Advancing AI Education in Elementary and Middle Schools: Challenges, Strategies, and a Path Forward for National Technological Leadership in China

Executive Summary

Artificial Intelligence (AI) represents a critical focal point for national dominance in the international technological competition in the future. The dissemination of AI education at the foundational educational stages holds vital strategic significance for the nation to maintain its leading position in technological development. Technologically advanced countries have already initiated a series of measures concerning top-level educational design, teacher training, cross-sector and cross-disciplinary collaboration, and widespread promotion.

This report involved a questionnaire survey of 449 elementary and middle school students and discovered a strong desire and diverse motivation for learning AI. However, it found that learning channels were limited, cognitive levels were relatively shallow, and there were significant group differences, with initial signs of differentiation in career planning at the secondary school stage.

A questionnaire survey and interviews were conducted with 199 elementary and middle school teachers. The majority acknowledged the value of popularizing AI education at the elementary and middle school levels but had a relatively broad understanding of it, generally unified ideas and plans for AI education, a common lack of teaching experience, and average self-assessment of competence. The report also included interviews with 12 teachers and experts from local education departments, industry researchers, school principals, enterprise personnel, and social organization members.

The interviews identified ongoing disputes in advancing AI popularization education at the elementary and middle school levels. The research reflected the difficulties and challenges faced in this field: the need for improvement in systematic curriculum construction, a severe shortage of specialized teachers, a lack of systematic teacher training, insufficient support mechanisms, and underutilization of extracurricular technological education resources. This report calls for close collaboration among all sectors of society to jointly participate in the undertaking of popularizing AI education at the elementary and middle school levels. It also recommends focusing on perfecting top-level educational system design, emphasizing teacher training and development, designing relevant curriculum content guided by core competencies, and fully considering regional, inter-school, and inter-student differences to collectively promote AI popularization education in elementary and middle schools.

Settings

In July 2017, the State Council of China released the “New Generation Artificial Intelligence Development Plan,” explicitly stating China’s gradual implementation of comprehensive intelligent education projects. The plan encompasses the introduction of artificial intelligence (AI)-related courses at the elementary and secondary school stages, the progressive promotion of programming education, and encouragement for societal participation in the development and promotion of engaging programming teaching software and games.

Another significant thrust in AI education is through the “Double First-Class University” initiative, launched in 2017 under Chinese President Xi Jinping. This initiative builds upon previous educational reforms, such as Projects 211 and 985, aiming to create world-class universities. Subsequently, in April 2018, China's Ministry of Education issued the “Education Informatization 2.0 Action Plan,” outlining the enhancement of curriculum schemes and standards and the enrichment of AI and programming course content, adapted to the developmental needs of the information and intelligent era.

Methodology

In this research, we utilized questionnaires with 449 students and 199 teachers, interviews with 12 experts, and an Ordinary Least Squares (OLS) statistical method to analyze factors influencing AI cognitive levels in elementary and middle schools.

To examine the possible factors influencing the cognitive level of artificial intelligence, the initial hypothesis was that there is a correlation among middle and elementary school students' interest in certain subjects (English, Mathematics, and Technology courses) and their level of participation in technological activities (such as visits to technology museums and frequency of participation in technological competitions) with their cognitive level of artificial intelligence. To explore this, a series of multiple regression analyses, including several regression equations, were conducted to preliminarily investigate the pattern of the influence of various factors on students' cognitive levels of artificial intelligence. The analyses indicated a significant positive correlation between the preference for technology courses in middle and elementary schools and the cognitive level of artificial intelligence. Similarly, the frequency of participation in technological activities such as visits to technology museums and technological competitions were also significantly positively correlated with the cognitive level of artificial intelligence. Furthermore, interest in technology courses in middle and elementary schools was significantly positively correlated with the two indicators of visits to technology museums and participation in technological competitions, creating a mediated effect through these activities. Since the correlation between preferences for English and Mathematics courses and the cognitive level of artificial intelligence was not significant, these were removed from the regression model.

Limitations: This quantitative survey research has been conducted using a sampling study method, and its data results are influenced by the sample. Due to the limitations of the research method and sample, as well as restrictions in the scope of data collection, the survey data only represents the basic situation of this particular project.

The execution of this quantitative survey was subject to time constraints, which impacted communication and increased difficulty during the period of end-of-term examinations and summer vacation in various schools. This had a definite effect on the quantity of sample collection.

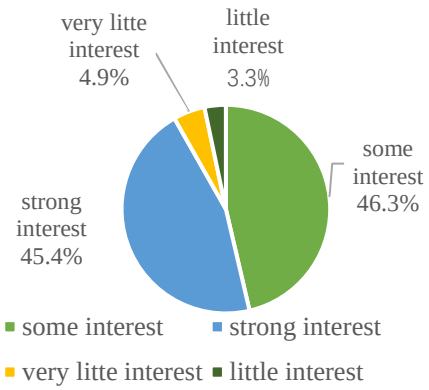
Furthermore, the quantitative survey was limited by the attributes of the student sample. Elementary and secondary students, particularly those in lower grades, have a limited capacity to handle complex questions, display unstable response stability, and exhibit inadequacies in self-perception and expressive ability. These factors objectively influence the scope of the survey and the accuracy of its results to a certain extent.

Key Findings

Primary and Secondary School Students Finding 1: Strong Interest in Learning Artificial Intelligence

Primary and secondary school students generally express a desire to learn more about content related to artificial intelligence. In a recent survey, 46.3% of students indicate “some interest,” 45.4% express “strong interest,” a mere 3.3% demonstrate “little interest,” and 4.9% indicate “very little interest.” Comparatively speaking, students with better academic performance show a markedly stronger interest in learning, and male students exhibit a higher proportion of interest.

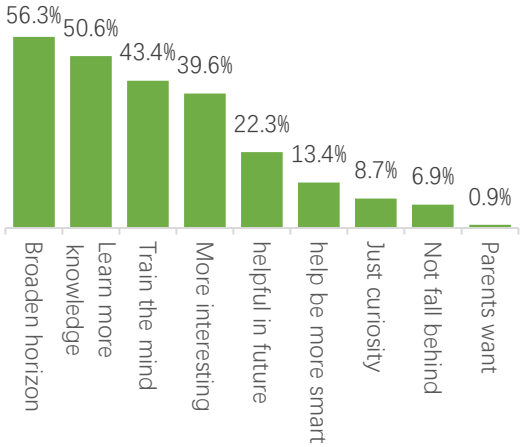
Figure 1. Primary and Secondary School Students Who Want to Learn AI



Primary and Secondary School Students Finding 2: Broadening Horizons, Acquiring Knowledge, Training Thought Processes, and Interest Serve as Main Driving Forces

The primary motivators for primary and secondary school students to engage with artificial intelligence learning at this stage are the broadening of horizons (56%), the acquisition of additional knowledge (50.6%), the training of thought processes (43.4%), and the experience of enjoyment (43.4%). While desiring to enhance personal quality and ability through artificial intelligence education, students also exhibit a pronounced interest in and anticipation for AI popularization education.

Figure 2. Reasons Why Primary and Secondary School Students Want to Learn AI



Primary and Secondary School Students Finding 3: A Majority of Students Self-Report Understanding the Concept of Artificial Intelligence; Noticeable Differences Among Schools and Learning Achievements

Nearly 80% of primary and secondary school students indicate some understanding of the concept of artificial intelligence. A comparative analysis shows that students in demonstration schools have a significantly higher level of understanding of artificial intelligence than those in ordinary schools, and students with above-average academic performance have a deeper knowledge.

Figure 3. Cognitive self-evaluation of primary and secondary school students on AI

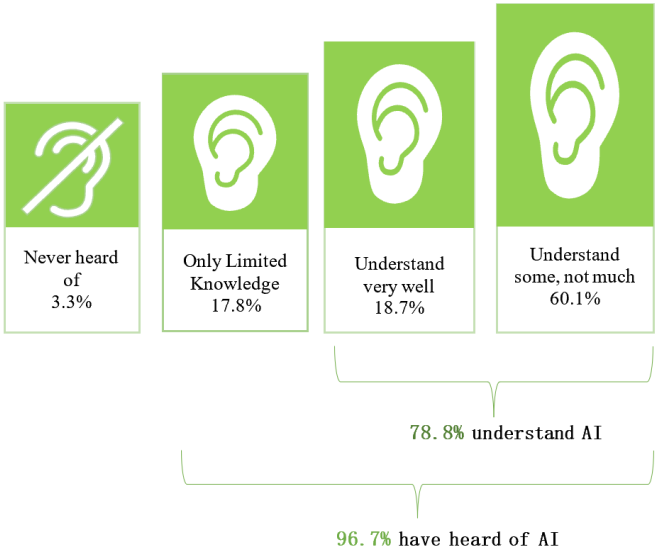
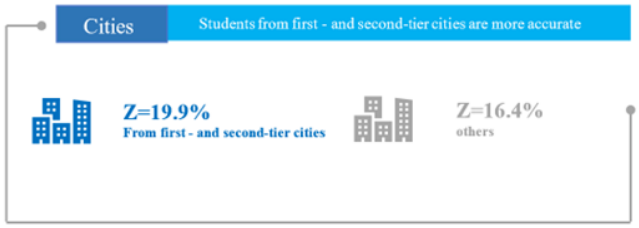
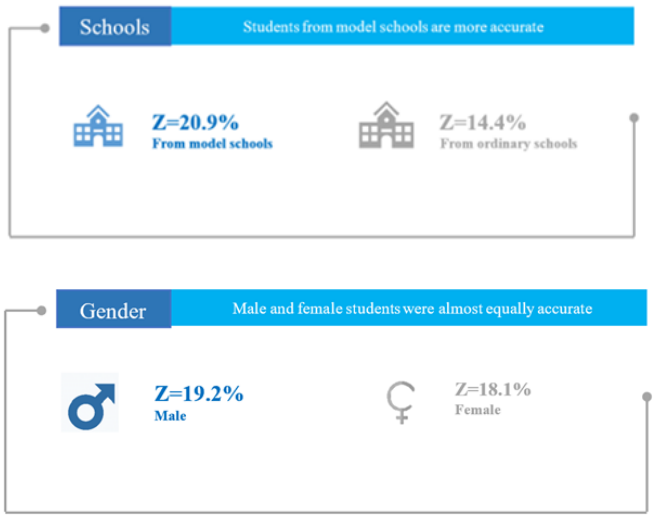


Figure 4. Difference of Cognitive Accuracy of AI Among Primary and Secondary School Students





Primary and Secondary School Students Finding 5: Students' Understanding of Artificial Intelligence is Superficial, Often Relying on Sensory and Concrete Levels

Students' understanding of artificial intelligence is generally shallow, largely depending on life experience and intuitive recognition, remaining at sensory and concrete levels. They have good recognition of functions in everyday life with strong interpersonal interactions, such as conversational robots, autonomous driving, voice-controlled air conditioning, etc., but struggle with abstract functions like fingerprint door locks, social media home page recommendations, and image searches. The most difficult area for students involves discerning the principles of artificial intelligence, with only 24.3% answering correctly, predominantly among junior and senior high school students.

Figure 5. Tools or Functions that Primary and Secondary School Students Think Are Used in AI

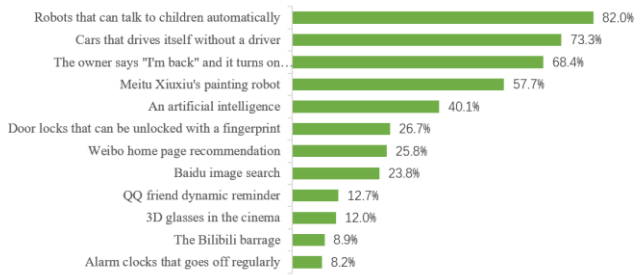
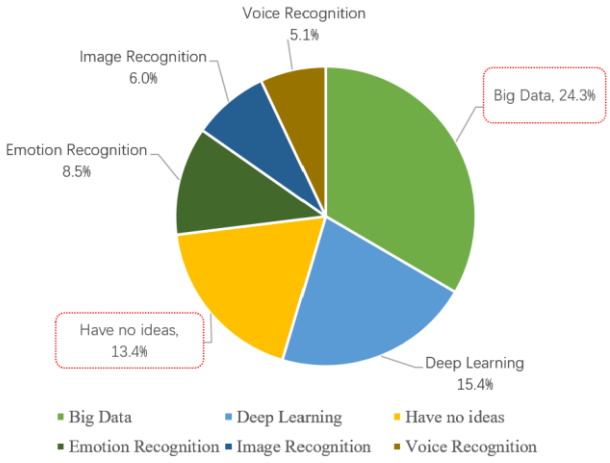


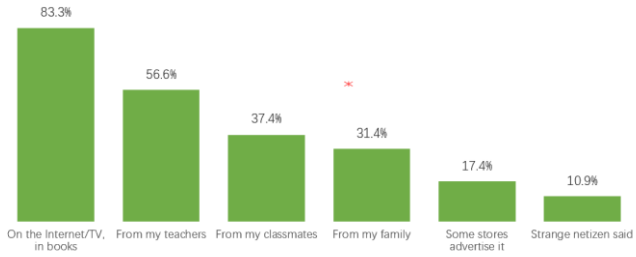
Figure 6. Answers to "Which is not AI Technology?"



Primary and Secondary School Students Finding 6: Mainly Self-Motivated Exploration of Artificial Intelligence

The majority of primary and secondary school students explore artificial intelligence on their own initiative, accounting for 83.3%, higher than the 56.6% who learn from teachers. Overall, at this stage, there is a lack of sufficient systematic and diversified sources of AI popularization and educational learning among these students, leaving substantial room for expansion in future AI learning channels for primary and secondary school students.

Figure 7. Channels for Primary and Secondary School Students to Understand AI



Primary and Secondary School Students Finding 7: Initial Signs of Career Planning Diversification at the Secondary School Level

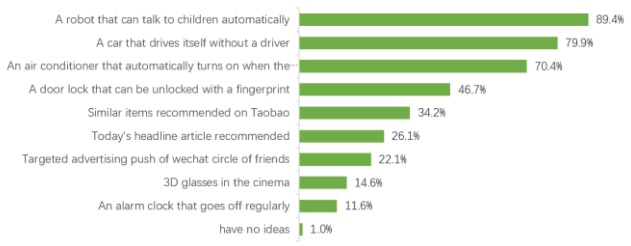
Secondary school students' preferences for learning artificial intelligence are highly correlated with career planning in science and technology fields. Those with a strong interest in AI studies exhibit clear inclinations towards scientific research, computing, and engineering professions, with more defined career planning, while those without any career planning account for only 4.7%.

Figure 8. Future career planning prototype of middle school students with strong interest in AI learning

Primary and Secondary School Teachers Finding 1: Superficial Understanding of Artificial Intelligence Applications

The surveyed teachers demonstrated a comprehensive understanding of artificial intelligence applications in practical everyday scenarios, but a lack of familiarity with more abstract business intelligence; their knowledge of various technical branches of artificial intelligence is also relatively limited, with only 29.1% able to answer correctly, and 10.1% explicitly stating "I don't know."

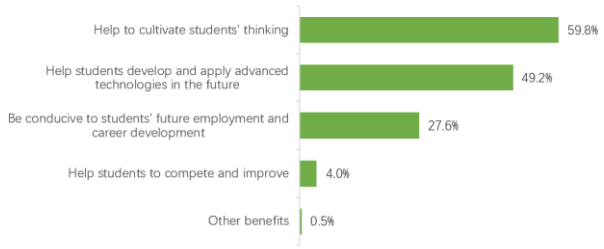
Figure 9. Tools that Elementary and secondary School Teachers think of that apply AI



Primary and Secondary School Teachers Finding 2: Strong Affirmation of the Necessity and Value of AI Education in Primary and Secondary Schools

AI education in primary and secondary schools is well-received by frontline teachers, with 78.9% believing that it is essential for students to learn about AI-related content. They primarily value AI education's potential in "fostering students' thinking skills" (59.8%) and its role in aiding future research, development, and application of advanced technology (49.2%).

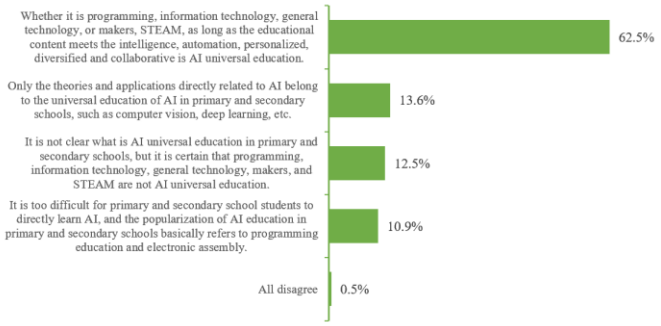
Figure 10. Value of "Primary and Secondary School Students Learning AI" from Primary and Secondary School Teachers' perspectives



Primary and Secondary School Teachers Finding 3: Broad Understanding of AI Education in Primary and Secondary Schools

62.5% of teachers possess a relatively broad understanding of AI education in primary and secondary schools, largely agreeing with the view that education content that satisfies criteria such as intelligence, automation, personalization, diversity, and collaboration falls under AI education. In contrast, 13.6% have a stricter interpretation, while 10.9% believe a more explicit focus is needed for implementation, such as programming education.

Figure 11. Understanding of The Scope of AI Education in Primary and Secondary Schools



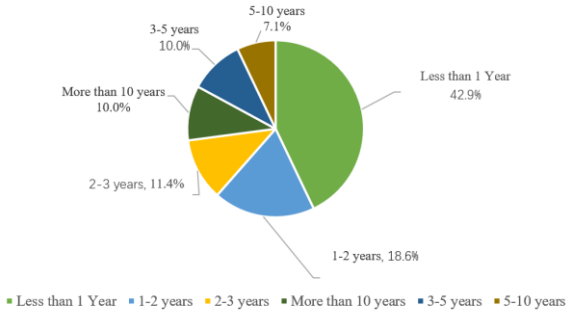
Primary and Secondary School Teachers Finding 4: Unified Approach to AI Education

Teachers generally concur that elementary education should focus on cultivating interest, and middle school should deepen cognitive and intellectual development. Learning evaluations are recommended to be project-based presentations, with a gradual progression from collective projects in elementary school to individual projects and written forms in later stages.

Primary and Secondary School Teachers Finding 5: Relative Lack of Educational Experience

Although the majority of surveyed teachers come from demonstration schools in the eastern and central regions, only 35.2% have taught AI-related content. Additionally, the teaching experience in AI-related subjects is generally short, with 42.9% having less than one year, 18.6% less than two years, and experienced teachers being a minority.

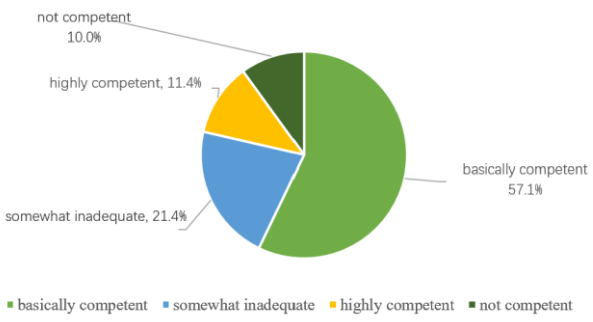
Figure 12. Number of Teaching Years of Teachers Who Have Taught AI



Primary and Secondary School Teachers Finding 6: Inadequate Teaching Competence

Among teachers who self-reported teaching AI-related content, 57.1% consider themselves basically competent, 21.4% feel somewhat inadequate, and only 11.4% regard themselves as highly competent. The main factors influencing teachers' self-evaluation of teaching competence are their professional background and practical experience, with teachers possessing a computing background feeling more confident, while those lacking practical experience exhibit less confidence in their teaching abilities.

Figure 13. Teachers' Sense of Competence in Their Experience of AI Education



Possible Factors Influencing the Cognitive Level of Artificial Intelligence

There is a significant positive correlation between

the preference for technology courses in middle and elementary schools and the cognitive level of artificial intelligence. Similarly, the frequency of participation in technological activities such as visits to technology museums and technological competitions were also significantly positively correlated with the cognitive level of artificial intelligence.

Figure 14. Three variables affect the cognitive level of AI

AI cognitive level	Beta	F
Preference for technology courses	0.328**	20.320**

AI cognitive level	Beta	F
Visits to technology museums	0.135**	29.371**

AI cognitive level	Beta	F
Participation in technological competitions	0.069**	35.363**

Furthermore, interest in technology courses in middle and elementary schools was significantly positively correlated with the two indicators of visits to technology museums and participation in technological competitions, creating a mediated effect through these activities. Since the correlation between preferences for English and Mathematics courses and the cognitive level of artificial intelligence was not significant, these were removed from the regression model.

Figure 15. Mediated Effects

Visits to technology museums	Beta	F
Preference for technology courses	0.806**	36.837**

Participation in technological competitions	Beta	F
Preference for technology courses	1.535**	28.623**

Insights that can be drawn from the data include the importance of cultivating interest in technology courses and participating in technological activities as essential factors in enhancing students' artificial intelligence cognition. These could be considered as educational entry points for implementing artificial intelligence popularization efforts. The survey results also revealed that the vast majority of middle and elementary school students (96.4% for science courses and 96.6% for technology courses) affirm the value of technology courses, suggesting that science and technology subjects could be integrated points for AI education within classroom learning.

Additionally, there is room for improvement in students' participation in technological activities: only 52.3% of students visit a technology museum at least once every six months, and 38.8% of the 75.3% who have participated in competitions have participated in technology-related competitions, with only 5.1% participating in AI competitions. Overall, artificial intelligence popularization education is still in its early stages, and further research is needed to determine how to combine it with extracurricular practice activities.

Discussions and Challenges

Definition of AI Education in elementary and middle schools. In the interviews, education industry experts, academics and primary and secondary school teachers expressed divergent opinions on how to define AI education in elementary and middle schools.

One perspective advocate for a broader definition of AI popularization education at this stage, without stipulating a specific and singular focus.

Three primary reasons support this view:

- Owing to China's vast territory and substantial disparities in educational development, a uniform definition might

exclude many regions and schools lacking the necessary conditions, and simultaneously hinder areas and schools with better conditions from leveraging their advantages.
- The richness of AI's inherent connotation and extension renders the boundaries of AI popularization education correspondingly ambiguous.
- The current practice of AI popularization education has not developed to a point that can sustain discussions on conceptual definitions; the fundamental issue is to clarify the purpose of AI popularization education in elementary and middle schools.

Another viewpoint argues for a more precise focus and content delineation for AI popularization education at this stage, such as programming, to facilitate practical implementation, management, supervision, and assessment by schools and teachers.

- One mentioned that "AI popularization education can be understood in both broad and narrow senses. Broadly, it includes any activity related to AI (intelligent hardware, children's programming, general technology, etc.). Narrowly, it should reflect what AI experts' study, which teachers should teach. However, a narrow understanding presents a problem as we are not aiming to train all students to become AI experts (since only a minority will choose AI as a profession). It is better to take a broader view, as 'this is just the beginning, and the concept should not be too rigidly defined, otherwise its future development may be limited."
- Another comment highlighted that "current AI refers to some rather advanced technologies, but the connotation and extension of a subject can change, and once prioritized by the state, the extension will expand. Perhaps, learning AI in elementary and middle schools means learning programming, which is unproblematic."

Besides, the understanding of the concept of AI popularization education among frontline elementary and middle school teachers can be summarized as follows:

- Whether it's programming, information technology, general technology, makers, or STEAM, if the educational content satisfies criteria of intelligence, automation, individualization, diversification, and collaboration, it's considered AI popularization education.
- Only theories and applications directly related to AI fall under the purview of elementary and middle school AI popularization education, such as computer vision, deep learning, etc.
- Some teachers were unclear about what constitutes AI popularization education but were certain that programming, information technology, general technology, makers, and STEAM were not part of it.
- Some teachers believed that learning AI directly is too difficult for elementary and middle school students, and AI popularization education at these levels essentially involves programming education and electronic assembly.

Agenda of AI Education in Primary and Secondary Schools. In the recent survey conducted, the respondents, who are primarily engaged in the education sector, demonstrated varying opinions regarding the agenda of introducing AI education in primary and secondary schools. Among the participants, 91.5% of frontline primary and secondary school teachers believe it is essential first to clarify the connotation and extension of "AI popularization education" before engaging in educational practice and promotion. This perspective is also endorsed by some researchers in the industry and corporate experts. Their primary consideration is that understanding the conceptual framework will better guide practical operations.

However, some researchers in the related industry argue that at this stage, it is not necessary to have a clear understanding of the concept. They mainly consider that AI popularization education has not

yet developed to a level that can support conceptual discussions. Moreover, defining the concept is not a fundamental issue; the real question is the purpose of AI popularization education.

Among the teachers who believe it is necessary, many teachers are confused about the boundaries of AI popularization education, such as what content falls within the realm of AI and what does not. This confusion is natural given the interdisciplinary nature of AI, encompassing software, hardware, theory, and technology. However, this confusion also needs to be resolved, especially with the rapid development of AI and internet-related technologies. Many professional concepts, such as deep learning, have specific definitions, but public perceptions lack clear boundaries, like "AI+." Therefore, there is a need to define what AI is, what AI popularization education should teach, and how it should be taught at different stages of primary and secondary education. "If it is to be a course, there must be standards. Many teachers are really unclear about what an AI course is. Without specific standards, it will be chaotic."

Among the teachers who believe it is not that necessary, there are two main voices:

- (Practice First) "Educational theory must be abstracted from practice, not imagined. Our practice has not reached that level; it cannot be imagined. Practice is the mother of theory." "The connotation and extension of the concept are bestowed by humans. We should first do the content well and then define it. Do the work well before studying the concept."
- (Education Purpose First) "From an educational point of view, we should consider what ability we hope children will gain in AI popularization education, what they will acquire at different ages, and then talk about what is suitable for primary and secondary schools. Technology is just a carrier; we should look more at the educational goals and the phased implementation path, rather than considering what is AI popularization education and what is not."

The surveyed primary and secondary school frontline teachers have significant differences in opinions on this issue. 54.8% of teachers believe that a separate subject should be set up for AI popularization education, with a frequency of 1-2 times a week. 45.2% of teachers think that AI popularization education should be integrated into existing subjects, such as robotics/makers/STEAM, information technology, programming, science classes, etc.

Independent or Convergent Implementation of AI Education in Primary and Secondary Schools. The survey analysis reveals divergent opinions on the implementation of AI education in primary and secondary schools. Some respondents, mainly researchers and teachers, favor integrating AI into existing subjects, citing content compatibility, student workload, and scheduling constraints as key considerations. A hybrid approach is also advocated, allowing for partial independence and integration based on content relevance and educational stage differences. A smaller group supports independent implementation, emphasizing the importance and flexibility of AI education. Finally, a segment focuses on content design rather than the mode of delivery, arguing that the quality of curriculum design is paramount.

The diversity of views highlights the complexity of introducing AI education, reflecting concerns about practicality, pedagogical appropriateness, and the unique needs of different educational stages. It underscores the need for a thoughtful approach that balances content relevance, student needs, logistical constraints, and educational goals in the incorporation of AI into the school curriculum.

Integration of AI Education into Existing Subjects or Activities: Among the surveyed population, the idea of integrating AI education into existing subjects or activities is primarily endorsed by researchers in relevant industries and some primary and secondary school teachers. The rationale behind this perspective can be categorized into three main areas:

- Content Compatibility: Some respondents argue that AI education can be seamlessly incorporated into comprehensive practical activities or even included as a chapter in information technology classes. The flexibility of AI education content makes it adaptable to the structure of various existing subjects.
- Student Workload Consideration: A significant portion of educators believes that AI education should not exacerbate the academic burden on students. Instead, it should be gracefully integrated into existing subjects, avoiding the creation of a separate and potentially overwhelming course.
- Scheduling Constraints: The logistical challenge of accommodating additional class hours for AI education is an acknowledged concern. Thus, the integration into other subjects is seen as a pragmatic solution to the scarcity of available class time.

Partial Independence and Partial Integration into Existing Subjects or Activities: This nuanced view, held by a mixture of industry researchers, primary and secondary school teachers, and social organizations, advocates for a hybrid approach. The considerations for this stance include:

- Content Compatibility: There's a proposition to introduce specialized AI courses, infusing them with humanities knowledge, while also allowing AI content to permeate other subjects, such as mathematics.
- Educational Stage Differences: The respondents note that cross-disciplinary teaching is essential at the primary level, but in high school, there is an opportunity to introduce a specific AI course, reflecting the maturity and readiness of students at different stages.
- Independent Implementation: A segment of primary and secondary school teachers firmly believes in the independent implementation of AI education. They argue that offering the course independently signals its importance, dismissing concerns about class hours, as schools have the flexibility to introduce AI within their unique curricular framework.
- Focus on Content Design: Lastly, some respondents emphasize that the debate between independent or integrated implementation is secondary. The crux of the matter, according to them, lies in the thoughtful design of the content. This perspective underscores the importance of a well-crafted curriculum that aligns with educational goals, irrespective of the mode of delivery.

Current Development Difficulties

The systematic construction of curricula spanning various educational stages requires further enhancement. Firstly, the initiation of textbook writing schemes is still pending, and a national debate is needed to decide whether a unified textbook should be adopted across the country or whether individual localities and schools should develop their own materials. The design of interdisciplinary curriculum frameworks must be carefully handled to align with existing subjects and avoid redundancy. Secondly, there has been no completion of standards for artificial intelligence (AI) education that would run through primary, secondary, and high schools. Moreover, evaluation mechanisms and guarantees for class hours have not yet been established, specifically manifested in the lack of corresponding standards, assessment mechanisms, and regulations to ensure the time allocated to AI education.

A mature system for teacher training and ongoing professional development has not been established. One significant bottleneck in implementing AI education in elementary and secondary schools is the lack of qualified teachers, making their training an urgent necessity.

Influenced by the scarcity of specialized teachers, self-evaluation of competence is generally low. Front-line teachers widely lack knowledge, teaching methods, and practical experience, resulting in a common situation where they are unsure how to conduct classes. Furthermore, the absence of professional development guidelines in the field leaves reserve teachers without a clear career path, thereby affecting the stability of the teaching staff.

In-school technological educational resources are not being utilized to their full potential. Research has found that out-of-school experiences such as visits to science venues and tech companies are factors affecting students' cognition levels in AI. In reality, the participation of elementary and secondary students in out-of-school technological activities still has room for growth. There is insufficient alignment between external technological educational resources, AI popularization resources, and the learning needs of elementary and secondary school students.

Implications and Recommendations

Integrate the "Core Competencies of Chinese Students" to Foster Rational Thinking, Critical Inquiry, and Innovative Exploration Abilities. Basic education should not be confined to the specific knowledge and techniques of artificial intelligence (AI) but should focus on cultivating students' core competencies within the context of AI education. Since AI encompasses multiple disciplines, existing elementary and secondary science courses, technology courses, and integrated practical courses form the content foundation and pedagogical medium for AI education. Guided by the "Core Competencies of Chinese Students," AI education should target the cultivation of scientific spirit and thinking abilities by integrating knowledge across different subjects. Such an approach aligns with educational principles and caters to the cognitive levels and ability requirements of elementary and secondary students. Solving the bottleneck and challenges of AI education at this stage primarily relates to teachers' professional abilities. High-quality elementary and secondary science and technology teachers will further help develop AI course resources tailored to different learning levels and stages. Teacher training should prioritize resources and be supported by diversified training mechanisms to enable more competent technology teachers to contribute both within and outside schools. This should be incorporated into the National Excellent Teacher Training Plan 2.0, focusing on collaboration between universities and schools, promoting reforms in training models, improving the quality of practical education, deepening international exchanges, and enhancing AI education-related teacher training and development.

Strengthen the Capacity Building of Science and Technology Education Teachers and Train Outstanding Teachers for AI Education. The ideal support mechanism for AI teacher training in elementary and secondary schools is characterized by diversified training methods, providers, and supports. Training methods can include offline intensive training, systematic university learning, online training, and self-study with online resources. Providers may encompass universities, research institutes, the research departments of tech companies, and exemplary schools. Lastly, training support can be mainly provided through special funds allocated by the education department, government support at all levels, training opportunities offered by schools, and resource aggregation platforms provided by related associations.

Construct a Comprehensive, Multi-level, and Operational Policy Guidance System. On the one hand, efforts must begin with top-level design to establish a comprehensive and three-dimensional policy support system covering macro guidance, curriculum standard formulation, teacher training, financial support, and mobilization of social resources. On the other hand, the policy must be stratified, allowing different regions to introduce guidance documents based on their educational development, aligning with realities and varying

priority areas.

Enhance Cross-Departmental Collaboration in Top-level Design and Build an Education Resource Aggregation Platform with Social Organizations as the Hub. Promoting AI education requires the state to more explicitly arrange top-level design, deployment of related science and technology education resources, and funding, identifying lead agencies to coordinate different social forces, and facilitate collaboration between departments. Considering China's context, the education administration should take the lead in mobilizing government resources for teacher reserves and continuous professional development; in the business world, leading tech companies should provide expert and technical support for AI education, and open spaces for student visits and practice; in social organizations, science and technology societies, and educational associations should lead in integrating academic groups, research institutes, science venues, and tech and education company resources, building social learning platforms for students and teachers, aligning in-school and out-of-school needs and resources, optimizing resource allocation, and enhancing the quality and efficiency of AI education.