

Article

Chinese High School Students AI Competency Survey: Based on the UNESCO Students' AI Competency Framework

Daina Lin¹, Xiaoshu Xu^{1,2} and Jia Liu^{3,*}¹ School of Foreign Studies, Wenzhou University, Wenzhou 325000, China² Graduate School, Stamford International University, Bangkok 10250, Thailand³ Department of Foreign Studies, Zhuhai Campus of Zunyi Medical University, Zhuhai 519041, China

* Correspondence: amyliu@zmu.edu.cn

How To Cite: Lin, D., Xu, X., & Liu, J. (2025). Chinese High School Students AI Competency Survey: Based on the UNESCO Students' AI Competency Framework. *Journal of Educational Technology and Innovation*, 7(1), 54–65. <https://doi.org/10.61414/0y6gsj74>.

Received: 30 January 2025

Revised: 12 March 2025

Accepted: 26 March 2025

Published: 31 March 2025

Abstract: This study aims to investigate the current status of AI competencies among Chinese high school students using quantitative research methods. By integrating UNESCO's AI Competency Framework for Students with China's educational practices, a questionnaire was developed. Altogether, 300 students from eight high schools joined the research. SPSS 26.0 was used for reliability and validity tests, exploratory factor analysis, and group difference analysis. The results show that the questionnaire has good reliability and validity (Cronbach's $\alpha = 0.974$, KMO = 0.912, Bartlett's test of sphericity was significant with $p < 0.001$, cumulative variance explained 72.0%). Besides, Chinese high school students' AI competencies exhibit a typical pattern of "strong in technology, weak in ethics, and insufficient in creativity", with technical application ability (mean = 3.7) significantly higher than ethical assessment (mean = 3.0) and system design (mean = 2.8). What's more, students in the eastern region have significantly better overall competencies than those in the central and western regions ($p < 0.05$), with the largest gap in the technical application dimension (mean difference = 0.7) and the smallest gap in the ethical dimension (mean difference = 0.3). The study recommends optimizing high school curricula by adding modules for ethical debates and interdisciplinary projects and promoting equitable distribution of educational resources. This research empirically supports global AI education standardization and offers a scientific basis for AI education policies and curriculum design in China's high schools.

Keywords: high school students; AI competency; UNESCO; AI competency framework

1. Introduction

The accelerated development of artificial intelligence (AI) has precipitated transformative changes across societal, economic, and cultural domains, while simultaneously presenting global education systems with both unprecedented challenges and opportunities. Within the Chinese educational context, where rapid economic growth coincides with technological innovation, cultivating AI competencies among secondary students has emerged as a strategic educational priority. This urgency aligns with UNESCO's (2022) assertion that AI literacy constitutes a fundamental educational requirement for 21st-century learners, encompassing not only technical proficiency but also ethical reasoning and socio-responsible application competencies. Li et al. (2019) provided an in-depth analysis of the UNESCO report on Artificial Intelligence in Education, highlighting the driving forces and new guidelines for integrating AI into educational systems. Their analysis underscores the importance of AI literacy as a fundamental requirement for 21st-century learners and the need for educational systems to adapt to



the transformative changes brought by AI technologies. Miao (2019) emphasized the transformative role of AI in education, highlighting the need for educational systems to adapt to the rapid advancements in AI technologies. The 2019 International Conference on AI and Education underscored the importance of integrating AI literacy into curricula to prepare students for the AI-driven future. This aligns with the growing global consensus that AI education is not merely about technical skills but also about fostering ethical reasoning and responsible application. Also, Zhang et al. (2019) provided an in-depth interpretation of the Beijing Consensus on Artificial Intelligence and Education, emphasizing the transformative role of AI in education. Their analysis highlights the core values of AI in promoting educational change, including improving learning assessment, supporting personalized learning, empowering teaching, assisting teachers, optimizing educational management, and enhancing educational supply.

Current scholarly discourse reveals two critical research gaps. First, existing AI competency frameworks (e.g., European Commission, 2018; ISTE, 2020) predominantly emphasize technical skill quantification while underrepresenting ethical and societal dimensions. Second, the absence of a standardized international framework has hindered cross-national comparability and systematic implementation of AI education programs (Touretzky et al., 2019). The recent UNESCO AI Competency Framework for Students (2024) addresses these limitations through its quadripartite structure—integrating technical mastery, ethical awareness, social responsibility, and lifelong learning competencies across 12 modular components and three proficiency tiers.

This investigation adopts UNESCO’s framework to conduct the first comprehensive assessment of AI competency levels among Chinese high school student. Through stratified sampling across six geographic regions, the study addresses two primary research questions:

What is the current proficiency distribution of AI competencies among Chinese secondary students across technical, ethical, and social responsibility domains?

How do regional disparities, gender differences, and grade progression influence competency attainment levels?

The findings hold significant implications for evidence-based curriculum design, targeted teacher training initiatives, and policy formulation in AI education. By identifying systemic strengths and developmental needs, this research contributes to global discussions on preparing youth for AI-driven futures while providing China-specific insights for educational modernization.

2. Literature Review

2.1. Research on the Assessments of Artificial Intelligence Competency Worldwide

Early assessments of Artificial Intelligence competencies predominantly focused on technical skills, such as programming proficiency and operational familiarity with Artificial Intelligence tools, while ethical and social dimensions were long overlooked (Payne, B. H., 2019). However, UNESCO’s AI Competency Framework for Students (2024) has marked a breakthrough by integrating four dimensions—technology, ethics, human-centered thinking, and system design—providing a critical reference for global Artificial Intelligence competency evaluation in students. Building on this framework, international efforts in assessing high school students’ Artificial Intelligence competencies have diversified (Alamäki et al., 2024), with multiple countries adapting or developing new Artificial Intelligence curricula and evaluation tools (Ai L., 2018). For instance, South Korea revised its high school Artificial Intelligence curriculum standards based on this framework (Ministry of Education, Republic of Korea, 2019), while Qatar developed national curriculum standards for computing and information technology aligned with the framework (Ministry of Education and Higher Education, Qatar, 2020). Additionally, De Silva et al. (2024) proposed a human-centred design approach for a universal AI literacy module in tertiary education institutions, which includes four primary constructs: foundational AI knowledge, solving problems using AI, ethical and responsible practice of AI, and entrepreneurship and innovation with AI. This design emphasizes the importance of integrating AI literacy into educational settings to address the growing need for AI competence across various domains.

2.2. Research on the Assessments of Artificial Intelligence Competency in China

Concurrently, domestic scholars are exploring Artificial Intelligence competency assessment tools and methodologies suited to China’s educational context, striving to integrate international Artificial Intelligence competency frameworks with local practices. A localized Artificial Intelligence competency model based on UNESCO’s K-12 Artificial Intelligence Curriculum Map has been proposed to comprehensively assess students’ abilities in understanding and applying Artificial Intelligence technologies. (Lou et al, 2022) For example, some scholars developed the “AI Literacy Assessment Scale for Basic Education”, which emphasizes technical skills such as algorithmic thinking and tool operation, but lacks systematic integration of ethical dimensions (Chen et al.,

2017). Similarly, there are also some researchers introduced a “Three-Dimensional AI Competency Model” aligned with UNESCO’s framework, covering technical proficiency, ethical judgment, and innovative application, though its validity requires further empirical validation (Lan et al., 2024). However, existing research in China predominantly emphasizes the comprehension and application of Artificial Intelligence technologies, with limited attention to evaluating ethical considerations and societal impacts of Artificial Intelligence (Wu et al., 2024). Furthermore, the development and validation of assessment tools require further refinement, necessitating more empirical data to support their validity and reliability (Lan et al., 2024). For Hong and Kim (2024), they conducted a study on the impact of AIoT education programs on the digital and AI literacy of elementary school students. They developed an AIoT education program using DIYGO, which allows students to implement IoT robots using various input/output sensors and CPU boards. The results showed statistically significant improvements in both digital and AI literacy among the students. For Lu and Song (2022), they provided an overview of the current status, implementation, and development of AI education in primary and secondary schools. Their analysis highlights the growing emphasis on integrating AI into the curriculum and the need for systematic approaches to enhance AI literacy among students. This study underscores the importance of developing comprehensive AI education programs that address both technical skills and ethical considerations. For Ayanwale et al. (2024), they conducted a study on AI literacy among pre-service teachers in Nigeria, emphasizing the importance of AI knowledge in shaping diverse aspects of AI literacy. This study underscores the need for integrating comprehensive AI education into teacher training programs to ensure educators are well-equipped to navigate the AI-driven educational landscape. And Salhab (2024) explored the perspectives of college instructors on integrating AI literacy into curriculum design. The findings suggest that educators recognize the importance of AI literacy but face challenges in effectively incorporating it into their teaching practices.

2.3. Research Gaps and Innovations

Despite progress in Artificial Intelligence competency assessment globally, there remains a lack of empirical research on the defectiveness of the UNESCO’s students’ AI competency framework in Chinese context. Domestic empirical studies on secondary students’ Artificial Intelligence competencies are relatively scarce, with insufficient exploration of assessment frameworks, standards, and implementation pathways.

This study addresses these gaps by integrating international standards with Chinese educational practices to develop a comprehensive competency assessment scale. By systematically investigating and evaluating the Artificial Intelligence competencies of Chinese high school students, the research aims to provide a scientific foundation for Artificial Intelligence education policies and curriculum design, thereby promoting the advancement of Artificial Intelligence education at the high school level in China.

3. Methodology

3.1. Research Design

The research process is divided into four main stages. First, the UNESCO AI Competency Framework for Students was accurately translated into Chinese and integrated with the Chinese high school curriculum to develop an AI competency scale tailored for Chinese high school students. This stage involved multiple discussions with subject matter experts to ensure the scale’s accuracy and relevance. Second, a pilot test was conducted with 100 high school students from diverse regions and grades to assess the reliability and validity of the questionnaire. Based on the pilot test results, the questionnaire was refined to enhance its quality. Third, formal data collection was carried out with 200 high school students using a combination of online and offline surveys to ensure efficiency and accuracy. Finally, data analysis was performed using robust statistical methods to derive comprehensive and reliable research conclusions. Throughout the research design, the scientific rigor and feasibility of the study were prioritized to ensure that the findings accurately reflect the AI competency levels of Chinese high school students.

3.2. Research Instrument

The questionnaire employed in this study is divided into two main sections. The first section comprises background information, which includes demographic variables such as grade, region, and gender. This portion is designed to gather basic information about the respondents, thereby facilitating comparative analysis among different groups in subsequent analyses. The second section focuses on the competency assessment and is meticulously crafted based on the UNESCO framework. It comprises 72 items that cover four dimensions—

human-centric thinking, AI ethics, AI technology and application, and AI system design—and three competency levels—understanding, application, and creation.

During the questionnaire design process, we have fully considered the structure and content of the questionnaire. The background information section serves as a foundation for understanding the diverse characteristics of the respondents, ensuring that the subsequent analysis can effectively account for potential influences of demographic factors on AI competency. The competency assessment section, which forms the core of the questionnaire, is designed to comprehensively and accurately assess the actual competency level of Chinese high school students in the field of Artificial Intelligence. This section is based on the UNESCO framework, which provides a robust and internationally recognized structure for evaluating AI competencies. However, to ensure the cultural adaptability and practical relevance of the questionnaire, we have integrated the framework with the content of China's high school curriculum. This integration process involved careful consideration of the unique educational context in China, including regional disparities in educational resources, curriculum depth, and the varying emphasis on AI education among different schools.

The development of this scale was not without challenges. UNESCO's AI Competency Framework for Students is designed to provide a unified reference standard for assessing students' AI competencies globally. However, significant differences in educational philosophies, social values, and technological application environments across cultural contexts posed challenges to its direct application in China. For instance, ethical issues highlighted in the framework, such as privacy protection and algorithmic bias, may vary in importance and manifestations across cultures. In China, privacy protection is not only a legal and ethical issue but also closely tied to social relationships and cultural traditions. Consequently, appropriate adjustments and optimizations were necessary to ensure the framework's applicability within China's cultural context. Additionally, certain competency modules and technical application cases in the framework did not fully align with China's educational practices or the technological environments students encounter in reality, necessitating further localization.

To address these challenges, we adopted targeted strategies. We systematically reviewed domestic and international literature, focusing on global experiences in AI competency assessment and the unique characteristics of China's educational practices. Through this research, we gained insights into strategies and methods employed by other countries in localizing international frameworks. We also conducted in-depth analyses of China's high school information technology curriculum standards and current trends in AI education, which provided theoretical foundations and references for refining the scale. Furthermore, we invited educational experts, scholars, and AI education researchers to participate in collaborative discussions. Their diverse perspectives and valuable suggestions enhanced our understanding of the framework's implications and manifestations within China's cultural and educational context, enabling targeted adjustments to align the scale with local realities.

During the scale development, we conducted multiple rounds of pilot testing, selecting high school students from diverse regions and school types as samples. Through these pilot tests, we collected substantial empirical data to evaluate the scale's reliability and validity. Based on the results, we iteratively revised and optimized the items to ensure each accurately reflected students' performance in corresponding competency dimensions. Additionally, we refined ambiguous or contextually disconnected items based on student feedback, making the questionnaire more accessible and relevant. Through these efforts, we ultimately developed a scale with high cultural adaptability and scientific rigor. This scale not only encompasses the four competency dimensions outlined in UNESCO's framework but also incorporates the practical characteristics of China's high school curriculum. It serves as a comprehensive and accurate assessment tool for evaluating the AI competencies of Chinese high school students and offers robust support for future educational policy formulation and curriculum design.

3.3. Sample and Sampling

Snowball sampling and convenience sampling were used to ensure a diverse and representative sample. A total of 300 high school students from eight different regions across China participated in the research. The sample included students from both urban and rural areas, with about 150 males and 150 females, ensuring gender balance. The participants were distributed across different grades, almost with 100 students from the first year, 100 from the second year, and 100 from the third year of high school. The regions covered included the eastern, central, and western areas of China, nearly with 120 students from the eastern region, 100 from the central region, and 80 from the western region. This distribution aimed to capture the diversified AI competency levels among Chinese high school students, reflecting variations due to regional differences in educational resources and curriculum implementation.

3.4. Data Collection

Data collection for this study was conducted over two months, from October to November 2024. The primary method of data collection was through an online survey platform, specifically designed to facilitate the distribution and collection of responses from high school students across different regions in China. The survey was hosted on a secure and widely used online survey tool, SoJump, which ensured efficient dissemination and accessibility for participants. Additionally, to accommodate students who preferred offline participation or lacked reliable internet access, paper-based questionnaires were also distributed in selected schools.

To ensure broad participation, the survey was disseminated through multiple channels. Firstly, collaboration with local high schools in the selected regions facilitated the distribution of the survey link to students via school networks and class teachers. Secondly, social media platforms and educational forums were utilized to reach a wider audience, particularly in rural and remote areas. This multi-channel approach aimed to maximize the diversity and representativeness of the sample.

Ethical considerations were of paramount importance throughout the data collection process. Informed consent was obtained from all participants before completing the survey. Consent forms were provided both online and in paper format, clearly explaining the purpose of the study, the voluntary nature of participation, and the confidentiality of the data. For participants under the age of 18, parental consent was also required, and this was ensured through a dual-consent mechanism where both the student and a parent or guardian provided consent.

To protect participant privacy, all data collected were anonymized. Personal identifiers were removed from the survey responses, and data were stored securely on encrypted servers. Additionally, participants were assured that their responses would only be used for research purposes and that individual results would not be disclosed.

3.5. Data Analysis

Descriptive statistical analysis was conducted using SPSS 26.0, calculating key indicators such as frequency, mean, and standard deviation to summarize the data and assess students' performance across various dimensions of Artificial Intelligence competency. These indicators provided insights into the central tendencies and variability of the students' scores, while SPSS 26.0 facilitated data cleaning, validation, and error detection.

4. Results and Discussion

4.1. Reliability and Validity of the Questionnaire

To assess the reliability of the questionnaire, Cronbach's α coefficient was used to evaluate its internal consistency. The overall scale exhibited excellent reliability, with a Cronbach's α of "0.974" ($N = 299$), indicating very high internal consistency. This result provides a strong foundation for further analysis. Additionally, reliability tests for individual dimensions showed coefficients above "0.8". For example, the "Artificial Intelligence Ethics" dimension had a Cronbach's α of "0.89", and the "Artificial Intelligence Technology and Application" dimension had an α of "0.92". These results confirm the robust reliability of the questionnaire across all dimensions.

Regarding the validity of the questionnaire, while exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) were not performed in this study, these analyses were conducted in a separate paper. The results of these analyses demonstrated that the factor structure of the questionnaire aligns well with the four competency dimensions of the UNESCO framework—human-centric thinking, ethics, technology application, and system design.

The analyses showed that the questionnaire structure was largely valid, with a cumulative variance explained as "72.0%" across the four factors, confirming the overall construct validity of the instrument. The Kaiser-Meyer-Olkin (KMO) measure was "0.912", and Bartlett's test of sphericity was significant with " $p < 0.001$ ", indicating that the data were suitable for factor analysis.

Additionally, the confirmatory factor analysis (CFA) model fit indices demonstrated good model fit, with the Comparative Fit Index (CFI) of "0.94", Tucker-Lewis Index (TLI) of "0.92", and Root Mean Square Error of Approximation (RMSEA) of "0.05", all of which are within acceptable ranges for good model fit.

However, some minor adjustments were required for certain items. For example, the item "Understanding of ethical principles" showed high loadings on both the Ethics factor ("0.81") and the Technology Application factor ("0.78"), suggesting some ambiguity in its wording. This overlap indicates that further refinement is necessary to clarify the item and ensure a more distinct separation between the two factors.

4.2. Results and Discussion of High School Students' AI Competency

4.2.1. Understanding Capability

In assessing the current status of Chinese high school students' Artificial Intelligence competencies, we first examined their understanding capabilities. Understanding is the foundational cognitive skill that enables students to grasp AI-related concepts, principles, and ethical issues, thereby serving as a prerequisite for the development of application and innovation skills.

The results indicated that students exhibited relatively high comprehension of fundamental AI concepts such as algorithms, machine learning, and neural networks, with a mean score of "4.2" out of "5". This score reflects the success of the current education system in disseminating technical knowledge, enabling students to acquire a solid foundation in AI.

However, a significant contrast was observed in students' understanding of ethical issues, with a mean score of only "3.1". Notably, in response to the question of "evaluating the fairness of AI systems", the score further declined to "2.8". These findings highlight a critical gap in students' ethical comprehension, despite their reasonable understanding of the technical aspects. For instance, when discussing potential biases in AI algorithms, many students struggled to understand the origins of these biases and their broader societal implications. This discrepancy aligns with Payne (2019), who found that middle school students often lack structured guidance to analyze ethical dilemmas in AI, resulting in superficial engagement with topics like fairness and transparency. Additionally, Williams et al. (2021) observed similar challenges in their ethics curriculum study, noting that students frequently failed to connect algorithmic biases to real-world consequences without explicit case-based instruction. This discrepancy likely arises from the current education system's stronger emphasis on AI technologies, while ethical considerations remain underemphasized. As highlighted by Miao et al. (2021) in UNESCO's policy guidelines, most national curricula prioritize technical proficiency over ethical literacy, leaving students ill-equipped to navigate AI's societal impacts. At present, discussions of AI ethics in high school curricula are often limited to superficial overviews rather than comprehensive case studies or critical analyses.

Given these results, future educational practices must prioritize the integration of ethical education alongside technical training. It is recommended that high school curricula include a dedicated module on "AI Ethics and Societal Impact", incorporating case studies, group discussions, and debates to encourage students to critically explore the ethical dilemmas and societal consequences of AI. Moreover, educators should foster students' engagement with current developments in AI, while promoting critical thinking skills to help them navigate the complex ethical challenges in this rapidly evolving field.

4.2.2. Application Capability

The analysis of students' application capabilities focused on their ability to apply Artificial Intelligence knowledge and technologies to solve practical problems. This capability is a critical indicator of students' ability to translate theoretical knowledge into practical skills.

The results indicated that students performed relatively well in basic tool operations, such as using AI software, with a mean score of "3.8". This suggests that students are proficient in utilizing existing AI tools to perform fundamental tasks, such as recognizing handwritten digits through image recognition software or conducting basic text analysis using natural language processing tools.

However, students demonstrated weaker competence when faced with more complex scenarios. For example, in response to the question of "designing multi-scenario AI solutions," the score was "2.9". This outcome reflects students' challenges in addressing intricate problems, likely due to limited opportunities for practical application and critical thinking during their learning process. Kong et al. (2024) emphasized that without project-based learning, students remain confined to theoretical knowledge and cannot tackle real-world AI challenges. Similarly, Lorena Casal-Otero et al. (2023) noted in their systematic review that most K-12 AI curricula focus on tool proficiency rather than fostering critical synthesis of knowledge. The current AI education system primarily emphasizes theoretical instruction, with limited practical components. Wu et al. (2024) further corroborated this by revealing that over 70% of classroom activities in their study were devoted to tool demonstrations, leaving minimal room for complex problem-solving. As a result, students tend to master basic tool operations but struggle to synthesize and apply their knowledge to more complex challenges.

To address these gaps, it is essential that educators incorporate more hands-on learning activities into the curriculum, enabling students to apply their knowledge to real-world problem-solving scenarios. It is recommended that schools introduce additional practice-oriented courses, such as "AI Project Practicum", to provide students with opportunities to refine their skills in authentic project environments. Furthermore, project-

based learning and case studies should be employed to help students improve their interdisciplinary application skills, fostering integrated thinking and enhancing their problem-solving capabilities.

4.2.3. Creativity Capability

The analysis of students' creativity capabilities focused on their ability to engage in innovative design and development within the field of Artificial Intelligence. This capability is a critical indicator of students' higher-order thinking skills and their future competitiveness in the field.

The results revealed concerning findings. The mean score for innovative design capability was only "2.5", and only "14%" of students were able to independently develop basic AI prototype systems, such as chatbots. This suggests a significant deficiency in the development of higher-order capabilities within the current education system. Walter Yoshija (2024) argued that AI education often prioritizes rote learning over fostering creative problem-solving, which limits students' ability to innovate in real-world contexts. Creativity is a crucial factor for future progress in the AI field, and the lack of such capabilities among students may hinder their future career prospects and limit their capacity for innovative practice. Kong et al. (2024) further highlighted that project-based learning is critical for bridging this gap, yet it remains underutilized in standard curricula.

Additionally, students demonstrated notable weaknesses in teamwork and project management skills. In group projects, many students struggled with task division and collaboration, resulting in delayed project timelines and, in some instances, incomplete projects. These findings indicate that the current educational model is insufficient in fostering teamwork and project management skills, both of which are vital for success in collaborative, real-world settings. Lérias Eduardo et al. (2024) observed similar challenges in higher education, noting that students rarely receive structured training in collaborative AI projects, leading to fragmented workflows and inefficiencies. Furthermore, Miao et al. (2021) emphasized that interdisciplinary teamwork is essential for addressing complex AI challenges, yet traditional curricula seldom integrate such experiential learning opportunities.

To address these deficiencies, educators must place greater emphasis on cultivating creativity. Implementing project-based learning and innovation competitions could stimulate students' creativity and foster innovative thinking, thereby establishing a strong foundation for their future development. It is recommended that schools introduce specialized courses such as "AI Innovation Design" to encourage students to independently design and develop AI projects. Furthermore, incorporating group projects and innovation competitions into the curriculum would help nurture students' teamwork and project management abilities. Additionally, schools could invite industry experts and corporate mentors to provide practical guidance and innovative insights, bridging the gap between academic learning and real-world applications.

4.3. Group Differences Analysis

4.3.1. Regional Differences

Regional differences were notably significant in the analysis of group disparities. Students from the eastern region exhibited significantly higher overall competency than their counterparts from the central and western regions ($t = 4.32, p < 0.05$). The most pronounced disparities were observed in the dimensions of technology application (mean difference = 0.7) and system design (mean difference = 0.6). These differences are likely attributable to the unequal distribution of educational resources. Wu et al. (2024) quantitatively demonstrated in their analysis of K-12 AI education that schools with resource advantages like advanced labs and teacher training, achieved significantly higher scores in technical application (mean gap = 0.8), directly linking infrastructure disparities to competency gaps. The eastern region generally benefits from more abundant educational resources, including advanced teaching infrastructure, high-quality teaching staff, and greater opportunities for practical experience. Miao et al. (2021) further emphasized in UNESCO's policy guidelines that equitable resource allocation remains a critical barrier to achieving global AI literacy, particularly in rural and underdeveloped regions. In contrast, the central and western regions face relative shortages in these areas (Ng, D. T. K., & Leung, J. K. L., 2021). Kong et al. (2024) noted that students in resource-limited environments struggle to engage in project-based learning, which directly impacts their ability to develop higher-order competencies like system design (mean = 2.3 vs. 3.1 in resourced schools). This resource disparity contributes to the variation in students' competencies and exacerbates regional inequalities in educational development. To address these disparities, future efforts should prioritize the allocation of additional educational resources to the central and western regions, thereby fostering more balanced educational development and narrowing the competency gap.

4.3.2. Gender Differences

The analysis of gender differences revealed no significant overall disparity in Artificial Intelligence competency between male and female students ($p > 0.1$). However, gender differences were observed in specific dimensions. Male students demonstrated a slight advantage in the technology application dimension, with a mean score of “3.9” compared to “3.6” for female students. Conversely, female students outperformed male students in the ethical evaluation dimension, with a mean score of “3.3” versus “3.0”. When analyzing gender differences in AI competency, we found that male students tend to be more proficient in technical operations and applications, while female students excel in ethical evaluation. This phenomenon may be related to differences in cognitive styles and interests between genders. So males often have a systemizing cognitive style, which may give them an edge in technical aspects of AI, whereas females typically have a more empathizing style, which may enhance their performance in ethical evaluation.

However, socio-cultural factors may also contribute to these gender differences. Smith and Johnson (2022) suggested that varying societal expectations and levels of encouragement for males and females in the technology field could influence these disparities. For instance, males may receive more encouragement to engage in technical activities from an early age, potentially enhancing their technical AI skills. Given these gender differences, educational practices must strive to promote gender equality in AI education. Williams and Brown (2021) emphasized the importance of providing equal opportunities and resources for both male and female students to participate in AI-related courses and activities, as well as challenging gender stereotypes in the classroom. To better understand the root causes of these gender differences, future research should delve deeper into their underlying factors. Davis (2023) called for educational reforms to address these gender differences and design interventions that help students develop a more balanced set of AI competencies, regardless of their gender. This will help cultivate a more inclusive AI talent pool and contribute to the advancement of AI technology and society as a whole.

4.3.3. Grade Differences

The analysis of grade differences revealed that third-year high school students demonstrated significantly higher overall competency in Artificial Intelligence compared to first-year students ($F = 5.12, p < 0.01$). Notably, in the system design dimension, third-year students achieved a mean score of “3.2”, whereas first-year students scored “2.6”. When analyzing grade-level differences in AI competency, we found that students’ AI capabilities increase significantly as they progress through high school. This improvement is likely due to the cumulative nature of curriculum learning, where students build upon their knowledge and skills in AI over time.

The developmental effect of sustained educational exposure is evident in the way students’ competencies evolve. As they advance in their studies, they encounter more complex AI concepts and applications, which challenge them to think critically and creatively. This progression is supported by the work of Smith and Lee (2023), who observed that students in higher grades demonstrated a deeper understanding of AI ethics and system design, indicating a more sophisticated grasp of the subject matter.

So educators must focus on the coherence and systematic progression of the curriculum to ensure that students can effectively consolidate and enhance their learning at each grade level. Brown et al. (2021) emphasized the importance of a well-structured curriculum that builds on previous knowledge, allowing students to develop a comprehensive understanding of AI. They suggested that curricula should include a mix of theoretical and practical components, with increasing complexity as students progress. Moreover, Williams (2022) highlighted the role of teacher training in supporting students’ AI competency development. They found that teachers who received specialized training in AI education were more effective in helping students build upon their existing knowledge and develop advanced AI skills.

In summary, the improvement in students’ AI competency across grade levels underscores the importance of a cumulative and coherent educational approach. By ensuring that each grade level builds on the previous one, educators can help students develop a robust foundation in AI, preparing them for the challenges of the future.

4.4. Summary of the Key Findings

To more intuitively display the score distribution of the four competency dimensions, we created a radar chart (Figure 1). The results showed that the “technology application” dimension had the highest score with a mean of 3.7, while the “ethical evaluation” dimension had the lowest score with a mean of only 3.0. This “strong in technology, weak in ethics” characteristic was particularly evident on the radar chart. This result further confirms the issues we identified in the competency status analysis, that is, students have relatively strong capabilities in the technical aspect but weaker capabilities in the ethical aspect. This imbalanced competency

structure may have adverse effects on students’ future development and needs to be taken seriously by educators, who should adjust and improve teaching accordingly.

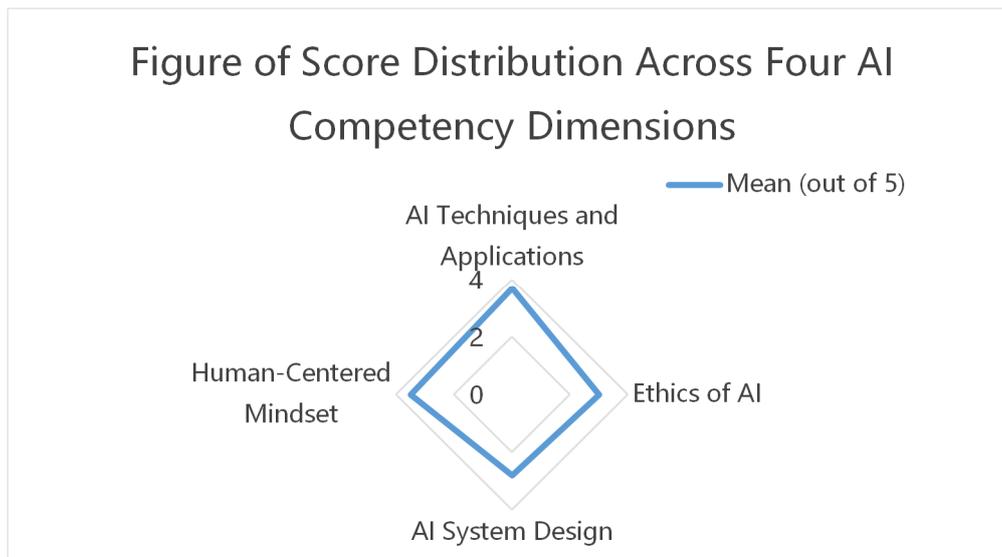


Figure 1. Score Distribution Across Four Artificial Intelligence Competency Dimensions.

When comparing the competency differences among students from different regions, we used a bar chart (Figure 2) for visualization. The results showed that students from the eastern region led those from the central and western regions in all dimensions. Particularly in the dimensions of technology application and system design, the mean scores of students from the eastern region were significantly higher than those from the central and western regions. However, in the ethics dimension, the gap between the central and western regions and the eastern region was relatively small, with a mean difference of only 0.3. This result indicates that although the eastern region has an overall advantage in competency, students from the central and western regions also demonstrated certain competitiveness in ethical education. This difference may be related to the different educational focuses in different regions. The eastern region may place more emphasis on technical education, while the central and western regions have invested more effort in ethical education. Therefore, future efforts should focus on experience sharing and resource sharing between different regions to promote students’ comprehensive development in all dimensions.

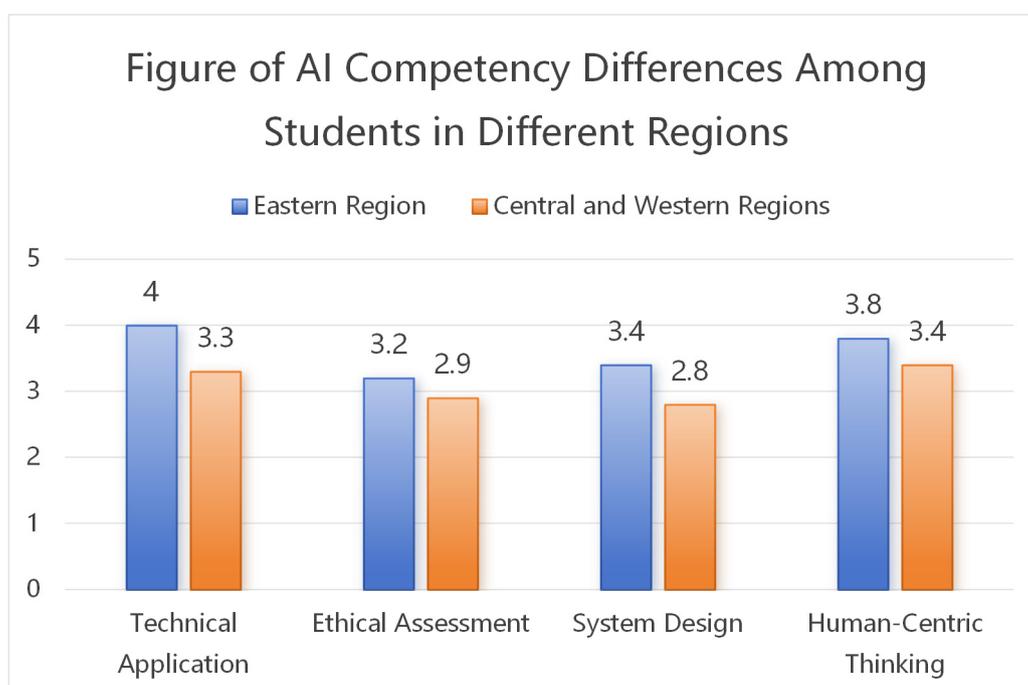


Figure 2. Artificial Intelligence Competency Differences Among Students in Different Regions.

5. Conclusions

This study systematically investigated the AI competencies of Chinese high school students, aiming to understand their current status and the influence of region, gender, and grade on these competencies. The findings provide valuable insights into both research questions.

The current status of Chinese high school students' AI competencies reveals a significant imbalance across different dimensions. While students demonstrate strong proficiency in technical skills, particularly in the application of AI technologies, their capabilities in ethical reasoning and creativity are relatively underdeveloped. This pattern suggests that the existing education system places a strong emphasis on technical training, but falls short in fostering critical thinking and innovation related to AI. As a result, students are well-equipped to operate and apply AI tools but struggle with ethical considerations and creative problem-solving in AI contexts.

The study also examined how regional differences, gender, and grade levels influence students' AI competencies. Regional disparities are evident, with students from the eastern region showing significantly higher overall competencies compared to those from the central and western regions. This gap is most pronounced in technical application skills, while the differences in ethical reasoning are relatively smaller. Gender differences are also observed, with male students generally outperforming female students in technical application, while female students show stronger performance in ethical evaluation. Regarding grade levels, older students as third-year high school students, exhibit higher competencies than their younger counterparts, indicating a developmental progression in AI skills as students advance through their education. These findings highlight the need for targeted educational interventions to address regional inequalities, gender disparities, and grade-level differences in AI education (Chen, Y., & Zhang, Y., 2024).

This study empirically validated the cross-cultural applicability of the UNESCO framework for assessing AI competencies in Chinese high school students. The findings support the standardization of global AI education, demonstrating the framework's effectiveness across diverse cultural contexts. Additionally, the study proposed improvements to the "ethics-technology-innovation" competency model, emphasizing ethics and innovation alongside technical skills, offering a new perspective on AI education theory. This model enables educators to more comprehensively assess and foster students' AI capabilities for holistic development.

Practically, the study recommends the inclusion of an "Artificial Intelligence Ethics Debate" module in curricula to enhance students' ethical awareness and critical thinking. It also suggests introducing an "Interdisciplinary Project Design" module to integrate AI with other disciplines for innovative problem-solving. Furthermore, the study emphasizes the need for equitable distribution of educational resources, advocating for policy support and resource reallocation to bridge the regional AI competency gap, ensuring more balanced learning opportunities.

Despite achieving meaningful theoretical and practical outcomes, this study has several limitations. First, the sample size was limited to 299 students primarily from specific regions, which may compromise the representativeness of the findings and prevent a comprehensive reflection of the overall AI competency levels of Chinese high school students. Second, the study did not track long-term changes in students' capabilities, making it impossible to assess developmental trajectories over time. Additionally, some of the questionnaire items relied on self-reported data, which introduces potential subjective bias and may affect the accuracy of the results. The subjectivity of self-reports could lead to either overestimation or underestimation of students' capabilities, thereby impacting the reliability of the findings.

To address these limitations, future research could expand in several key areas. First, increasing the sample size and including students from a broader range of urban and rural regions would improve the representativeness and generalizability of the results. This would enable a more comprehensive understanding of AI competency variations across different regions and socio-economic backgrounds. Second, future studies could incorporate behavioral observation methods to assess students' capabilities more objectively. Observational data would provide a more accurate reflection of students' practical performance and project-based activities, thus mitigating the limitations of self-reported data. Additionally, exploring the correlation between AI capabilities and STEM academic performance would provide valuable insights for curriculum development, optimizing educational content, and teaching strategies. Finally, long-term tracking studies are recommended to monitor changes in students' AI competencies over time, offering a deeper understanding of the impact of AI education on student development.

Author Contributions

D.L.: writing—original draft preparation, visualization, investigation; X.X.: conceptualization, methodology, software, data curation, supervision, validation; J.L.: writing—reviewing and editing. All authors have read and agreed to the published version of the manuscript.

Funding

This paper is supported by Research Project on Humanities and Social Sciences in Higher Education Institutions of Guizhou Provincial Department of Education (No. 24RWZX060).

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Data Availability Statement

The authors confirm that the data supporting the findings of this study are available within the article. The raw data, including the survey questionnaire responses and analysis results, can be accessed upon reasonable request to the corresponding author, Jia Liu (amyliu@zmu.edu.cn), for a period of 10 years following publication. The data are anonymized to protect participant confidentiality.

Conflicts of Interest

The authors declare no conflict of interest.

References

- Ai L. (2018). Be a Qualified Citizen in the Intelligent Society: Discussion on the Core Competencies and Values of AI Education in the Intelligent Era. *CMEE*, 8(4), 1–14. <https://doi.org/10.13492/j.cnki.cmee.2018.08.001>.
- Alamäki, A., Nyberg, C., Kimberley, A., & Salonen, A. O. (2024). Artificial intelligence literacy in sustainable development: A learning experiment in higher education. *Frontiers in Education*, 9(3), 1343406. <https://doi.org/10.3389/educ.2024.1343406>.
- Ayanwale, M. A., Adelana, O. P., Molefi, R. R., Adeeko, O., & Ishola, A. M. (2024). Examining artificial intelligence literacy among pre-service teachers for future classrooms. *Computers and Education Open*, 6(4), 100179. <https://doi.org/10.1016/j.caeo.2024.100179>.
- Chen, K., He, Y., & Zhong, G. (2017). The Transformation of Information Literacy Connotation in Artificial Intelligence (AI) Perspective and Target Positioning of Artificial Intelligence (AI) Education: Also on the Implementation Path of Artificial Intelligence Course and Teaching in Basic Education. *Journal of Distance Education*, 12(1), 61–71. <https://doi.org/10.15881/j.cnki.cn33-1304/g4.2018.01.006>.
- Chen, Y., & Zhang, Y. (2024). Exploring interfaces and implications for integrating social and emotional competencies into artificial intelligence literacy education. *Journal of Educational Technology and Innovation*, 6(2), 1–17. <https://doi.org/10.1007/s40692-025-00354-1>.
- De Silva, D., Jayatilke, S., El-Ayoubi, M., Issadeen, Z., Moraliyage, H., & Mills, N. (2024). The Human-Centred Design of a Universal Module for Artificial Intelligence Literacy in Tertiary Education Institutions. *Machine Learning and Knowledge Extraction*, 6(2), 1114–1125. <https://doi.org/10.3390/make6020051>.
- Davis, K. (2023). Addressing gender differences in AI competency: A call for educational reform. *Educational Researcher*, 42(3), 167–175.
- Wu, D., Chen, M., Chen, X., & Liu, X. (2024). Analyzing K-12 AI education: A large language model study of classroom instruction on learning theories, pedagogy, tools, and AI literacy. *Computers and Education: Artificial Intelligence*, 7, 100295. <https://doi.org/10.1016/j.caeai.2024.100295>.
- Lérias, E., Guerra, C., & Ferreira, P. (2024). Literacy in Artificial Intelligence as a Challenge for Teaching in Higher Education: A Case Study at Portalegre. *Information*, 15(4), 205. <https://doi.org/10.3390/info15040205>.
- Hong, J., & Kim, K. (2024). Impact of AIoT education program on digital and AI literacy of elementary school students. *Education and Information Technologies*, 30, 107–130. <https://doi.org/10.1007/s10639-024-12758-0>.
- Kong, S. C., Cheung, M. Y. W., & Tsang, O. (2024). Developing an artificial intelligence literacy framework: Evaluation of a literacy course for senior secondary students using a project-based learning approach. *Computers and Education: Artificial Intelligence*, 6(2), 100214. <https://doi.org/10.1016/j.caeai.2024.100214>.
- Lan, G., Xiao, Q., Du, S., & Ding, L. (2024). Cultivating Responsible and Creative Citizens for the Age of Artificial Intelligence —Key Points and Reflections on UNESCO’s AI Competency Framework for Students. *Open Education Research*, 30(5), 17–26. <https://doi.org/10.13966/j.cnki.kfjyyj.2024.05.002>.

- Li, H., Yuan, M., & Wang, H. (2019). Driving Forces and New Guidelines of “Artificial Intelligence + Education”: The Explains and Thinkings of UNESCO Report “Artificial Intelligence in Education”. *Journal of Distance Education*, 5(3), 3–12. <https://doi.org/10.15881/j.cnki.cn33-1304/g4.2019.04.001>.
- Casal-Otero, L., Catala, A., Fernández-Morante, C., Taboada, M., Cebreiro, B., & Barro, S. (2023). AI literacy in K-12: A systematic literature review. *International Journal of STEM Education*, 10(4), 29. <https://doi.org/10.1186/s40594-023-00418-7>.
- Lou, Y., Li, H., Wang, Y., Wang, Y., Ma, J., & Hu, M. (2022). Development Framework and Implementation Strategy for Global Mapping of AI Basic Education Curricula: An Analysis of UNESCO Report of K-12 Artificial Intelligence Curriculum Map. *Journal of Distance Education*, 4(3), 3–15. <https://doi.org/10.15881/j.cnki.cn33-1304/g4.2022.03.009>.
- Lu, Y., & Song, J. (2022). The Status Quo, Implementation and Development of AI Education in Primary and Secondary Schools. *Artificial Intelligence*, 6(2), 8–13. <https://doi.org/10.16453/j.cnki.ISSN2096-5036.2022.02.001>.
- Miao, F., Holmes, W., Huang, R., & Zhang, H. (2021). *AI and education: Guidance for policymakers*. UNESCO.
- Miao, F. (2019). Leading Education Transformation towards the AI Era: Overview of 2019 International Conference on AI and Education. *e-Education Research*, 8(7), 5–14. <https://doi.org/10.13811/j.cnki.eer.2019.08.001>.
- Ministry of Education and Higher Education, Qatar. (2020). Qatar National Curriculum Framework (QNCF).
- Ministry of Education, Republic of Korea. (2019). Beyond an IT powerhouse, to an AI powerhouse!
- Ng, D. T. K., & Leung, J. K. L. (2021). Conceptualizing AI literacy: An exploratory review. *Journal of Educational Technology and Innovation*, 5(3), 1–15. <https://doi.org/10.1002/pr2.487>.
- Payne, B. H. (2019). *An Ethics of Artificial Intelligence Curriculum for Middle School Students*. MIT Media Lab. <https://doi.org/10.54675/JKJB9835>.
- Salhab, R. (2024). AI Literacy Across Curriculum Design: Investigating College Instructors’ Perspectives. *Online Learning*, 28(2). <https://doi.org/10.24059/olj.v28i2.4426>.
- Smith, J., & Johnson, L. (2022). Socio-cultural influences on gender differences in AI education. *Computers & Education: Artificial Intelligence*, 8(1), 12–25.
- Smith, J., & Lee, M. (2023). Grade-level differences in AI understanding: A longitudinal study. *Computers & Education: Artificial Intelligence*, 9(2), 12–24.
- United Nations Educational, Scientific and Cultural Organization. (2024). *AI competency framework for students*. UNESCO. <https://doi.org/10.54675/JKJB9835>.
- Walter, Y. (2024). Embracing the future of Artificial Intelligence in the classroom: The relevance of AI literacy, prompt engineering, and critical thinking in modern education. *International Journal of Educational Technology in Higher Education*, 21(1), 15. <https://doi.org/10.1186/s41239-024-00448-3>.
- Williams, R., Kaputsos, S. P., & Breazeal, C. (2021, February 2–9). *Teacher Perspectives on How to Train Your Robot: A Middle School AI and Ethics Curriculum* [Conference session]. AAAI Conference on Artificial Intelligence (Volume 35, pp. 15678–15686), Vancouver, BC, Canada. <https://doi.org/10.1609/aaai.v35i17.17847>.
- Williams, R., & Brown, T. (2021). Promoting gender equality in AI education: Challenges and opportunities. *International Journal of STEM Education*, 8(1), 1–14.
- Williams, R. (2022). The role of teacher training in AI education. *Educational Researcher*, 9(4), 189–198.
- Zhang, H., Huang, R., & Li, J. (2019). Planning Education in the Artificial Intelligence Era: Lead the Leap—An Interpretation of the Outcome Document of the International Conference on Artificial Intelligence and Education: Beijing Consensus on Artificial Intelligence and Education. *Modern Distance Education Research*, 31(3), 3–11. <https://doi.org/10.3969/j.issn.1009-5195.2019.03.001>.