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Educational environment and college students: an investigation of scientific literacy of early childhood education students in two Chinese normal universities

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Abstract: Scientific literacy was seen as an important component of national quality, also as the foundation of social civilization. This study investigated the scientific literacy (SL) of early childhood education students (ECEs) in two Chinese normal universities. Altogether 177 ECEs were surveyed and randomized semi-structured interviews were conducted with 5 ECEs. The results revealed that ECEs demonstrated unbalanced and uneven scientific knowledge reserves. While they possessed positive attitudes in improving the SL, there was minimal progress in terms of taking action. Clearly, school, family and society, the so called educational environment, had insufficient support for ECEs' SL development.

Key words: scientific literacy; early childhood education students; educational environment

1 Introduction

Attaching importance to scientific and technological talents is a global trend. Countries around the world have implemented various strategies to cultivate talent, starting from emphasizing education at all stages. China continued to update its policies to promote the improvement of scientific literacy for all citizens, such as *Outline of the Action Plan for National Scientific Literacy (2021-2035)* (State Council of China, 2021). The *Opinions on Strengthening Science Education in Primary and Secondary Schools in the New Era* (Ministry of Education of China,2023) [12] reflects that China focuses on scientific education at the basic education level, and emphasizes country's overall planning for the development of high-quality education and the cultivation of high-quality scientific and technological talents. Scientific literacy is something that every citizen should possess, and education should serve as a platform to help people acquire scientific literacy. As a foundational stage of national education and lifelong learning, kindergarten education nurtures children's scientific literacy, which can ignite their interest in scientific exploration and lay the foundation for them to become highly scientifically literate talents in the future. Therefore, it is necessary to cultivate children's scientific literacy during the early childhood education stage.

The National Science Research Council of the United States believes that preschool children can develop knowledge and skills through participation in scientific activities. The Ministry of Education of China considered the development of early childhood science as a core competency in child development and a key area of kindergarten education [10][11]. Kindergarten teachers are the direct organizers and implementers of educational activities and curriculum in kindergarten. Numerous empirical studies have shown that their professional beliefs, knowledge, and abilities significantly impact the quality of kindergarten education and the holistic development of children [1][4]. This has also been confirmed in terms of science education and scientific literacy in kindergartens [2].This study thus investigated the SL of ECEs who are talent reserve for the future early childhood education.

2 Scientific literacy

"Scientific literacy" was first introduced by the American educator J.B. Conant. In 2021, the State Council of China issued that citizen's scientific literacy refers to the promotion of scientific spirit, the establishment of scientific thinking, the mastery of basic scientific methods, the understanding of necessary technological knowledge, and the ability to apply them to analyze and solve practical problems. Based on the descriptions of scientific literacy by Miller, PISA, and OECD, it can be seen that scientific literacy should be multifaceted, including at least scientific knowledge and scientific skills. It can also incorporate scientific attitudes and emotions, as well as scientific processes and methods [18].

Table 1. The definition or components of scientific literacy by major institutions/scholars in different periods

Years	Institution/Scholar	Definition/ Components
1952	J. B. Conant	College general education level
1958	Hart	Understanding science and its applications in society.
1983	Miller	Understanding scientific principles and concepts; familiarizing oneself with major scientific terminology and methods; comprehending how technology influences individuals and society [9].
1996	The U.S.A: *National Science Education Standards*	Scientific concepts and knowledge, scientific inquiry and processes, science, technology, and society, history of science and the nature of science.
2000	PISA	Understanding science and technology, physical and life sciences, earth and space sciences, being aware of the process of scientific research; comprehending scientific questions, describing and explaining scientific phenomena, making scientific predictions, drawing conclusions, etc.; having scientific concepts, scientific interests, and environmental awareness, etc [14].
2006	OECD	Understanding the technology in daily life; possessing knowledge about the natural world and science itself; being able to provide scientific explanations for phenomena and draw well-founded conclusions; having a passion for science, supporting scientific research, and engaging in responsible behavior [15].
2021	State Council of China: *Outline of the Action Plan for National Scientific Literacy* (2021-2035)	Adhering to the spirit of science, embracing scientific thinking, mastering basic scientific methods, acquiring essential technological knowledge, and possessing the ability to apply them for analyzing and solving real-world problems [17].

2022	Ministry of Education of China: *Science curriculum standards for compulsory education（2022）*	Mastering fundamental scientific knowledge and developing preliminary scientific concepts; acquiring basic thinking methods and possessing initial scientific thinking abilities; grasping basic scientific methods and possessing initial inquiry and practical skills; cultivating a fundamental scientific attitude, having the correct values, and a sense of social responsibility [8].

In September 2023, the proportion of Chinese citizens with scientific literacy reached 12.93%, which is a 2.37-percentage-point increase from 10.56% in 2020. This survey on citizens' scientific literacy follows international standards which used the indicator of Civic Scientific Literacy (CSL). CSL can reflect the development level of scientific literacy among the population. It comprises six dimensions across two levels: knowledge (content knowledge, procedural knowledge, and cognitive knowledge) and abilities (everyday life, participation in science, and scientific decision-making). This study employed these dimensions.

3 Methods

3.1 Participants

H and N Normal Universities are located in two different provinces of central China, the quality of ECE teaching in the two universities is comparable. The demographic information of these ECEs is shown in Table 2.

Table 2. Demographic characteristics of participating students (N=177)

	Students (N=177)
Gender	
Female	158 (89%)
Male	19 (11%)
Grade	
Freshman year	16 (9%)
Sophomore year	8 (5%)
Junior year	110 (62%)
Senior year	43 (24%)
Subject background before college	
Liberal arts in high school	147 (83%)
Science in high school	30 (17%)
Hometown	
Village	106 (60%)
County town	43 (24%)
City	28 (16%)

3.2 Data collection

3.2.1 Questionnaires

This study designed a questionnaire to investigate the SL of ECEs. The questionnaire consists of three parts. The first part includes demographic background information, such as gender, subject background before college, grade in college. The second part refers to the *Chinese Civic Scientific Literacy Standards* (Ministry of Science and Technology of China and et al., 2016) (CCSLS) [13], which comprises 26 criteria and 132 benchmark points. For assessment purposes, 50 benchmark points were randomly selected from the 132 benchmark points, ensuring coverage of all 26 criteria. Based on each benchmark point, survey questions were designed to create a question bank. During the assessment, 50 questions were randomly selected from a pool of 500 questions (while ensuring coverage of all 26 criteria). The format of the questions was either true/false or multiple choice, with each question carrying 2 points. Attaining a correct rate of 60% or higher was considered as having basic scientific literacy. Following this requirement, this study randomly selected 50 questions covering all 26 criteria, divided into three dimensions: scientific knowledge, scientific abilities, and scientific attitudes. Moreover, the third part of the questionnaire consists of self-assessment of scientific literacy and factors influencing the cultivation of scientific literacy.

Before officially distributing the questionnaire, a pilot study was conducted on a small scale, and the reliability of the questionnaire was tested using SPSS 20.0, yielding a Cronbach's Alpha value of 0.851 (a reliability coefficient between 0.8 to 0.9 indicates acceptable reliability for a scale). Additionally, two ECE experts were invited to evaluate the validity of the questionnaire's basic logic and content, leading to adjustments and improvements in the questionnaire's details.

Based on convenience, the formal questionnaires were distributed to students majoring in preschool education at H Normal University and N Normal University, using the "WenJuanXing" platform. A total of 201 questionnaires were distributed. Invalid questionnaires were excluded based on criteria such as completion time being less than 100 seconds or patterns in option choices. This resulted in 177 valid questionnaires, yielding a final questionnaire validity rate of 88%.

3.2.2 Interviews

Considering that standardized questionnaires be difficult to measure the emotional attitudes, 6 ECEs from H Normal University and N Normal University were randomly selected for semi-structured interviews. The interviews focused on topics such as their views on scientific literacy, current status, willingness to improve, and methods. These interviews served as a supplementary method to the questionnaire survey, aimed to gain in-depth understanding of the SL of ECEs.

Furthermore, *the ECEs Talent Cultivation Plans* (ECEs' TCP) of H Normal University and N Normal University were collected to further validate the accuracy of the information obtained from the questionnaire survey and interviews.

3.2.3 Data analysis

After conducting inferential statistical analysis on the survey questionnaire data using SPSS 20.0, it was found that there were no statistically significant differences in the impact of background information variables on scientific literacy. Therefore, the following text will focus on describing the results of descriptive statistics.

4 Findings

4.1 Scientific knowledge reserves of ECEs

The second part of the questionnaire consists of 50 items assessing SL, covering multiple dimensions of SL, including examination of scientific knowledge across various disciplines. The overall mean score is 53.56 (out of 100), with the lowest score being 28 and the highest score being 90. The mean score 53.56 is close to the median, indicating that ECEs had insufficient knowledge reserves in multiple scientific domains. On the whole, the results are not ideal.

However, according to the scoring method specified in the CCSLS, 26.97% of ECEs achieved an accuracy rate of 60% or higher, which means that the proportion of ECEs possessing scientific literacy is 26.97%. This percentage is fourteen-percentage-points higher than the Chinese citizens' average of 12.93% announced in September 2023. From this perspective, ECEs' SL is an acceptable current situation.

Table 3. The five questions with the lowest accuracy rate among the 50 SL questions (N=177)

Question number	Question	Accuracy	The benchmark items
6	If you are a scientist and, while collecting data for an experiment, you find that a small portion of the assistant's localized data calculations is inaccurate, but the overall experimental results are as expected, which of the following statements do you think is correct?	6.81%	Benchmark 3: Having a basic scientific spirit, understanding the fundamental process of scientific and technological research.
26	The possible dates for a solar eclipse to occur are ( ).	17.1%	Benchmark13: Mastering basic astronomical knowledge.
23	The natural elements currently discovered by humans in the natural world are ( ).	18.2%	Benchmark12: Mastering basic chemistry knowledge.
50	The southeast coastal area of our country has more people and less land, and the northwest inland area has less people and more land, so we should emigrate to the western area in large numbers. The claim is ( ).	22.7%	Benchmark26: Understanding the hazards of environmental pollution and its mitigation measures, utilizing land and water resources rationally.
32	In general, the normal range of blood pressure for adults is ( ).	23.9%	Benchmark16: Understanding human physiology.

According to Table 2, it can be observed that the five questions with the lowest accuracy rates are from two levels: scientific spirit and specific scientific knowledge. The sixth question with the lowest accuracy rate is a detailed question about data processing in the scientific research process, which is included in the *ECEs' TCPs*. Based on the *ECEs' TCPs* from two universities, both offered curriculums of ECE scientific research methods. These curriculums are taught in the second semester of the sophomore year or the first semester of the junior year, and 86.44% of the participants have already taken this curriculum, which indicated that they should have acquired knowledge about educational scientific research process. Unexpectedly low accuracy rate for this question requires further investigation.

Table 4. The five questions with the highest accuracy rate among the 50 SL questions (N=177)

Question number	Question	Accuracy	The benchmark items
12	The financial tsunami that erupted in 2008 not only swept through the United States but also affected other developed countries and many developing countries. The global economy faced significant challenges, which indicates ( ).	89.77%	Benchmark6: Promote the concept of ecological civilization and live in harmony with nature.
39	If you experience a malfunction while riding in an elevator, the best course of action is to ( ).	89.77%	Benchmark19: Acquire basic knowledge of safe travel and use transportation correctly.

18	The fastest information currently comes from ( ).	88.64%	Benchmark9: Master scientific methods of acquiring knowledge or information.
41	According to the rules for safe use of gas, the incorrect practice among the following is ( ).	86.36%	Benchmark20: Understand common sense of safe electricity and gas usage, and use household appliances and electronic products correctly.
40	The "W" marked on the air conditioner refers to ( ).	81.82%	Benchmark20

Considering the content of questions with the highest and lowest accuracy rates in combination, the results revealed that ECEs demonstrated excellence in their knowledge reservoirs of general life skills, as well as principles of philosophy and economic foundations. However, ECEs performed a weak understanding of common knowledge related to scientific and technical subjects such as astronomy, chemistry, and physics.

4.2 Attitudes of ECEs to SL

The results of the survey indicate that 90.9% of ECEs believed it was necessary to improve their SL. Overall, ECEs' attitude towards SL and enhancing SL is quite positive. In interviews, ECEs demonstrated a basic understanding of the concept of scientific literacy. For example, student H thought that SL includes "scientific knowledge and scientific spirit, understanding some scientific methods". ECEs already recognized the importance and necessity of SL. Student L believed that having SL could "benefit the work, learning, and life". They also recognized that SL is one of the core competencies that children should possess. As future kindergarten teachers, they felt it is necessary to enhance their own SL in order to promote the development of SL of children. This view was made explicit by a student, as follows.

In the future, someday, I will become a preschool teacher, will be cultivating preschool children, but if I do not possess scientific literacy, being unable to answer or wrongly answer questions posed by children frequently, which may mislead them, make children have a distorted understanding of life and the world. I would consider that was very terrible … (Student M)

ECEs, who already have internship experience in kindergartens, also have their own views on the current implementation of science curriculum in kindergartens. For example, they observed that children enjoy playing in the science area. They noticed that the kindergarten where they interned did not prioritize science activities, relied on pre-packaged material kits from education companies deeply. They also observed that the kindergarten, in order to meet parents' expectations to prepare children for elementary school and future academic pursuits, had the older children in the kindergarten learn elementary school content inappropriately, such as memorizing mathematical addition and subtraction rules by rote. These perspectives reflect the emphasis placed by ECEs on fostering children's SL through activities, implementing science curriculums. Meanwhile, ECEs hold the point that ECE teachers need post-service trainings to stimulate their SL continuously developing. Additionally, during the interviews, ECEs expressed their willingness to participate in interesting science experiments or science curriculums, if the college or department offered them.

4.3 Actions of ECEs to SL

Unlike declaring one' s positive attitude to SL, actions of SL are typically not viewed as simple. One's attitude can influence actions, and expressing an attitude is easy while taking action requires a lot of effort. In this survey, the positive perception of SL of ECEs had not translated into behavior to enhance their SL. Only slightly over half of ECEs (56.3%)

thought they had actively improved SL. The results from the fifty-item SL questionnaires mentioned earlier also reveal that even among ECEs who claim to actively and continuously improve their SL, there are significant gaps in their scientific knowledge. The ideal state of learning and practice is the integration of knowledge and action. Currently, ECEs only possess awareness in terms of "knowledge" but lack the practical implementation of what they know. Without putting knowledge into action, it cannot be considered true "knowledge". Probably, for their part, learning SL hard and deeply is extrinsically motivated (i.e.it is goal oriented). It is worth exploring what can stimulate their initiative in learning SL.

5 Discussion

Sociocultural theory employed by this study considers that the cultural and historical contexts contributes to children development. Through the investigations in both questionnaire and interview, it was demonstrated that ECEs were not got enough support from the environment throughout the lifespan. It mainly manifests in three aspects: neglecting the cultivation of scientific literacy in the family environment, insufficient emphasis on cultivating scientific literacy in school environments, and inadequate depth of influence from the social environment.

5.1 Family, society and school as educational environments

Those ECEs were born in this millennium when Ministry of Education of China issued *Guidelines for Kindergarten Education* (*Trial Version) (2001)*, which already included educational goals for the development of early childhood science. As they grow, the government was increasingly emphasizing the development of citizens' SL and providing more policies and financial support. However, it is evident that there is still great space for exploration in terms of the support from family, school, and societal environments for ECEs to enhance SL. The following excerpt of interviews could demonstrate this finding.

I did not grow up in an environment with a scientific atmosphere. For example, I never visited science museums or read books about science like "One Hundred Thousand Whys". There were no public facilities like science museums near my home, and my parents didn't place much emphasis on cultivating an interest in this area. My parents worked in Guang zhou and only had a junior high school education...Most of my scientific knowledge comes from studying science subjects in middle and high school. (Student H)

For student H, his family was once limited by economic factors, and the influence of his parents' education level prevented them from providing him with sufficient nourishment in SL during his childhood. This reflects a microcosm of the development of our times. At the same time, it also reflects the inadequate emphasis placed on the cultivation of SL as an important part of students' growth in schools. Especially in colleges, the so-called higher education institutions, which serve as specialized places for knowledge transmission and skill development, there is insufficient attention to enhancing students' SL and limited support in terms of teaching resources.

College, as a virtual institution of educational environment, does not strongly focus on cultivating students' SL. College students do not have much exposure to science-related content after the national college entrance examination, and their current scientific knowledge is mainly based on what they have learned in middle and high school. In the questionnaire survey, only 13.6% of ECEs believed that their current level of SL was mainly derived from their university education. There are few activities related to SL organized by college, and there is also a lack of choices for public courses in the TCPs. There are no corresponding course modules in the TCP for SL. For ECEs, there are few courses directly related to SL, typically only 1-2 courses, and there is very little space for choosing general education courses. As shown in the following example, the traditional form of classroom teaching or recorded online courses (non interactive online courses) fail to stimulate students' interest in improving their SL. Large class sizes do not take into account individualized instruction, which leads some students to find the material too challenging to benefit fully from the learning experience.

The teaching style of the teachers is similar to that in middle and high school, with a majority of content being overly theoretical and specialized, which was difficult for me. In the end, I didn't gain much from it. (Student M)

…In a recorded online course format, you watch videos to complete chapter assignments and take online exams at the end. I searched answers of the tasks online, in the end, I don't actually gain much from it, and I am just doing it to fulfill the tasks. (Student P)

I prefer the approach of conducting scientific experiments over traditional teaching methods. (Student T)

Beyond that, universities have a positive impact on ECEs' scientific attitudes and scientific spirit. The curriculums they offered help students acquire the necessary scientific knowledge for ECE studies and cultivate scientific inquiry skills related to educational research. For example, ECEs mentioned that teaching methods courses such as *Mathematical Activities and Guidance for Children*, and *Science Education Activities and Guidance for Children*, improve their teaching skills and consolidate their scientific knowledge through simulated teaching approaches.

The inadequate depth of influence from the social environment mainly manifests in the following aspects. The mass media or new media in the social environment provide fragmented knowledge with selective scientific attitudes and processes to ECEs. Purely online learning still requires continuous exploration to facilitate deep learning. ECEs often stop exploring after finding the information they need online, making it difficult to comprehensively and deeply enhance their SL. According to a survey, 78.5% of ECEs considered internet resources as one of the main ways to improve their SL, indicating that the nourishment they receive regarding SL primarily comes from the internet in the social environment. In interviews, three ECEs repeatedly mentioned collecting scientific knowledge and skills through social medias such as Xiao Hong Shu (Chinese popular social media apps) and TikTok. It is evident that the social environment plays an important role in improving ECEs' SL. However, this role is relatively limited. According to previous studies, offline scientific venues, such as public libraries, scientific museum, research centers should also play a role in nurturing SL. A social environment where everyone believes in science and promotes science can also contribute to enhancing ECEs' SL. As yet, these factors have limited impact on improving ECEs' SL in the present social environment.

6 Conclusion

This study investigated the current status of SL among ECEs at H Normal University and N Normal University in China, as well as its influencing factors. Data was collected through surveys, interviews, and analysis of *ECEs' TCPs*, with mutual validation conducted between the methods. The results revealed a lack of scientific knowledge among ECEs, while their scientific attitudes and mindset were positive. Meanwhile, the support provided by family, schools, and society in developing SL during their growth process was found to be insufficient. These findings indicate that current ECEs require diverse resources and support, while maintaining a spirit of enthusiasm for science. It is important for them to strive for the integration of knowledge and action, which will not only benefit themselves but also impact future ECE practices.

There are issues in cultivating SL of ECEs in colleges, including insufficient emphasis on developing SL in *ECEs' TCPs*. a. There is a lack of direct corresponding content. b. Few science-related curriculums are offered, and the teaching methods are often monotonous. c. Colleges or departments rarely organize science-related activities. Meanwhile, the direct support from society for the development of SL of ECEs is limited , with insufficient depth of involvement.

Moreover, the cultivation of SL is a lifelong learning process that continues throughout one's life. Normal colleges should pay attention to deep learning of ECEs and the integration of knowledge and action. This requires colleges and departments to carefully consider the direction and orientation of their educational goals when designing TCP, guiding ECEs to value the enhancement of SL, and motivating their proactive engagement in learning. By exploring the spiritual aspirations and cultural factors behind learning scientific knowledge, practicing scientific skills, and fostering a scientific mindset, science education can be infused with vitality and nurture higher-order thinking among college students [6].

Colleges and departments can offer public curriculums on the history of science and perspectives on science culture. Alternatively, colleges and departments can use mass media platforms to disseminate content related to the history of science and perspectives on science culture. These initiatives can help ECEs understand the development of science from various channels and perspectives, enabling them to deeply comprehend the complex relationship between science and societal development. Such an understanding can foster a genuine sense of identification and responsibility for scientific learning from within, providing intrinsic motivation for deep learning in science [16].

The development of ECEs' SL is influenced by their surrounding environments, such as the family and school in the microsystem, science museums and cultural institutions in the exosystem, and the national cultural background in the macrosystem. It requires colleges, where ECEs spend most of their time, to fully leverage role in education and social service while actively seeking collaboration and support from various sectors of society. Society should also share responsibility for cultivating ECEs.

In addition, colleges can also explore new approaches for cultivating SL of ECEs. Colleges can collaborate with kindergartens to provide educational practices for ECEs to gain practical experience in scientific knowledge and the application of scientific skills. Hope K. G. et al.'s research on 67 U.S. Beginning School Programs found a correlation between self-efficacy in science activities and the frequency at which teachers involved children in science instruction [3]. If teachers receive science education-related content and practical opportunities during their pre-service education, it would increase their likelihood of conducting science learning activities in the classroom. If ECEs are exposed to, learn, and master science education-related knowledge, it will contribute to their willingness to engage in science education activities in their future ECE practices.

7 Limitations and future research directions

The present research could be improved in three aspects. Firstly, why ECEs' score low in these areas and high in others, and conducting in-depth interviews can provide insights into the reasons. Analyzing from the perspective of individual characteristics and other factors can help identify specific reasons. This information can then be used to develop more targeted support strategies. Secondly, while investigating ECEs' scientific knowledge and awareness has been done, it is also important to assess their specific scientific skill development. Using methods like observation could offer a more intuitive approach to explore this aspect. In the end, the initiative of ECEs in learning also deserves attention.

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Conflicts of interest

The author declares no conflicts of interest regarding the publication of this paper.

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