enabling them to transform from passive information consumers to active promoters of social change, and contribute indispensable wisdom and strength to the full realization of the United Nations 2030 Agenda for Sustainable Development.

4.2. Weights of IL Evaluation Indicators

This round of research will continue to invite the aforementioned 30 experts and scholars to conduct questionnaire surveys, which will be distributed both online and offline. The questionnaire format is shown in Appendix B. The index data of each dimension collected were geometrically averaged and processed and calculated using the AHP software SPSSAU to obtain the weight of each evaluation index of college students' IL competency.

By constructing a judgment matrix of the first-level indicators, SPSSAU software was used to conduct pairwise comparison and weight analysis on the first-level indicators of the college students' IL evaluation index system. The results showed that the consistency test Consistency Ratio (*CR*) value was 0.071 (less than 0.1), indicating that the conditions for the consistency test were met, as shown in Table 7.

Next, by constructing judgment matrices for the secondary indicators, the weights of the second-level indicators for evaluating university students' IL competency were calculated using the AHP tool in the SPSSAU software, as shown in Tables 8–11. The *CR* values for the consistency test were 0.000, 0.000, 0.017, and 0.000, respectively, all below 0.1, indicating that the results passed the consistency test.

Table 7. Results of first-level index weight analysis calculated by SPSSAU software.

First-Level Indicators	Information Awareness and Attitude	Information Ethics, Law and Security	Information Knowledge and Skills	Information Integration and Innovation	W_i
information awareness and attitude	1	0.5	0.25	0.2	0.0807
information ethics, law and security	2	1	0.25	0.333	0.1236
information knowledge and skills	4	4	1	3	0.5028
information integration and innovation	5	3	0.333	1	0.2930

Table 8. Results of second-level index weight analysis calculated by SPSSAU software (1).

Second-Level Indicators	Information Awareness	Information Attitude	W_i
information awareness	1	0.5	0.3333
information attitude	2	1	0.6667

Table 9. Results of second-level index weight analysis calculated by SPSSAU software (2).

Second-Level Indicators	Information Ethics and Law	Information Security	W_i
information ethics and Law	1	0.5	0.3333
information security	2	1	0.6667

Table 10. Results of second-level index weight analysis calculated by SPSSAU software (3).

Second-Level Indicators	Information Foundation and Operation	Information Acquisition Methods	Information Management	Information Evaluation and Utilization	W_i
information foundation and operation	1	2	3	4	0.4597
information acquisition methods	0.5	1	2	4	0.2945
information management	0.333	0.5	1	2	0.1572
information evaluation and utilization	0.25	0.25	0.5	1	0.0886

Table 11. Results of second-level index weight analysis calculated by SPSSAU software (4).

Second-Level Indicators	Information Integration and Collaboration	Problem Solving and Innovation and Creation	W_i
information integration and collaboration	1	0.3333	0.2500
problem solving and innovation and creation	3	1	0.7500

The weights of the evaluation indicators for university students' IL competency, obtained through aggregation, are presented in Table 12.

Table 12. Weight results of evaluation indicators of college students' IL competency.

First-Level Indicators	Weight Value	Second-Level Indicators	Weight Value
information awareness and attitude	0.0807	information awareness	0.3333
		information attitude	0.6667
information ethics, law and security	0.1236	information ethics and Law	0.3333
		information security	0.6667
information knowledge and skills	0.5028	information foundation and operation	0.4597
		information acquisition methods	0.2945
		information management	0.1572
		information evaluation and utilization	0.0886
information integration and innovation	0.2930	information integration and collaboration	0.2500
		problem solving and innovation and creation	0.7500

4.3. Empirical Fuzzy Comprehensive Evaluation

4.3.1. Sample Selection and Preliminary Preparation

Because the author works in the library of Yancheng Institute of Technology, and to facilitate information verification, the research sample was selected from full-time undergraduate and graduate students at Yancheng Institute of Technology. The reasons are as follows: 1. Yancheng Institute of Technology offers a comprehensive range of disciplines, with 69 undergraduate majors covering engineering, science, economics, management, literature, law, and other fields, and 20 graduate programs. 2. Yancheng Institute of Technology has an excellent network environment. The campus network has two outbound links, one from the China Education and Research Network and the other from China Telecom, with bandwidths of 1000 Mbps and 300 Mbps, respectively. These links are distributed throughout the teaching area, office area, faculty dormitories, and student accommodation. Internal bandwidth is 1000 Mbps backbone and 100 Mbps to the desktop. 3. Yancheng Institute of Technology prioritizes IL education among its students, and its students possess a strong level of IL.

To test the evaluation criteria, this study applied them in practice during the final phase. Ten representative groups of college students from different majors and grades (group numbers B1 to B10) were selected from Yancheng Institute of Technology for evaluation. The students' professional backgrounds include science, engineering, liberal arts, and art, and their grade distribution includes undergraduate and graduate students, totaling 151 students. The number of college students in different majors (grades) evaluated is shown in Figure 2. To ensure the research's reliability, the authors assured the students that the data would be used solely for scientific research and would not be used with their real names.

4.3.2. Fuzzy Analysis Evaluation

Because each student's IL skills vary in strengths and weaknesses, we first use a single-factor evaluation followed by a comprehensive comparison to determine each student's level of achievement across various indicators and ensure the accuracy of the information. Therefore, one student (numbered $B1_1$) from the B1 group of the second-year university students, majoring in civil engineering, was selected as the subject of single factor evaluation.

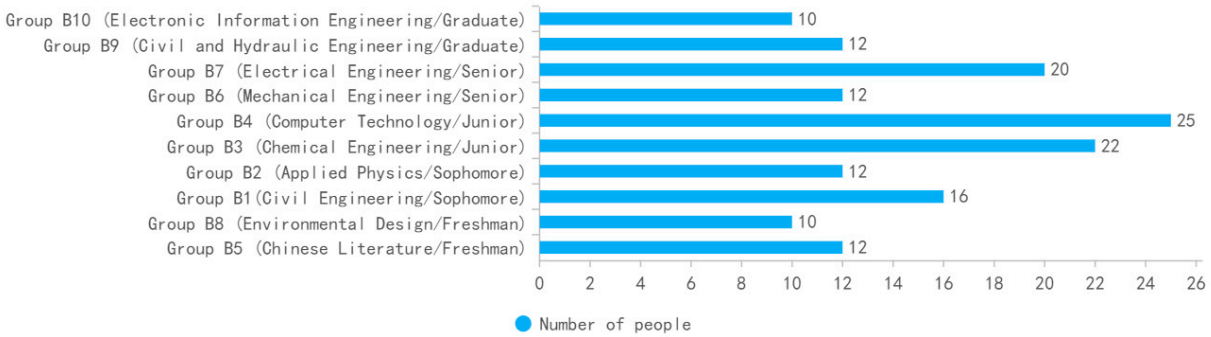


Figure 2. Number of university students from different majors (grades) participating in the evaluation.

(1) Determine the evaluation factor set

After determining the weights of the indicators, the FCEM was used to evaluate and analyze the questionnaire data to make a more accurate evaluation of the IL ability of the professional college students at Yancheng Institute of Technology. Since the weights of the evaluation indicators have been determined, only the evaluation factor set and the comment set need to be constructed. Based on the college student IL ability evaluation system constructed in this paper, the indicator system set of the fuzzy comprehensive evaluation can be determined as follows.

$$U = \{U_1, U_2, U_3, U_4\}$$

where U_1 represents information awareness and attitude, U_2 represents information ethics, law, and security, U_3 represents information knowledge and skills, and U_4 represents information integration and innovation, respectively. U_1 = {U_{11} (information awareness), U_{12} (information attitude)} U_2 = {U_{21} (information ethics and law), U_{22} (information security)} U_3 = {U_{31} (information foundation and operation), U_{32} (information acquisition methods), U_{33} (information management), U_{34} (information evaluation and utilization)} U_4 = {U_{41} (information integration and collaboration), U_{42} (problem solving and innovation and creation)}

(2) Determining the review set

The review set is a collection of possible reviews of the evaluation object. This article divides the review levels into five levels, represented by V, where $V = \{v_1, v_2, v_3, v_4, v_5\}$. Here, v_1 represents very dissatisfied (1 point), v_2 represents dissatisfied (2 points), v_3 represents average (3 points), v_4 represents satisfied (4 points), and v_5 represents very satisfied (5 points).

As shown in Table 7, the weight vector w of each evaluation index is obtained using factor analysis.

$$w_U = (0.0807, 0.1236, 0.5028, 0.2930)\ w_{U1} = (0.3333, 0.6667)\ w_{U2} = (0.3333, 0.6667)$$

$$w_{U3} = (0.4597, 0.2945, 0.1572, 0.0886)\ w_{U4} = (0.2500, 0.7500)$$

(3) Establishing a fuzzy evaluation matrix

A total of 30 students and teachers from $B1_1$'s major evaluated him according to this evaluation standard. By collating the data from 30 valid questionnaires, the college students' evaluation results for the 10 indicators were analyzed statistically. The results are summarized in Table 13.

Table 13. Evaluation results statistics.

First-Level Indicators	Second-Level Indicators	Very Low	Low	Average	High	Very High
U_1	U_{11}	2	3	5	9	11
	U_{12}	1	2	9	8	10
U_2	U_{21}	0	1	7	10	12
	U_{22}	0	1	4	10	15
U_3	U_{31}	1	1	5	10	13
	U_{32}	0	2	6	11	11
	U_{33}	2	3	7	10	8
	U_{34}	1	1	8	10	10
U_4	U_{41}	1	2	7	9	11
	U_{42}	1	2	8	11	8

The evaluation results are processed to calculate the membership matrix R for each evaluation index under the five comment levels. The calculation formula is as follows.

$$r_{ij} = N_i / N \tag{8}$$

where N_i represents the frequency of evaluation indicator i at comment level j, and N is the total number of evaluators. The indicator membership matrix obtained through calculation is presented in Table 14.

Table 14. Evaluation index membership matrix.

First-Level Indicators	Second-Level Indicators	Very Low	Low	Average	High	Very High
U_1	U_{11}	0.067	0.100	0.167	0.300	0.367
	U_{12}	0.033	0.067	0.300	0.267	0.333
U_2	U_{21}	0.000	0.033	0.233	0.333	0.400
	U_{22}	0.000	0.033	0.133	0.333	0.500
U_3	U_{31}	0.033	0.033	0.167	0.333	0.433
	U_{32}	0.000	0.067	0.200	0.367	0.367
	U_{33}	0.067	0.100	0.233	0.333	0.267
	U_{34}	0.033	0.033	0.267	0.333	0.333
U_4	U_{41}	0.033	0.067	0.233	0.300	0.367
	U_{42}	0.033	0.067	0.267	0.367	0.267

The fuzzy comprehensive evaluation membership matrix R can be obtained from Table 10:

$$R_1 = \begin{pmatrix} 0.067 & 0.100 & 0.167 & 0.300 & 0.367 \\ 0.033 & 0.067 & 0.300 & 0.267 & 0.333 \end{pmatrix}$$

$$R_2 = \begin{pmatrix} 0.000 & 0.033 & 0.233 & 0.333 & 0.400 \\ 0.000 & 0.033 & 0.133 & 0.333 & 0.500 \end{pmatrix}$$

$$R_3 = \begin{pmatrix} 0.033 & 0.033 & 0.167 & 0.333 & 0.433 \\ 0.000 & 0.067 & 0.200 & 0.367 & 0.367 \\ 0.067 & 0.100 & 0.233 & 0.333 & 0.267 \\ 0.033 & 0.033 & 0.267 & 0.333 & 0.333 \end{pmatrix}$$

$$R_4 = \begin{pmatrix} 0.033 & 0.067 & 0.233 & 0.300 & 0.367 \\ 0.033 & 0.067 & 0.267 & 0.367 & 0.267 \end{pmatrix}$$

According to formula (6), the fuzzy comprehensive evaluation result vector S_1 is calculated:

$$S_1 = w_{U_1} * R_1 = (0.3333,\ 0.6667) * \begin{pmatrix} 0.067 & 0.100 & 0.167 & 0.300 & 0.367 \\ 0.033 & 0.067 & 0.300 & 0.267 & 0.333 \end{pmatrix}$$
$$= (0.0443\ \ 0.0780\ \ 0.2557\ \ 0.2780\ \ 0.3443)$$

$$S_2 = w_{U_2} * R_2 = (0.3333,\ 0.6667) * \begin{pmatrix} 0.000 & 0.033 & 0.233 & 0.333 & 0.400 \\ 0.000 & 0.033 & 0.133 & 0.333 & 0.500 \end{pmatrix}$$
$$= (0.0000\ \ 0.0330\ \ 0.1663\ \ 0.3330\ \ 0.4667)$$

$$S_3 = w_{U_3} * R_3 = (0.4597,\ 0.2945,\ 0.1572,\ 0.0886) * \begin{pmatrix} 0.033 & 0.033 & 0.167 & 0.333 & 0.433 \\ 0.000 & 0.067 & 0.200 & 0.367 & 0.367 \\ 0.067 & 0.100 & 0.233 & 0.333 & 0.267 \\ 0.033 & 0.033 & 0.267 & 0.333 & 0.333 \end{pmatrix}$$
$$= (0.0286\ \ 0.0535\ \ 0.1960\ \ 0.3430\ \ 0.3786)$$

$$S_4 = w_{U_4} * R_4 = (0.2500,\ 0.7500) * \begin{pmatrix} 0.033 & 0.067 & 0.233 & 0.300 & 0.367 \\ 0.033 & 0.067 & 0.267 & 0.367 & 0.267 \end{pmatrix}$$
$$= (0.0330\ \ 0.0670\ \ 0.2585\ \ 0.3503\ \ 0.2920)$$

Thus, we obtain the fuzzy comprehensive evaluation matrix:

$$R = \begin{pmatrix} S_1 \\ S_2 \\ S_3 \\ S_4 \end{pmatrix} = \begin{pmatrix} 0.0443 & 0.0780 & 0.2557 & 0.2780 & 0.3443 \\ 0.0000 & 0.0330 & 0.1663 & 0.3330 & 0.4667 \\ 0.0286 & 0.0535 & 0.1960 & 0.3430 & 0.3786 \\ 0.0330 & 0.0670 & 0.2585 & 0.3503 & 0.2920 \end{pmatrix}$$

Then the fuzzy comprehensive evaluation result S is calculated:

$$S = w_U * R = (0.0807,\ 0.1236,\ 0.5028,\ 0.2930) * \begin{pmatrix} 0.0443 & 0.0780 & 0.2557 & 0.2780 & 0.3443 \\ 0.0000 & 0.0330 & 0.1663 & 0.3330 & 0.4667 \\ 0.0286 & 0.0535 & 0.1960 & 0.3430 & 0.3786 \\ 0.0330 & 0.0670 & 0.2585 & 0.3503 & 0.2920 \end{pmatrix}$$
$$= (0.0276\ \ 0.0569\ \ 0.2155\ \ 0.3387\ \ 0.3614)$$

(4) Fuzzy comprehensive evaluation results.

The fuzzy comprehensive evaluation scores of each first-level indicator and the overall satisfaction score are calculated using Formula (7):

$$G = S * V^T = \begin{pmatrix} 0.0276 & 0.0569 & 0.2155 & 0.3387 & 0.3614 \end{pmatrix} * \begin{pmatrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \end{pmatrix} = 3.9497$$

$$G_1 = S_1 * V^T = \begin{pmatrix} 0.0443 & 0.0780 & 0.2557 & 0.2780 & 0.3443 \end{pmatrix} * \begin{pmatrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \end{pmatrix} = 3.8009$$

$$G_2 = S_2 * V^T = \begin{pmatrix} 0.0000 & 0.0330 & 0.1663 & 0.3330 & 0.4667 \end{pmatrix} * \begin{pmatrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \end{pmatrix} = 4.2304$$

$$G_3 = S_3 * V^T = \begin{pmatrix} 0.0286 & 0.0535 & 0.1960 & 0.3430 & 0.3786 \end{pmatrix} * \begin{pmatrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \end{pmatrix} = 3.9886$$

$$G_4 = S_4 * V^T = \begin{pmatrix} 0.0330 & 0.0670 & 0.2585 & 0.3503 & 0.2920 \end{pmatrix} * \begin{pmatrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \end{pmatrix} = 3.8037$$

To facilitate analysis of the performance of each secondary indicator, the secondary indicator score is calculated by multiplying the membership set of each secondary indicator by the corresponding comment set. Taking "Information Awareness" as an example, the membership is (0.067, 0.100, 0.167, 0.300, 0.367), resulting in a score of 0.067 × 1 + 0.100 × 2 + 0.167 × 3 + 0.300 × 4 + 0.367 × 5 = 3.803. Similarly, the scores for the other secondary indicators can be calculated. The evaluation scores of each primary and secondary indicator are summarized to produce the fuzzy comprehensive evaluation score table, as shown in Table 15.

Table 15. Fuzzy comprehensive evaluation result score.

$B1_1$ Student's Comprehensive Score of IL Competency	First-Level Indicators	Index Score	Second-Level Indicators	Index Score
3.9497	U_1	3.8009	U_{11}	3.803
			U_{12}	3.800
	U_2	4.2304	U_{21}	4.097
			U_{22}	4.297
	U_3	3.9886	U_{31}	4.097
			U_{32}	4.037
			U_{33}	3.633
			U_{34}	3.897
	U_4	3.8037	U_{41}	3.901
			U_{42}	3.771

The evaluation scores for the comments (1, 2, 3, 4, and 5) were then calculated using a percentage system to obtain a comprehensive evaluation score of 78.99 (100 × 3.9497/5) for $B1_1$. The same method was used to evaluate the IL competency of other students in Group

B1 and each student in the other nine groups. The evaluation scores for each group were averaged. The average scores of IL competency evaluation for each major and grade group are shown in Table 16.

Table 16. Average scores of IL competency evaluation of college students in groups B1 to B10.

Evaluation Target	Major/Grade	Number of People	Average Score of IL
Group B5	Chinese Literature/Freshman	12	71.65
Group B8	Environmental Design/Freshman	10	72.39
Group B1	Civil Engineering/Sophomore	16	78.58
Group B2	Applied Physics/Sophomore	12	79.47
Group B3	Chemical Engineering/Junior	22	81.79
Group B4	Computer Technology/Junior	25	86.43
Group B6	Mechanical Engineering/Senior	12	83.77
Group B7	Electrical Engineering/Senior	20	85.26
Group B9	Civil and Hydraulic Engineering/Graduate	12	85.83
Group B10	Electronic Information Engineering/Graduate	10	86.37

4.3.3. Discussions of Evaluation Results

The empirical evaluation results (Table 16) provide nuanced insights into the IL competencies of the students at Yancheng Institute of Technology. Overall, the average scores indicate that students' IL proficiency is above the intermediate level, yet significant variations exist across disciplines and academic years, aligning with and extending prior research findings.

(1) Disciplinary Disparities and Curriculum Integration

The observed superiority in IL scores among science and engineering students (e.g., Groups B4, B7, B10) compared to their humanities and arts counterparts (e.g., Groups B5, B8) is consistent with the existing literature. This disparity often stems from the deeper integration of data analysis, specialized software, and information-intensive tasks into STEM curricula [20,25]. For instance, the ACRL Framework emphasizes "Searching as Strategic Exploration" and "Information Creation as a Process," competencies that are naturally exercised in engineering project-based learning. Conversely, the lower scores in humanities groups suggest a potential gap in effectively embedding IL instruction—particularly concerning digital resource evaluation and ethical information use—into non-STEM disciplines. This echoes findings by Liu et al. [15], who highlighted the need for discipline-specific IL adaptation in Chinese higher education. Our results reinforce the necessity of moving beyond one-size-fits-all IL education towards tailored modules that address distinct information practices within each academic field.

(2) Academic Progression and Institutional Support

The positive correlation between academic year and IL competency (e.g., senior undergraduates and graduates outperforming freshmen) underscores the cumulative effect of sustained exposure to academic research and to institutional resources. This progression is consistent with the "Research as Inquiry" and "Scholarship as Conversation" thresholds outlined in the ACRL Framework [25], which students gradually internalize through advanced coursework and thesis projects in their senior year. The higher scores among graduate students (Groups B9, B10) further validate the role of intensive research demands

in fostering advanced IL skills, such as information synthesis and innovation. However, the moderate scores even among upper-year students—particularly in "information evaluation and utilization" (U_{34}) and "problem solving and innovation" (U_{42})-suggest that current IL support systems (e.g., library workshops, credit-based courses) may not fully bridge the gap between basic skill acquisition and higher-order critical application. This aligns with criticisms raised in China's national policy discussions [16] regarding the insufficient emphasis on transformative information use in existing curricula.

(3) Critical Gaps in Evaluation and Innovation Competencies

While students demonstrated strengths in operational skills (e.g., information retrieval, security awareness), their relative underperformance in evaluation, management, and innovation indicators (e.g., U_{33}, U_{34}, U_{42}) reveals critical areas for improvement. This finding mirrors global concerns about students' overreliance on surface-level information gathering without developing robust critical evaluation or creative repurposing abilities [23,25]. In practice, this gap highlights the limitation of traditional IL instruction, which often prioritizes tool literacy over critical discernment and ethical reasoning. The fuzzy evaluation results thus serve as an empirical validation of theoretical calls, such as those by Repanovici and Salcă Rotaru [11], to integrate sustainability and ethical reasoning into IL education. For educators, this implies a need to redesign assignments to include authentic tasks such as misinformation debunking, data synthesis projects, and collaborative knowledge creation, thereby fostering "information wisdom" [15] alongside technical skills.

(4) Implications for Policy and Pedagogy

The study's results offer actionable insights into enhancing IL education practices. First, the AHP-derived weights (Table 12), which prioritize "Information Knowledge and Skills" (0.5028) and "Information Integration and Innovation" (0.2930), provide a quantitative basis for curriculum redesign. Institutions should allocate resources to advanced modules focusing on critical evaluation, meta-cognitive strategies, and ethical information use—competencies essential for lifelong learning in the digital era. Second, the significant disciplinary variations call for collaborative efforts between librarians and faculty to develop embedded IL instruction within major-specific courses, as pioneered in models like Zhou's MOOC [17]. Finally, the lower scores among early-year students underscore the importance of front-loaded IL interventions, such as mandatory first-year seminars incorporating AI literacy components, to establish a strong foundation.

This study's findings not only validate the proposed evaluation model's practicality but also illuminate persistent challenges of IL education. By contextualizing results within international frameworks and local practices, we bridge the gap between theoretical standards and on-the-ground implementation, offering a replicable approach for diagnosing and addressing IL deficits in comparable institutions in the future.

Although this study constructs an IL competency framework and determines indicator weights through expert consensus, it is crucial to emphasize that this framework must be interpreted cautiously through the lens of complexity theory. The competency structure and weights presented herein should not be regarded as a static or universal gold standard. More accurately, they represent the key patterns and priority consensus identified at a specific point in time by a particular group of experts, based on their extensive experience in teaching and management practice. As complexity theory emphasizes, IL competencies are dynamic, emergent, and highly context-specific. Therefore, this framework should be considered a starting point for dialog and a tool for diagnosis and planning, rather than a definitive conclusion. The process of its application, adaptation, and even revision in authentic educational settings is, in itself, a dynamic, situated, and emergent practice.

5. Conclusions, Recommendations and Limitations

5.1. Main Conclusion

In the digital age, information technology has permeated all aspects of society. As the main force in the construction of future society, strengthening IL education for college students and improving their IL skills are the inevitable requirements of higher education in an information society.

(1) Through literature analysis of the connotation and development status of college students' IL, the paper proposes the elements for evaluating college students' IL, which are divided into four aspects: information awareness and attitude, information ethics, law and security, information knowledge and skills, and information integration and innovation. The paper also explains in detail the true meaning of each component, providing a basis for the subsequent evaluation of college students' IL.

(2) Using the Delphi method and questionnaire survey, the paper establishes an evaluation system for college students' IL. The paper adopts the hierarchical analysis method to construct a judgment matrix, solve the indicator weights, and establish an evaluation model for IL using the FCEM. Through case analysis, the paper effectively realizes the quantitative evaluation of college students' IL, provides an accurate basis for the decision-making of college administrative departments in the future, and can effectively promote the sustainable development of higher education informatization.

5.2. Recommendations

(1) Humanization of information retrieval public courses. To apply the rationalization and humanization of education concepts to practice, while taking into account the differences in the IL ability levels of college students, colleges and universities should set up courses that are both selective, basic and open in the process of arranging information retrieval courses according to students with different foundations and levels.

(2) Diversification of teachers' teaching models. Teachers should follow a student-centered, interactive, collaborative, participatory and creative teaching method based on constructivist thinking to achieve this goal. Not only should they provide access to specialized knowledge, information and discussion tools, but they should also guide students to learn independently, promote the development of good IL, and continuously improve their own IL ability.

(3) Diversification of information services in university libraries. Holding special lectures can not only increase the learning interest of students but also broaden their horizons and expand their knowledge of the subject. Establishing subject navigation and database navigation provides students with sufficient information resources and a convenient environment for obtaining information. Introducing personalized reference consultation services to meet the different needs of college students.

The evaluation index system for college students' IL constructed in this study only lists secondary indicators. Furthermore, the evaluation index system was only applied to students at Yancheng Institute of Technology during the actual survey, resulting in a relatively limited dataset. Subsequent research will further evaluate students' IL skills, both overall and through different evaluation methods for each dimension, aiming to improve the evaluation system for college students' IL.

5.3. Limitations

The limitations of this study are in its methodological paradigm. Research methods based on expert opinion inherently carry a top-down character, which creates a philosophical tension with the 'bottom-up' emergent nature of IL as informed by complexity theory. To address this limitation and advance the field, future studies should employ methods

that are fully aligned with complexity theory. For instance, socio-cultural observations, learning analytics, and qualitative analysis of students' information practices in authentic tasks (bottom-up approaches) can reveal how IL competencies form, develop, and manifest across different disciplinary contexts and tasks. Contrasting, dialoguing, and integrating the expert view from this study with the practitioner (student) view from future research will provide a more comprehensive and dialectical understanding of the complexity of IL, thereby facilitating the continuous evolution of assessment frameworks.

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Appendix A. Expert Consultation Questionnaire on Evaluation Indicators for College Students' Information Literacy

Dear Experts:

Hello! Thank you very much for taking the time to read and complete the "Expert Consultation Questionnaire on Evaluation Indicators for College Students' Information Literacy." This questionnaire was developed to obtain expert advice on key indicators and recommendations for evaluating college students' information literacy. After consultation with experts, we screened and modified the indicators based on your suggestions, constructing four primary indicators and 10 secondary indicators. Next, we will solicit your feedback on each indicator through a questionnaire. Thank you for your support. Each statement in this questionnaire has five response options: "Very Unimportant," "Unimportant," "Normal," "Important," or "Very Important." Simply select the level of importance you consider in the corresponding column. If you believe any areas need improvement, please write in the suggestion column below each section. The information you provide will be treated with absolute confidentiality, adhere to academic standards, and be used only for academic research. I wish you good luck with your work!

Your teaching/work experience: <5 years, 5–10 years, 10–15 years, 15–20 years, >20 years

Your title: Teaching, Assistant Lecturer, Associate Professor, Professor

Part 1: Information Awareness and Emotion (This part includes two secondary indicators: information awareness and information attitude)

Second-Level Indicators	Very Unimportant (1 Point)	Unimportant (2 Points)	Average (3 Points)	Important (4 Points)	Very Important (5 Points)
information awareness					
information attitude					

Part 2: Information Ethics, Law, and Security (This part includes two secondary indicators: Information Ethics and Law, and Information Security)

Second-Level Indicators	Very Unimportant (1 Point)	Unimportant (2 Points)	Average (3 Points)	Important (4 Points)	Very Important (5 Points)
information ethics and Law					
information security					

Part 3: Information Knowledge and Skills (This part includes four secondary indicators: information foundation and operation, information acquisition methods, information management, and information evaluation and utilization)

Second-Level Indicators	Very Unimportant (1 Point)	Unimportant (2 Points)	Average (3 Points)	Important (4 Points)	Very Important (5 Points)
information foundation and operation					
information acquisition methods					
information management					
information evaluation and utilization					

Part 4: Information Fusion and Innovation (This part includes two secondary indicators: information integration and collaboration, and problem solving and innovation and creation)

Second-Level Indicators	Very Unimportant (1 Point)	Unimportant (2 Points)	Average (3 Points)	Important (4 Points)	Very Important (5 Points)
information integration and collaboration					
problem solving and innovation and creation					

Appendix B. Expert Consultation Questionnaire for the AHP Evaluation Index System for College Students' Information Literacy

Dear Expert:

Hello! Thank you for taking the time to complete this consultation form on the weighting of indicators in the evaluation index system for college students' information literacy. This questionnaire is about the relative weighting of indicators in the evaluation index system for college students' information literacy. There are no right or wrong answers and it is for research purposes only. We sincerely ask for your valuable feedback and to rate the importance of the two factors. The importance assignments are as follows:

Scale	Meaning	Scale	Meaning
1	the two are equally important		
3	the former is slightly more important than the latter	1/3	the former is slightly less important than the latter
5	the former is significantly more important than the latter	1/5	the former is significantly less important than the latter
7	the former is strongly more important than the latter	1/7	the former is strongly less important than the latter
9	the former is extremely more important than the latter	1/9	the former is extremely less important than the latter
2, 4, 6, 8	values in between the above scales	1/2, 1/4, 1/6, 1/8	values in between the above scales

Please provide a judgment matrix for the first-level indicators.

First-Level Indicators	U_1: Information Awareness and Attitude	U_2: Information Ethics, Law and Security	U_3: Information Knowledge and Skills	U_4: Information Integration and Innovation
U_1: information awareness and attitude	1			
U_2: information ethics, law and security		1		
U_3: information knowledge and skills			1	
U_4: information integration and innovation				1

Please provide a judgment matrix for the secondary indicators.

Second-Level Indicators	U_{11}: Information Awareness	U_{12}: Information Attitude
U_{11}: information awareness	1	
U_{12}: information attitude		1

Second-Level Indicators	U_{21}: Information Ethics and Law	U_{22}: Information Security
U_{21}: information ethics and Law	1	
U_{22}: information security		1

Second-Level Indicators	U_{31}: Information Foundation and Operation	U_{32}: Information Acquisition Methods	U_{33}: Information Management	U_{34}: Information Evaluation and Utilization
U_{31}: information foundation and operation	1			
U_{32}: information acquisition methods		1		
U_{33}: information management			1	
U_{34}: information evaluation and utilization				1

Second-Level Indicators	U_{41}: Information Integration and Collaboration	U_{42}: Problem Solving and Innovation and Creation
U_{41}: information integration and collaboration	1	
U_{42}: problem solving and innovation and creation		1

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