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Application of Programming Education in the Cultivation of Children's Core Literacy

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This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The role of programming education in cultivating children's core literacy in the era of digital intelligence is becoming increasingly prominent. The article defines core concepts such as children's core literacy and programming education, and summarizes the relevant policies and measures of UNESCO, the European Union, and governments of various countries on core literacy and programming education; The role of programming education in children's intelligence literacy, information literacy, innovation literacy, and humanistic literacy was studied through case studies; Based on the cognitive patterns and developmental characteristics of children, methods suitable for children's programming education have been proposed; Analyzed the challenges faced by children's programming education and proposed targeted countermeasures.

Keywords: Programming education; core literacy; children; cultivation methods; problems countermeasures.

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1. INTRODUCTION

In the era of digital intelligence, the rapid development of artificial intelligence and digital technology has not only changed people's production and lifestyle, but also profoundly influenced their way of thinking and values. Therefore, the demand for core literacy in the era of digital intelligence has sharply increased. Adapting to and surpassing the times in thinking, scientific spirit, innovation ability, etc. have become the core literacy for the development of people in the era of digital intelligence (Wan, 2020; Era, 2023; Han, 2023). Children are the future of a country and the hope of a nation. Every country is committed to improving the core literacy of children in order to have a place in future global competition.

The methods adopted in this study are: (1) Literature review, by studying a large number of domestic and foreign documents, a deep understanding of the concept and connotation of children's core literacy has been gained; (2) Case practice method, through the practical teaching of children's programming cases, the impact pathways, methods and effects of programming education on children's core literacy in the digital and intelligent era are explored.

2. THE CONCEPT AND CONNOTATION OF CHILDREN'S CORE LITERACY AND PROGRAMMING EDUCATION

2.1 Age Definition of Children

According to the latest age segmentation proposed by the World Health Organization, the age range of seven to eighteen years old is classified as adolescents, with seven to twelve years old defined as children, corresponding to grades 1-6 of primary school in China; Thirteen to seventeen years old are considered teenagers. The children's programming education studied in this article is specifically focused on primary school programming education.

2.2 Core Literacy

Core literacy refers to the essential qualities and key abilities that individuals need to adapt to lifelong and social development needs (Chen & Zhao, 2024). It points to the fundamental question of 'what kind of people should education cultivate', covering various abilities such as knowledge, skills, emotional attitudes, etc. It is the most critical and necessary basic literacy. The cultivation of core literacy not only contributes to the comprehensive development of individuals and enhances their overall qualities, but also has positive value for society, promoting harmony and progress. It is the driving force behind education and curriculum reform.

2.3 Children's Core Literacy and its Composition

Children's core literacy is the key ability and excellent character that children must possess to adapt to future social needs and personal lifelong development (Sun, 2020). The core literacy of children in the era of digital intelligence includes aspects such as intelligence literacy, information literacy, innovation literacy, and humanistic literacy.

2.4 Programming Education

Programming education is mainly divided into two forms: visual programming and code programming (Li, 2023). Programming learning in primary school is not about students writing or running program code, but about understanding programming concepts through learning programming knowledge, thereby enhancing their logical thinking, computational thinking, and problem-solving abilities. Visual programming is particularly suitable for elementary school students, therefore, programming education can be defined as the process in which children use computers or other programming tools to create a series of instructions that enable objects (robots or computers, etc.) to perform corresponding actions or programs, solve specific tasks or problems, and develop their thinking abilities (Liu, 2021). A large amount of practice has shown that through visual programming, children can have a deeper understanding of the digital world they are in, focus on the logical structure in programming, and not overly pay attention to grammar details, which can reduce their learning burden.

3. RESEARCH STATUS OF CORE LITERACY AND PROGRAMMING EDUCATION

3.1 Research on Core Literacy

In 1996, UNESCO proposed four pillars of lifelong learning in its report "Education - Wealth Hidden within", namely learning to seek knowledge, learning to do things, learning to

coexist, and learning to survive (Wang, 2016). Later, "learning to change" was added as the fifth pillar. In recent years, UNESCO has further refined the composition of core literacy, proposing a complete system of core literacy consisting of four dimensions: cognitive ability, emotional attitude, social participation, and innovative practice. In 1997, the Organization for Economic Cooperation and Development (OECD) launched the "Definition and Selection of Literacy (Chen & Zhao, 2024): Theoretical and Conceptual Foundations" project, which promoted the construction of core literacy frameworks in countries around the world. In 2000, EU member states held a summit in Lisbon, the capital of Portugal, with the aim of establishing a core competency system that could serve as a common educational goal for EU member states. In 2006, the EU released the final version of the Core Competency Framework, which includes eight areas: native language communication skills, foreign language communication skills, mathematical and technological literacy, information literacy, learning to learn, social and civic literacy, innovation and entrepreneurship, cultural awareness and performance. Each area is composed of three dimensions: knowledge, skills, and attitudes (Chen, 2023). The core concept is to enable all EU citizens to have lifelong learning abilities, so that they can achieve personal success and economic and social development in the challenges of globalization and the knowledge economy (Wang, 2016).

In 2014, the Chinese Ministry of Education issued the "Opinions on Fully Deepening Curriculum Reform and Implementing the Fundamental Task of Moral Education", which first proposed the concept of "core literacy". The core literacy of Chinese students' development are centered on cultivating "well-rounded individuals", which are divided into three aspects: cultural foundation, independent development, and social participation. The comprehensive manifestations include six major competencies: humanistic heritage, scientific spirit, learning to learn, healthy living, responsibility, and practical innovation (Shi, 2024).

3.2 Research on Programming Education

The UK was one of the first countries to implement mandatory education in computational thinking and programming in schools. In 2014, it introduced the "Computer Science" curriculum, which requires children to start learning programming and computer science knowledge from the age of 5 and complete secondary education at the age of 16; The US government is also actively promoting children's programming education, with relevant policies mainly formulated by state education departments. For example, New York City public schools have launched the "Computer Science Education Program," providing children's programming courses and incorporating them into school curricula; The EU focuses on promoting the digital transformation of the entire education process, tailoring teaching to the different stages of individual student growth. According to the requirements of the EU 2020 Strategy, 21 member states including Ireland, Germany, Belgium, Portugal, and Poland have made computer programming a compulsory course in primary schools; Finland adopts an interdisciplinary approach to programming education; South Korea also included programming education in the regular compulsory curriculum of primary schools in 2018 (Zhu, 2022). The Singapore government has incorporated children's programming education into its national education policy and launched the "Programming for the Future" program to cultivate students' computational thinking and creativity, helping them gain a competitive advantage in the field of technology.

In recent years, China has also accelerated the pace of catching up with the world's children's programming education. In 2018, the Ministry of Education of China issued the "Education Informatization 2.0 Action Plan", which requires enriching the content of artificial intelligence and programming courses that meet the needs of the information age and intelligent age. In 2019, the Ministry of Education began to promote the establishment of artificial intelligence related courses in primary and secondary schools, gradually promoting programming education (Gong, 2021). Different levels of programming teaching should be implemented in different stages, learning to use programming to solve practical problems, and cultivating basic literacy in the information age such as computational thinking and innovative thinking (Cai, 2022).

4. THE ROLE OF PROGRAMMING EDUCATION IN CULTIVATING CHILDREN'S CORE LITERACY

Applying programming education to children's education practice can promote the improvement of children's core literacy.

4.1 The Cultivation of Intelligent Literacy Through Programming Education.

Intelligent literacy refers to the comprehensive qualities demonstrated by individuals to adapt to the needs of life, learning, and work. The era of digital intelligence is manifested in individuals' exploration, understanding, application, and appreciation of artificial intelligence. Programming education can cultivate children's logical thinking ability, problem-solving ability, human-computer collaboration ability, etc (Alam & Hasan, n.d.).

4.1.1 Cultivate logical thinking ability

Programming itself is a process that requires rigorous logical thinking, following certain logical rules and syntax. It requires children to break down complex problems into a series of simple and executable steps, and express these steps logically through actions or programs (Mafara & Abdullahi, 2024). In this process, children need to use logical thinking abilities such as classification, induction, and inference to promote their rationality and orderliness in daily life.

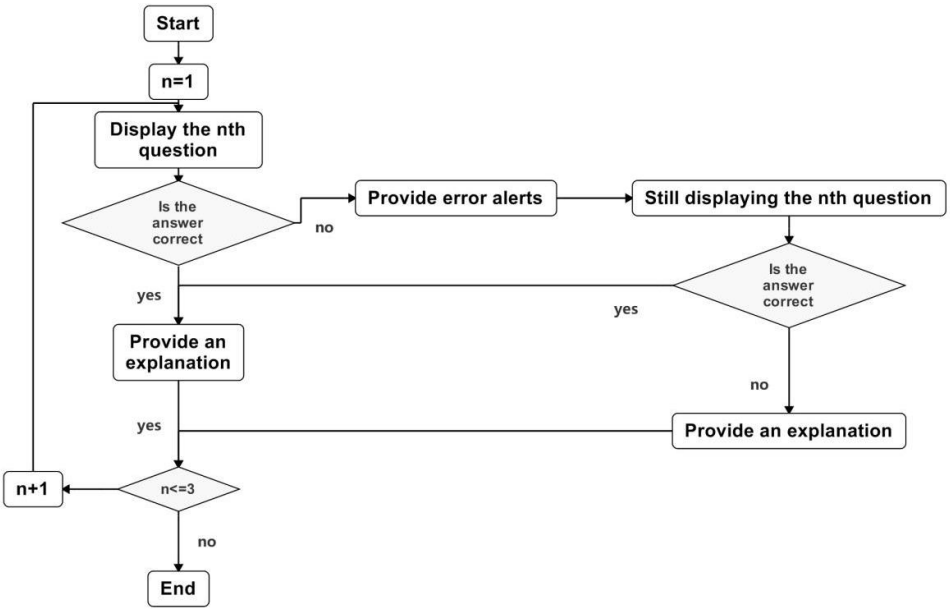

Fig. 1. Use of linked lists in scratch - sequential problem solving process diagram

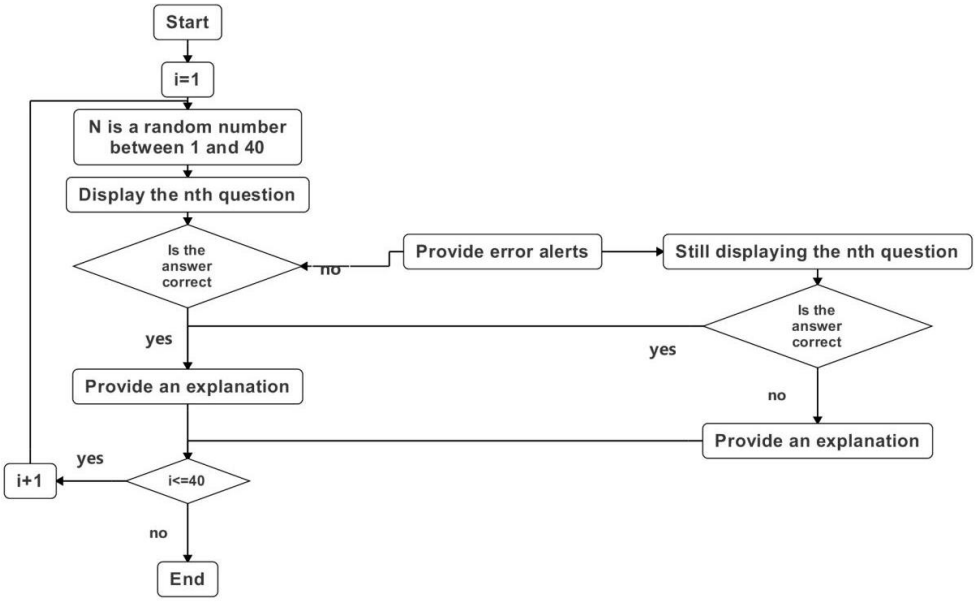

Fig. 2. Use of linked lists in scratch - random question generation process diagram

Constructivist learning theory posits that teaching should be student - centered. It emphasizes that knowledge is actively constructed by learners based on their prior experiences, through interactions with the environment and peers within a specific context. Therefore, teachers must provide different programming projects for students according to their interests.

For example, in the book "The Use of Linked Lists in Scratch", using Scratch to design questions for ancient poetry conferences, you can first use the linked lists in Scratch to provide the process of three questions. After students answer the questions, they can judge whether they are correct or not and accumulate scores. The process of problem thinking can be displayed in the form of a flowchart to cultivate students' logical thinking ability.

4.1.2 Developing problem-solving skills

During the programming process, children will encounter various complex problems that require them to analyze, identify the key points of the problem, and design solutions. This process requires children to constantly try, iterate, and make mistakes, in order to cultivate more resilient and flexible problem-solving abilities. For example, in "The Use of Linked Lists in Scratch", in addition to sequential problem solving, random problem solving can also be performed. After mastering the method of sequential problem solving, students can be guided to think about random problem solving and accumulate scores, and draw a flowchart of the random problem solving process.

4.1.3 Cultivate human-machine collaboration ability

With the development of artificial intelligence technology, programming education is also adapting to this change, gradually evolving from the traditional manual coding method to a new human-machine collaboration method based on artificial intelligence technology assistance. This helps students establish a correct understanding of human-machine coexistence and collaboration, and possess the necessary artificial intelligence literacy to meet the basic needs of talent in the era of artificial intelligence. The flowchart design in "The Use of Linked Lists in Scratch" is difficult for elementary school students to understand and master. It can be achieved through human-machine collaboration using artificial intelligence platforms such as Kimi or Doubao to build and optimize the process (Najmiddinova, 2024).

4.2 The Cultivation of Information Literacy Through Programming Education

Information literacy refers to an individual's ability to acquire, process, utilize, and evaluate information in the information society, including core elements such as information awareness, information knowledge, information ability, and information ethics.

4.2.1 Cultivating Information Awareness

Information awareness refers to the sensitivity of individuals to information, which is a psychological state in which people consciously and spontaneously identify, acquire, and use information in production and life. It requires individuals to be able to keenly capture information, judge the value of information, and realize the importance of information in solving problems and creating value. If encountering difficulties in programming learning, students can be educated to not only seek advice from teachers, but also use search engines and artificial intelligence (AI) to retrieve information, forming a broad awareness and method of obtaining information.

4.2.2 Cultivating Information Knowledge

Information knowledge is the knowledge related to information technology that people should master and possess in order to obtain and utilize information, including modern communication technology, computer technology, network technology, database technology, multimedia technology, etc. Information knowledge is the foundation of information literacy, which helps individuals to utilize information technology tools more effectively. By learning programming languages, students can understand algorithms and logic, which helps them understand how information is processed by computers.

4.2.3 Cultivating Information capability

Information capability refers to the ability to apply information knowledge, technology, and tools to solve information problems (Wan, 2020). Information capability is the core of information literacy, which enables individuals to efficiently acquire, evaluate, organize, and utilize information (Wan, 2020), such as the collection,

organization, and management of information resources, the selection and use of information technology and its tools, and the design of information processing processes. For example, in "The Use of Linked Lists in Scratch", through the practice of randomly selecting questions from ancient poetry and accumulating scores in programming projects, students have mastered the methods of randomness and accumulation, which can be extended and applied to the design of practical problems such as idiom competitions and random duty table arrangement.

4.2.4 Cultivating Information morality

Information morality refers to the information ethics that should be followed in the process of using information capabilities to solve practical problems (Wan, 2020). Information morality is the guarantee of information literacy, which ensures the legality and legitimacy of information activities. In the era of digital intelligence, children need to possess good moral qualities, requiring individuals to respect the intellectual property rights of others, comply with laws and regulations, not disseminate false information, and not infringe on the privacy of others when obtaining, using, and communicating information. In particular, artificial intelligence (AI) has penetrated into various aspects of learning, work, and life, such as article writing, image generation, music creation, etc. Students should learn knowledge and technology seriously with a curious attitude, and cannot rely on AI content generation, let alone become AI porters.

4.3 The cultivation of Innovative Literacy Through Programming Education

Innovation literacy refers to an individual's ability to propose novel and unique solutions when facing complex problems. Innovation is an important driving force for social progress and development. In the era of digital intelligence, children need to have innovative consciousness and ability, be brave enough to try new things and methods, and constantly explore new fields and possibilities. For example, 'Clone Features in Scratch' uses examples to help students understand cloning features and achieve the effect of fireworks by using methods such as' cloning oneself ',' when starting as a clone ',' deleting the clone ', etc. It can also develop a small game called' bullet shooting 'to cultivate students' innovative literacy.

4.4 The Cultivation of Humanistic Literacy Through Programming Education

Humanistic literacy refers to the knowledge, abilities, and emotional attitudes that individuals possess in the field of humanities. In the era of digital intelligence, children need to possess good cultural literacy and a sense of social responsibility in order to better integrate into and serve society. The use of linked lists in Scratch not only enables students to master the techniques and methods of using linked lists, but also enhances their accumulation of ancient poetry; In the teaching of Scratch "Drawing Characters", teachers can simulate the transformation of Peking Opera facial makeup, so that students can understand the characteristics of Peking Opera characters through the transformation of character shapes, stimulate their love and recognition of traditional Peking Opera culture, and thus enhance their humanistic literacy.

5. METHODS FOR CULTIVATING CHILDREN'S PROGRAMMING ABILITIES

The cultivation of children's programming ability is a gradual process that requires mastering certain methods and approaches based on their cognitive patterns, developmental characteristics, and interests.

5.1 Develop Teaching Plans that are Suitable for Different Age Groups

It is crucial to develop corresponding programming education and teaching plans for children of different age groups (Era, 2023). For lower grade students, they can start with graphical programming and use simple and intuitive programming environments and visual programming languages such as Scratch and Blockly. This teaching method can enable students to learn programming fundamentals through interest and fun, and cultivate their logical thinking and problem-solving abilities. For senior students, text-based programming languages such as Python and Java can be gradually introduced to enable them to learn more complex programming concepts and skills.

5.2 Introducing Project-based Learning and Practical Activities

Programming education should focus on the introduction of project-based learning and

practical activities. By involving students in real programming projects and practical activities, they can apply the knowledge they have learned to real-life situations, enhancing their creativity and problem-solving abilities (Han, 2023). Project based learning can also cultivate students' teamwork and communication skills, enabling them to learn how to interact with others in programming.

5.3 Provide Diversified Learning Resources and Support

In order to promote the effective implementation of programming education, it is necessary to provide diverse learning resources and support. Schools and educational institutions can establish programming laboratories and maker spaces, providing computer equipment and programming software for students to practice and explore. At the same time, teachers need to receive professional training to enhance their programming knowledge and teaching abilities, and provide guidance and support for students. In addition, online learning platforms and programming education websites can be utilized to provide rich teaching resources and learning materials, allowing students to have learning opportunities both inside and outside the classroom (Vinnervik, 2023).

5.4 Encourage Innovation and Personalized Learning

Programming education should encourage students to engage in innovative and personalized learning. Students should be encouraged to try different programming projects and practices to develop their interests and strengths. Teachers can provide guidance and inspiration, while giving students a certain degree of autonomy and freedom, allowing them to show their creativity and personality in programming learning.

5.5 Interdisciplinary Integration of Programming Education

In order to better implement programming education and improve the cultivation effect of children's core literacy, programming education can draw on the advantages of SAEAM education, deeply integrate with subjects such as mathematics, science, language, and art, and cultivate children's interdisciplinary thinking and innovation abilities.

5.5.1 Integration of mathematics and programming

Mathematics and programming are closely related, and programming can help students transform abstract mathematical concepts into concrete computational processes, thereby better understanding and applying mathematical knowledge. For example, programming can achieve graphical display and dynamic simulation of mathematical formulas, allowing students to understand mathematical concepts more intuitively. At the same time, programming can also help students solve mathematical problems, conduct data analysis and statistics, etc. In teaching practice, mathematics teachers can combine programming education to design relevant mathematical programming projects and activities, allowing students to learn mathematical knowledge in practice.

5.5.2 Integration of science and programming

There is also a strong correlation between science and programming. Programming can help students simulate scientific experiments and analyze data, cultivating their scientific exploration ability and scientific thinking. Through programming, students can design and simulate scientific experiments, observe and analyze data, thereby gaining a deeper understanding of scientific principles and phenomena. Teachers can guide students to use programming for scientific practice and exploration by combining specific scientific topics (Younas et al., 2023).

5.5.3 Integration of language and programming

Language learning and programming can mutually promote each other. Programming can help students improve their language expression and logical thinking abilities. In programming, students need to clearly express their intentions and logical relationships in order to cultivate their writing and oral expression abilities (Drew, 2012). Programming can also guide students in literary creation, design interactive stories and games, and stimulate their imagination and creativity. Teachers can combine programming education to design interesting language learning projects and activities to enhance students' language abilities and creative thinking (Younas et al., 2023).

5.5.4 Integration of art and programming

The combination of art and programming can cultivate students' creativity and aesthetic ability. Through programming, students can create and design artistic works such as graphics, music, and animation. Programming can provide various creative tools and techniques, allowing students to express their creativity and ideas. Teachers can combine programming and art education to carry out interdisciplinary art creation projects, showing students' creativity and artistic expression abilities in programming.

5.5.5 Integration of social sciences and programming

Programming can also be integrated with social sciences to help students understand social issues and conduct social research. Through programming, students can collect and analyze data, explore social phenomena and development trends. They can design simulation and data visualization tools to extract useful information from large amounts of data, helping them analyze and solve social problems. Teachers can combine programming and social science education to guide students in conducting social surveys and research projects, cultivating their social observation and analysis abilities.

6. CHALLENGES AND COUNTERMEASURES FACED BY CHILDREN'S PROGRAMMING EDUCATION

Programming education has a promoting effect on the comprehensive development of children's core literacy, but it also faces some challenges.

6.1 Challenges Faced by Children's Programming Education

6.1.1 Lack of suitable unified textbooks and teaching resources

Since the country advocated popular science education and emphasized the cultivation of students' programming abilities, textbooks for children's programming have sprung up like mushrooms after rain. There are also a wide variety of textbooks and related equipment for children's programming on the market. However, due to the lack of unified standards, the content of the textbooks produced is also uneven, and the lack of suitable textbooks and teaching resources is currently the main problem, especially for students of different ages and ability levels, which are still relatively scarce (Drew, 2012).

6.1.2 Insufficient teaching staff

An excellent team of programming education teachers is the key to promoting programming education, but there are still problems with insufficient teacher training and low teacher skill levels. The lack of experienced programming education teachers is another major challenge. Due to the novelty and complexity of programming education, many educational institutions and schools lack professional programming teachers. Cultivating and attracting more teachers with programming backgrounds and teaching experience, providing professional training and support, is crucial for promoting the popularization of programming education.

6.1.3 Lack of educational resources and facilities

The computer equipment and software resources required for programming education are limited for many schools and families. Some schools in certain regions may lack computer laboratories or suitable programming equipment, while some households may not be able to afford to purchase open-source hardware related to computers and robots (Gocen & Aydemir, 2020). Providing sufficient educational resources and facilities, including computer equipment, programming software, and network connectivity, is an important task in promoting programming education.

6.1.4 Single teaching content and methods

There are a large number of programming languages, tools, and teaching methods in the field of programming education. Choosing programming languages and tools suitable for children and designing effective teaching methods is a challenging task (Aggarwal et al., 2023). Teachers in educational institutions need to choose appropriate teaching content and methods based on students' age, interests, and learning abilities to ensure the effectiveness and sustainability of programming education.

6.1.5 The evaluation system needs to be improved

A scientific learning evaluation system is crucial for the development of children's programming education. The existing evaluation system lacks unified standards and places too much emphasis

on results, among other issues that need further improvement to ensure accurate assessment of students' learning outcomes.

6.2 Countermeasures to Improve the Effectiveness of Children's Programming Education

Despite the challenges faced by programming education for children, the value of programming education in cultivating children's core literacy cannot be ignored. By establishing appropriate educational policies and adopting effective teaching methods, the role of programming education can be fully utilized to promote the comprehensive development of children's core literacy.

6.2.1 Develop a more comprehensive programming education policy

The government and educational institutions can develop more comprehensive programming education policies and guidance, encourage schools and educational institutions to carry out programming education projects, and provide necessary resource support. The formulation of policies can promote the popularization of programming education and ensure the quality and sustainability of programming education.

6.2.2 Strengthen teacher training and professional development support

In order to address the challenge of insufficient teaching staff, it is necessary to strengthen the training and professional development support for programming education teachers. Teachers can participate in professional programming training courses and seminars to enhance their programming knowledge and teaching abilities. At the same time, establish a community and communication platform for programming education teachers to promote cooperation, exchange, and experience sharing among teachers, and jointly promote the development of programming education.

6.2.3 Expand cooperation between schools and communities

Schools can establish cooperative relationships with community organizations, technology companies, and programming education institutions to jointly promote the development of programming education. Community organizations and professional institutions can provide support and assistance to schools, enriching students' programming learning experience. This collaboration can be achieved through organizing programming lectures, workshops, and programming competitions, providing students with more practical opportunities and learning resources.

6.2.4 Innovative teaching modes and technological applications

Keeping up with the continuous advancement of technology, innovating teaching modes and technology applications, and enhancing the effectiveness and attractiveness of programming education. For example, utilizing virtual reality and augmented reality technology to provide students with immersive programming learning experiences; Utilizing artificial intelligence technology (Wang & Wang, 2024) to provide personalized learning support and assessment; Utilize online learning platforms and mobile applications to expand students' learning scope and opportunities.

6.2.5 Encourage family participation and support

Family is an important environment and supporter for children's learning. Parents should encourage their children to participate in programming learning and provide corresponding support and resources. Support children to participate in programming clubs and activities, provide computer equipment and programming software, and explore the fun and applications of programming with children, creating a strong programming learning environment together.

7. CONCLUSION

Programming education in the era of digital intelligence plays an important role in cultivating children's core literacy. By learning programming, children can not only master the basic principles and skills of computer science, but also cultivate their core literacy such as intelligence, information literacy, innovation literacy, humanistic literacy, as well as scientific spirit, team consciousness, and the ability to adapt to future society. In the era of digital intelligence, we need to leverage the advantages of new information technologies such as artificial intelligence. Governments, educational institutions, schools, families, and communities should work together to promote the in-depth and rapid development of children's programming education.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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