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# Fostering Scientific Literacy in University Students Majoring in Elementary Education Based on Mental State

Edward Harefa<sup>1,2\*</sup>, Xiao Huang<sup>1</sup>

<sup>1</sup> College of Teacher Education, Zhejiang Normal University, Jinhua 321004, China

<sup>2</sup> Faculty of Teacher Training and Education, Universitas Nias, Gunungsitoli 22812, Indonesia

\*Email: [edwardharefa@unias.ac.id](mailto:edwardharefa@unias.ac.id)

### Articles Information

### Abstrak

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Meningkatkan literasi sains dari mahasiswa program studi Pendidikan Guru Sekolah Dasar (PGSD) merupakan elemen penting dalam membentuk konsep sains yang solid sebelum terjun langsung dalam mengajar peserta didik sekolah dasar. Dalam penelitian ini, peneliti menyelidiki efektivitas dan kemampuan mahasiswa PGSD dalam mempelajari mata kuliah Konsep Dasar IPA dengan mengembangkan kuesioner kondisi mental dan mengembangkan tes literasi sains. Hasil penelitian menunjukkan bahwa mahasiswa PGSD memiliki kondisi mental yang lebih tinggi dalam proses pembelajaran mata kuliah tersebut, dan prestasi akademik mahasiswa berbeda secara signifikan dalam hal variabel latar belakang seperti jenis kelamin dan tempat lahir. Lebih lanjut, terdapat korelasi yang signifikan antara kondisi mental dan prestasi akademik. Penilaian multidimensi terhadap prestasi akademik berdasarkan status mental akan membantu pengajar di universitas dalam mengembangkan literasi sains mahasiswa PGSD.

#### Abstract

Improving the scientific literacy of teacher-training students majoring in elementary education is important in training elementary science education talents in colleges and universities before teaching their prospective students. In this study, we investigated the effectiveness of elementary education teacher-training students' learning the course Fundamentals of Natural Science by developing a mental state questionnaire and a science literacy quiz. The results showed that teacher-training students majoring in elementary education had higher mental states in the course learning process, and their academic achievement was significantly different in terms of background variables such as gender and birth origin. Moreover, there was a significant correlation between mental states and academic achievement. A multidimensional assessment of academic achievement based on mental status will help develop elementary education students' scientific literacy.

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## INTRODUCTION

At present, pre-service teachers in elementary education in colleges and universities as a whole are science-oriented, they have a positive attitude toward learning science and are full of expectations for improving their scientific literacy (Harefa, 2023; Kong & Yuen, 2022; Mao et al., 2021; Şen, 2013). However, there are obvious differences in the degree of their mastery of natural science knowledge due to the different degrees of natural science education they have received in the student category because of the distinction between educational background, gender, and mental condition (Chen et al., 2020; Darling-Hammond et al., 2020; Khan et al., 2022; Makarova et al., 2019). At the same time, the following problems exist in the teaching process of basic natural science courses in colleges and universities: teaching overemphasizes theory and the lecture form is single; course hours are limited, course content is large, experiments are often squeezed or presented through videos; teacher-training students are less likely to engage in project-based cooperative learning and scientific inquiry, passively accept scientific knowledge, and homework is limited by textbooks; teacher-training students have low mental input, low interest, unclear learning goals, and they lack active thinking, and their mastery of scientific knowledge remains superficial and cannot form deep cognition; the evaluation of the curriculum is based on classroom attendance and final tests, and the evaluation results emphasize the transmission of scientific knowledge, but neglect the formation of scientific ability (Ding, 2022; Kampourakis, 2017; Karanggulimu & Harefa, 2022; Lee & Boo, 2022; Ploj Vrtič, 2022; Wahyudiana et al., 2021). The one-sidedness of "knowledge-only education", the excessive reliance on teaching materials, and the lack of contextual practice and disciplinary thinking training have limited their professional horizons and ability development.

The embodiment of cognition theory suggests that cognition is an embodied activity that is closely linked to the individual's physical, psychological, and cultural factors (Bondebjerg, 2017). Chi et al. (1994) reported that the ontology of knowledge classifies mental states into "emotional" and "intentional" categories. O'Connor et al. (2019) showed that there is a significant correlation between individuals' learning achievement and their internal and external mental representations. Agnafors et al. (2021) further subdivided mental states into emotions, intentions, internal knowledge representations, and external mental representations, with external mental representations including sub-dimensions such as problem-solving and propositional judgment, and internal mental representations including sub-dimensions such as mental image formation, knowledge doubt, knowledge transformation and connection, and doubt processing. Poor student mental health is clearly a problem, but it also has implications for science academic performance. Both depression and anxiety have been found to negatively impact the academic performance of university students. Mental health issues have been found to negatively impact achievement levels and progress (Pagerols et al., 2022) and whether students finished individual modules or even their degrees (Mojtabai et al., 2015).

The learning process of learners is the process of individual construction of a conceptual representation system, and the state of mind can reveal the specific details of students' mental processes,

which is of great significance for practical teaching. The results of a single academic assessment cannot comprehensively map students' mental cognitive processes, nor can they characterize students' mastery of different dimensions of course knowledge in a disaggregated manner. It is necessary for teachers to dig deeper into the structure of students' mental representations - states of mind - in understanding or viewing problems, to help them construct a framework of course knowledge, which helps them internalize the course knowledge system and eventually form the proper literacy. National Science Education Standards (1996) and Al Sultan et al. (2021) define scientific literacy as the ability to apply knowledge and understanding of scientific concepts and processes to such matters as personal decision-making, participation in cultural affairs, and productive activities in order to make understandings and decisions about the natural world and the changes to it through human activities.

Therefore, it is of great practical significance to carry out the research on the cultivation of scientific literacy of university students majoring in elementary education to reform the students' cultivation mode and the construction of the pre-service elementary teachers based on their mental state. This factor could be used in colleges and universities as a conservative factor for elementary teacher students mental state by promoting a sense of connectedness in the science learning process.

## **METHOD**

The subjects of the study were 217 teacher-training students majoring in elementary education in Gunungsitoli, Indonesia, including 98 male students and 119 female students. The study was conducted mainly through the methods of developing a mental state questionnaire and developing academic achievement assessment test questions. In this study, we developed the questionnaire and subdivided the mental state into four dimensions: emotion, intention, internal mental representation, and external mental representation; the internal mental representation includes four sub-dimensions: doubt processing, mental image formation, knowledge doubt, and knowledge connection and transformation; the external mental representation includes two sub-dimensions: propositional judgment and practical application. The external mental representations include two sub-dimensions: propositional judgment and practical application. The questionnaire was rated on a five-point Likert scale, ranging from 1 to 5 on a scale from not at all to fully, to reflect the degree of agreement with each question statement.

To ensure the validity of the scale, two senior teachers in the field of education in colleges and universities, three full-time teachers in elementary school science education and three teacher-training students in elementary school education were invited to review the 65 questions initially proposed. After the pretest of the mental status questionnaire, the questions were subjected to omitted value test, mean, variance, skewness coefficient, independent sample t-test for high and low groups, the correlation between the revised questions and the total score, and the change in alpha coefficient after the deletion of the question was judged. The items were analyzed, and the questions of the questionnaire were deleted and modified, and a total of 33 questions of the mental status questionnaire were finally determined, and the number of questions and interpretations of each dimension are shown in Table 1. The consistency

coefficient  $\alpha$  of each sub-dimension ranged from 0.729 to 0.881, and the total scale reliability  $\alpha$  also reached 0.911. The above results showed that the mental status questionnaire developed in this study had good validity and reliability.

**Table 1.** Interpretation of all dimensions of mental state.

Dimensionality	Number of Topics	Interpretation
Emotion	5	Emotions toward learning in natural science subjects
Intention	4	Intention to receive affirmation from others in the course of learning
Conceptual inner mind representation	13	Includes representations of scientific concepts, sceptical attitudes toward scientific concepts, the ability to switch between different representations of knowledge, the ability to connect classroom the ability to connect learning with daily life experiences, and the tendency to seek help when encountering problems
Conceptual external mind representation	11	Application of knowledge representation of different concepts in problem-solving process and judgment of scientific concept proposition representation

**Table 2.** Comparison of academic achievement test questions and rubric dimensions for Fundamentals of Natural Science course.

Type of Test Questions	Question Score	Rubric dimensions
Multiple choice questions	16 questions, 2 points each, 32 points in total	Scientific knowledge, including subject knowledge and procedural knowledge, for a total of 40 points
Judgment questions	1 question, 2 points each, 2 points in total	
Short answer questions	1 question, 6 points each, 6 points in total	
Multiple choice questions	4 questions, 2 points each, 8 points in total	Explaining scientific phenomena, for a total of 16 points. Assessing and designing scientific investigations, 22 points in total
Judgment questions	4 questions, 2 points each, 8 points in total	
Short answer questions	2 questions, 6 points each, 12 points in total	
Multiple choice questions	1 question, for a total of 10 points	Interpreting scientific data and supporting scientific evidence, for a total of 22 points
Judgment questions	2 questions, 6 points each, 12 points in total	
Short answer questions	1 question, for a total of 10 points	

According to the teaching objectives of the Fundamentals of Natural Science course, the academic achievement test questions were developed, and the question types and scores were distributed, as shown in Table 2. The average discrimination and difficulty values of the academic achievement test questions

were 0.29 and 0.76, respectively, which were within the acceptable range according to the definition of the range of good and bad discrimination indices reported by Kheyami et al. (2018) and Taib & Yusoff (2014).

## RESULTS AND DISCUSSION

### State of mind and science academic achievement of teacher-training students before the course of study

The lowest average score of university students majoring in elementary education in the mental state survey is 2.61. The university students with an average score of 2.61~3.99 were classified into the middle mental state group (M-state for short), a total of 159; Normal students with an average score of 4.00-5.00 were classified into the strong mental state group (H-state for short), a total of 58 people. The overall average score of normal students majoring in primary education in mental state is 3.80, which is high. The average score of internal mental representation and external mental representation is 3.67 and 3.63, respectively. The average score for the emotional dimension is 4.02, and the average score for the intention dimension is 4.43.

The respondents' academic evaluation scores are low both in terms of scientific knowledge and scientific ability, and the overall score rate is only 40.46%. In different fields of knowledge and different background variables, there are obvious differences among the university students of elementary education major. For example, in the field of earth and universe science, science itself and two interdisciplinary dimensions, the scoring rate is low, 36.42% and 38.25%, respectively, and in the dimension of life science, the scoring rate is high, 48.35%. The score of female students in scientific ability is significantly higher than that of male students, with  $t = 3.302$  and  $p = 0.001$ .

### State of mind and science academic achievement of teacher-training students after the course of study

After learning the Fundamentals of Natural Science, the number of students in the M-state group reached 72, and this result was lower than the before studying the course. The number of students in the strong H-mental state group reached 145. The overall average score of mental state is 4.08. The average scores of internal mental representation and external mental representation were 4.25 and 3.98, respectively, which were higher than before learning the course. The average score of emotion dimension and intention dimension are 3.87 and 4.38, respectively.

The post-study academic achievement scores of the students improved significantly compared to their pre-study scores, with 93.69% of the students achieving an intermediate or higher level. Among them, 20 (6.31%) were to be improved (scores below 60), 89 (28.08%) were moderate (scores between 60 and 69), 136 (42.90%) were good (scores between 70 and 79), and 72 (22.71%) were excellent (scores between 80 and 100). In the scientific knowledge dimension, boys scored slightly higher than girls, while in the scientific ability dimension, girls scored slightly higher than boys; however, they did not reach significant differences in their scores in scientific knowledge, scientific ability, and overall achievement.

## Discussion

The state of mind of university students majoring in elementary education and their academic achievement are closely related, and their state of mind in the course of learning the Fundamentals of Natural Science or indirectly affects their eventual academic achievement. Academic achievement can characterize the degree of mastery of curriculum knowledge and the ability to solve scientific problems of elementary education teacher trainees. However, the assessment scores do not fully map the mental process of internalizing their curriculum knowledge. The mental state measures individuals' motivation for learning the curriculum, their processing of the knowledge system, and their output methods from the perspective of psychological cognition, revealing the specific details of primary education teacher candidates' mental representations in the course of learning the curriculum and reflecting more objectively their mechanisms of constructing the curriculum knowledge system, and the findings are more consistent with the findings of other scholars (Lai et al., 2022; Wu et al., 2022). Mental state and academic achievement are two important dimensions for evaluating individuals' mastery and application of the curriculum knowledge system, and combining them will help to further explore the structure of individuals' internal and external mental representations for understanding problems or solving them, and to find the root causes of their cognitive difficulties.

In terms of the performance of students' mental states, internal and external mental representations are fundamental to the internalization and application of course knowledge, and the use of multiple forms of experimental teaching and practice, combined with theoretical knowledge, is an important way to enhance their scientific literacy. This is because the application of multiple modes of curriculum instruction can lead teacher educators to sustain high emotions and intentions to learn and generate positive motivation. In terms of disciplinary teaching values, organic integration within and between disciplines aims to break down the fragmented and superficial knowledge structure and establish a systematic system of disciplinary knowledge (Furman Shaharabani & Yarden, 2019; Mavhunga & van der Merwe, 2020). The teaching of core concepts as the main axis, based on long-term, continuous and progressive progression, is an effective way to organize the teaching of the curriculum, and the core concepts of science are conceptual knowledge that is based on facts, but also the scientific method, scientific ideas, and scientific concepts abstractly summarized (Falloon, 2019). The content of the Fundamentals of Nature Course course is based on the core concept of science, i.e. the principle of "less and more" is used to unify the content of the course, the appropriate expression is chosen according to the knowledge situation, and the interest and intention of teacher-training students are stimulated through novel, intuitive, experiential and operational teaching methods, which will help them construct a scientific knowledge system in their mental cognition, prompt them to connect experimental phenomena, prior knowledge, scientific theory and scientific practice, achieve a deep understanding of scientific knowledge, and finally master the essence of science.

Based on the individual differences of elementary education teacher trainees, a diversified and multidimensional course teaching evaluation is an important guarantee for the teaching of the

Fundamentals of Natural Science course according to their abilities. The combination of academic achievement assessment and mental state survey can help teachers accurately understand the internal and external factors that affect the teaching of the course and obtain feedback on the improvement of the course. Based on the comprehensive analysis of the relevant factors and feedback information, teachers should choose the appropriate teaching methods according to the individual differences of teacher-training students, which will help to achieve the teaching objectives of the course.

## CONCLUSION

Through the teaching of the core concept of the course Fundamentals of Natural Science as a concept for elementary education teacher candidates, most of them have mastered the basic scientific knowledge of the course, have the scientific ability to solve practical problems, and have basically reached the scientific literacy that teacher trainees should have. However, their psychological mechanisms in learning the course Fundamentals of Natural Science are obviously different due to the differences in student background, gender and other factors. As educators who are responsible for the training of teachers in basic education, we can only create a big environment for them by taking into account the real needs of teacher-training students in elementary education, facing their differences in life experiences and abilities, grasping their mental state levels, fully exploiting the advantages of resources inside and outside the school, and forming a big environment for the whole staff and all-round education. This will help them maintain a high mental state and thus cultivate their scientific literacy. This research gives about the understanding of how to make the course and other professional courses organically integrated, and more effectively improve the comprehensive literacy of teacher-training students in elementary education, and more in-depth research is needed to investigate them.

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