# A Confirmatory Factor Analysis of Scientific Literacy Model's General Science Student Teachers at Rajabhat University in Thailand

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## Abstract

Scientific literacy is acrucial need to apply for understanding phenomenon and problem solving of general science student teachers and necessary to prepare for work in school. This research developed model of scientific literacy of general science student teachers at Rajabhat University, which consisted of 4 components, namely scientific attitude, understanding the nature of science, scientific inquiry ability and application of science to contexts including 12 indicators, and aimed to confirm the model with empirical data. The samples were 400 second-year general science studentteachersof16 Rajabhat Universities, selected by two-stage random sampling. Data collection was conducted through a questionnaire with 36 questions. The data were analyzed using descriptive statistics such as mean, standard deviation and confirmatory factor analysis (CFA). The research finding revealed that the model of scientific literacy components'general science student teachers was confirmed by the four components. The model was confirmed by the second order CFA which the factors were consistent with empirical data ($\chi^2$=55.201, df=43, p=0.100, relative $\chi^2$=1.284, GFI=0.978, AGFI=0.961, NFI=0.987, RMR=0.006, SRMR=0.0251, RMSEA=0.027).In addition, the standardized scores loading of four components were in the range of 0.788-0.860, the AVE was in the range of 0.746-0.878, and the CR was in the range of0.898-0.951. The highest score loading was the scientific inquiry ability followed by the understanding of the nature of science, application of science to context and

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scientific attitude (standardized scores loading 0.860, 0.826, 0.8925 and 0.788 respectively). These results employed to develop a scientific literacy test for assessment general science student teachers at Rajabhat University's skills and develop instructional model for promote their abilities.

**Keywords:** Scientific literacy, Confirmatory factor analysis, General science student teacher

## Introduction

In the 21st century, the advancement of science and technology play a role and impact human life rapidly and volatile in all aspects, becoming an essential part of the culture of human society (Mali, 2019; Office of the Basic Education Commission, 2017) Therefore, in the scientific situation, all citizens must develop into science-literate. They require learning science to gain sufficient scientific knowledge and skills for awareness and application in their life (Kitkeukool, 2013) Nowadays, countries around the world have focused on promoting scientific literacy for students at all levels, especially in the primary education system, in order to enable students to gain scientific knowledge and understanding and develop various scientific skills, which affect their ability and performance in their future work (Hermita et al., 2020) Many countries have participated in the Programme for International Student Assessment (PISA) to evaluate the scientific literacy of their students (OECD, 2019) including Thailand. According to the PISA Report 2018, Thai students still scored lower than the OECD average on the PISA test, and their average score remained constant. Moreover, regional school students needed help identifying, explaining, and applying scientific knowledge in real-life situations (IPST, 2021). One of the leading causes of this problem was the teaching and assessment methods of teachers who focused on content knowledge, which resulted in students needing more competence to apply their knowledge in their daily lives (Rangabthuk, 2020). Researchers and educators agree that the scientific literacy of science teachers is an essential factor for students' scientific literacy and achievement (Al Sultan et al., 2018 ; Barber & Mourshed, 2007)Since science teachers had a role in preparing effective science teaching, teacher literacy was the key to success in developing scientific literacy at all levels (Barber & Mourshed, 2007), especially for students in local contexts (Hanushek et al., 2014). However, numerous schools in local areas of Thailand still need more teachers specializing in their subject contents and effective teaching techniques (IPST, 2012, cited in Wansudon et al., 2017).

Researchers reported that science teachers need to improve their ability to promote an understanding of the nature of science, which is an essential component of scientific literacy (Agustiani et al., 2020; Kamsrikaew et al., 2018; Supprakob et al., 2017). Science student teachers who in process of prepare science education also have limited scientific literacy, especially they have misconceptions about the nature of science in various issues (Agustiani et al., 2020; Jaruanlikitkawin & Chaikit, 2020; Jituafua et al., 2015; Khumraksa&Rakbamrung, 2020; Sairattanain, 2015). Even though they practice professional experience in school, they have misconceptions about the nature of science and limitations in the skills of applying and integrating knowledge in teaching to make students understand the nature of science (Jituafua et al., 2015; Gamjadpai, 2019;Safkolam&Thiangchanthathip, 2021).Teacher preparation programs in universities in local contexts should enhance the scientific literacy of general science student teachers, which will result in their competence and effectiveness.In the local context of Thailand, Rajabhat Universities, a group of universities, is responsible for preparing quality teachers that are consistent with the local context (Rajabhat University Act 2004, 2020). They have an essential role in enhancing the scientific literacy of general science student teachers to perform their duties according to the context. In promoting scientific literacy for the general science student teachers according to the context, it is necessary to know the elements of scientific literacy appropriate to the context. However, research on the components of scientific literacy of general science student teachers in local contexts is limited. This research focuses on developing scientific literacy models for measuring and teaching models for promoting scientific literacy to general science student teachers.

## Theoretical Review: Concept of Scientific Literacy

Scientific literacy originated in Western society and was introduced in the United States in the 1950s to solve the problem of science education in the education system. The US government brought it to define a policy that all citizens must receive a comprehensive primary science education. (Hurd, 1958). Furthermore, the central component of scientific literacy is the adequate understanding of the nature of science, which was conceptualized and defined by the science education community during the past 100 years (Abd-El-Khalick & Lederman, 2000). The concept of scientific literacy is consistent with the constructivist theory, which emphasizes that learners create knowledge for themselves. (Ladhachart & Ladhachart, 2018). Scientific literacy is humans' essential ability to apply to understand various phenomena and solve problems in scientific situations. It helps individuals to understand scientific knowledge along with the process of inquiry or the way of obtaining scientific knowledge and to be able to use scientific knowledge creatively for society in a context-appropriate manner (IPST, 2021; ORST, 2019).

In the research, we review research documents to establish the components of scientific literacy that align with global perspectives and to adjust some aspects to align with the local context of Thailand. The foundational understanding was derived from an analysis of historical developments in scientific literacy over the past 70 years (e.g., DeBoer, 2000; Holbrook & Rannikmae, 2007; Hurd, 1958; Laugksch, 2000). This theoretical understanding was complemented by policies from relevant organizations in science education (e.g., IPST, 2021, NRC, 2006; OECD, 2019) and research works of various academics (e.g., BouJaoude, 2002; Costa et al., 2021; Dirks & Knight, 2016; Five et al., 2014; Pella et al., 1965; Sawatmool, 2002). This comprehensive review aimed to establish a framework of concepts that align with the context of general science educators.

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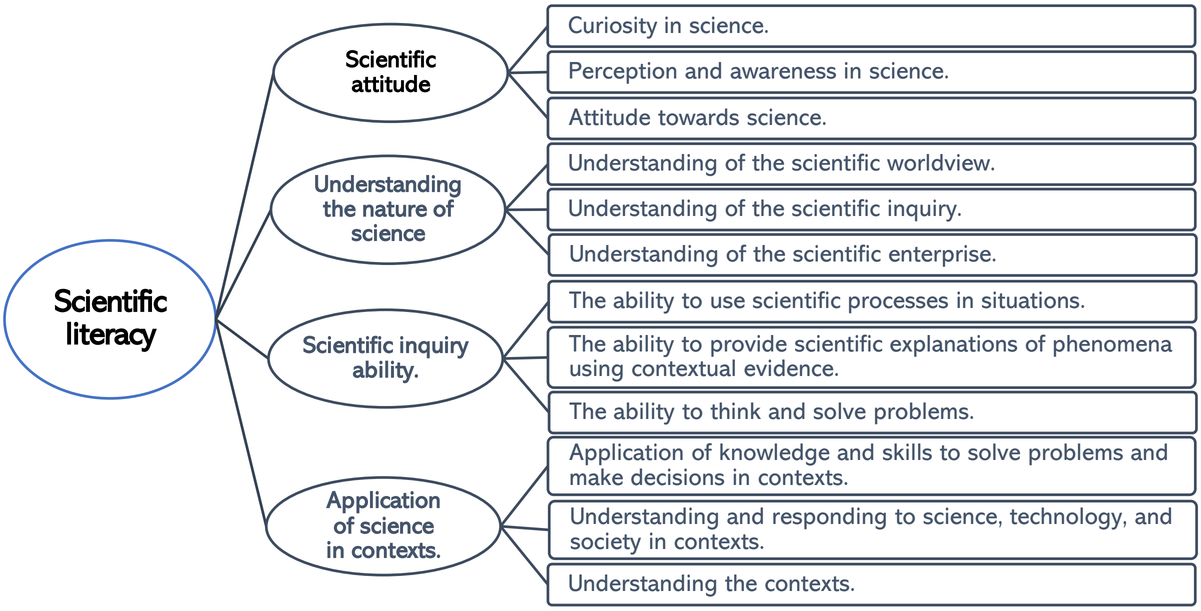


**Figure 1** Conceptual framework of scientific literacy's general science student teachers at Rajabhat University.

1. Scientific attitude is the motivation that drives a person to change their knowledge and skills towards practicing inquiry using scientific processes and methods willingly (Gauld, 1982). This ability identifies: a) Curiosity is an attitude that arises from aspiration that results in interest, curiosity, or intention to learn science. For example, being curious about various phenomena, being interested in science-related things, and intending to develop science. b) Perception and awareness of the value of science arise from motivation that stimulates the perception and use of science to create value. For example, having values, believing in science, seeing the value and importance of science, and having scientific ethics. Furthermore, c) Attitude towards science is a process that arises from responding to positive and negative emotional states. (BouJaoude, 2002 ; Champagne & Klopfer, 1982 ; Costa et al., 2021 ; Dirks & Knight, 2016 ; Fives et al., 2014 ; IPST, 2018 ; ORST, 2019 ; Pella et al., 1965 ; Sawatmool, 2002).

2. Understanding the nature of science refers to the ability to interpret, expand, and explain with reasons related to the specific characteristics of science, the pursuit of scientific knowledge, and the relationship between science, technology, and society. This ability identifies a) an understanding of scientific worldview, an understanding of the perspective that science has on various phenomena around it, according to the philosophy of science, based on evidence and reason, b) an understanding of scientific inquiry: an understanding of the

process of inquiry for scientific knowledge, which includes reasoning, empirical evidence, imagination and creativity to provide explanations and predictions and summarize for use as scientific knowledge without bias and c) an understanding of scientific enterprise: an understanding of interrelationship of science, technology, and society, which in scientific context. (BouJaoude, 2002; Costa et al., 2021; Fives et al., 2014; Holbrook & Rannikmae, 2007; NRC, 2006 ; OECD, 2019; ORST, 2019 ; Pella et al., 1965; Sawatmool, 2002 ; Yore et al., 2007).

3. Scientific inquiry ability refers to applying scientific methods and skills in scientific situations (ORST, 2019). It has sub-components: a) the ability to use scientific processes, b) the ability to explain phenomena in context, citing evidence and various theories to support claims with cause and effect, and c) the ability to think, solve problems and make decisions in scientific situations. (Champagne & Klopfer, 1982; Costa et al., 2021; NRC, 2006; Fives et al., 2014; Holbrook &Rannikmae, 2007; OECD, 2019; ORST, 2019; Pella et al., 1965; Sawatmool, 2002; Yore et al., 2007).

4 . The Application of science in context refers to the ability to apply scientific knowledge and skills in contexts appropriately. General science teachers should have the following abilities: a) application of knowledge and skills to solve problems and make decisions in context, b) understanding and responding to science, technology, and society in context, and c) Understanding the context at the individual, social, national, and global levels (BouJaoude, 2002 ; Champagne & Klopfer, 1982 : Costa et al., 2021; Holbrook & Rannikmae, 2007; Fives et al., 2014; NRC, 2006; OECD, 2019; ORST, 2019;Pella et al., 1965; Sawatmool, 2002; Yore et al., 2007)

## Objectives

To analyze and validate the confirmatory factor model of scientific literacy's general science student teachers at Rajabhat University with empirical data.

## Research Method

This quantitative research uses the secondary confirmatory factor analysis technique to investigate the consistency of the scientific literacy model of general science student teachers at Rajabhat University. The research method is as follows:

**1. Population and Sample:** The population consisted of 1200 undergraduate students who in the second year of the academic year 2022 in general science programme of Rajabhat University. The sample was general science student teachers from Rajabhat University who are currently studying in the second year of the academic year 2022. The sample size was calculated using the G*power program, with 12 observed variables, 33 parameters to be estimated, an Effect Size equal to 0.3 at the statistical significance level 0.05, and a test power value equal to 0.80. Calculate the degrees of freedom of model (df) using the method of Schumacker and Lomax (2010) obtained 45, resulting in an appropriate minimum sample size of 322. In the research, a sample size of 400 persons was determined, which exceeded the minimum number aligned with Gagne and Hancock (2006) also recommended a minimum sample size of 400 for confirmatory factor analysis of component structures. We recruit samples by a multi-stage random sampling method: 1) Stage 1: Stratified random sampling: We select representatives from 16 universities, all divided into seven regional groups. The universities were chosen proportionally from each region using a random sampling method, and 2) Stage 2: Convenience Sampling: We selected 400 second-year students from the selected universities were randomly chosen, with 25 students from each university.

**2. Instrument:** The research instrument consisted of a questionnaire divided into two parts: 1) Part 1 contained three questions about respondents' general information, and 2) Part 2 contained 36 Likert-scale questions designed to measure respondents' opinions on their scientific literacy in four dimensions: scientific attitude, understanding of the nature of science, scientific inquiry ability, and application of science in contexts—The questionnaire was checked for validity by five experts for the Index of Item Objective Congruence (IOC). Items with an IOC value above 0.50 were selected (Rovinelli & Hambleton (1977). The resulting questionnaire items had IOC values between 0.80-1.00, indicating their content validity. The questionnaire was tried out with 30 science student teachers and calculated Cronbach's alpha coefficient for reliability, which had a coefficient equal to 0.979. The four dimensions of scientific literacy, 1) scientific attitude, 2) understanding of the nature of science, 3) scientific inquiry ability, and 4) application of science in context, demonstrated high reliability with coefficients of 0.913, 0.940, 0.942, and 0.925, respectively. Nunnally et al. (1978) suggested that a coefficient value greater than or equal to 0.70 is an acceptable value.

**3. Data Collection:** After obtaining approval from the Human Research Ethics Committee (COA No. BSRU-REC 660206), we sent questionnaires and a request for a data collection authorization letter to the 16 selected state universities for data collection. Upon receiving authorization, the universities returned the questionnaires by mail. We prepared and categorized samples for data analysis. The samples were 71 male respondents (17.75% of the total sample) and 329 female respondents (82.25% of the total sample).

**4. Data Analysis:** We analyzed the data using the following analytical methods: 1) descriptive statistics, i.e., mean, standard deviation, coefficient of variation, Skewness, and Kurtosis ; 2) Pearson's correlation coefficient; and 3) secondary order confirmatory factor analysis. We assess the scientific literacy model's construct validity by the second-order CFA examining the relationships among latent factors (second-order factors) that explain the observed correlations between measured variables (first-order factors).

## Results

The basic statistics showed that scientific literacy had an average of 4.49, a standard deviation of 0.47, and a coefficient of variation (C.V.) of 0.10. When taking the data to test the skewness and kurtosis by considering the skewness criteria of Meyers et al. (2006), which proposed that it should be no more than 0.50 and considering the kurtosis criteria of Bollen (1989), it was proposed that the kurtosis It should be no more than 3. The analysis result showed that the data were slightly negatively skewed, and the kurtosis was within the criteria. However, for data exceeding 200 samples, the normality of the data except this criterion was excluded (Hair et al., 2006). Therefore, the data obtained from the data collection can be used for CFA analysis. The data collection was analyzed by Pearson’s correlation of variables. The correlation matrix analysis of the 12 observed variables shows the correlation among latent variables with a significant statistic correlation at 0.01. The correlation value ranged between 0.452 and 0.879.Moreover, the correlation matrix is not an identity matrix. It shows that all variables are sufficiently related to each other to be used for further component analysis (Bartlett's Test of Sphericity: Approx. Chi-Square=4105.523, df=66, p=0.000) The parameters of the scientific literacy for general science student teachers at Rajabhat University were organized and analyzed by confirmatory factor analysis. The first-order factor analysis was for the indicators (Table 1), and the second-order factor analysis was for factors (Table 2).Table 1 and 2 show the confirmatory factor analysis results of the scientific literacy of general science student teachers at Rajabhat University. The model fit indices are as follows:

Chi-square ($\chi^2$) = 55.201 (df = 43, p = 0.100), Relative Chi-square ($\chi^2$/df) = 1.284, RMSEA = 0.027, GFI = 0.978, AGFI = 0.961, CFI = 0.997, NFI = 0.987, NNFI=0.995, RMR = 0.006, and SRMR = 0.025. All the fit indices meet the specified criteria. Relative chi-square is less than 2, RMSEA, RMA, and SRMA are less than 0.05, and GFI, AGFI, NFI, and NNFI are greater than 0.95.

**Table1** Estimated parameters and statistics of first-order CFA of scientific literacy model for general science student teachers at Rajabhat University.

| Factors | $\beta$i | bi | SE | t | $r^2$ |
|---|---|---|---|---|---|
| 1. Scientific Attitude(SA) | | | | | |
| SA1: Curiosity in science. | 0.893 | 0.437 | - | - | 0.798 |
| SA2: Perception and Awareness in science. | 0.936 | 0.474 | 0.017 | 28.330 | 0.876 |
| SA3: Attitude towards science | 0.853 | 0.422 | 0.018 | 23.818 | 0.728 |
| 2. Understanding of the nature of science (NOS) | | | | | |
| NOS1: Understanding of the scientific worldview. | 0.863 | 0.423 | - | - | 0.745 |
| NOS2: Understanding of the scientific inquiry. | 0.849 | 0.373 | 0.018 | 20.821 | 0.721 |
| NOS3: Understanding of the scientific enterprise | 0.849 | 0.417 | 0.020 | 20.866 | 0.720 |
| 3. Scientific inquiry Abilities (SIA) | | | | | |
| SIA1: The ability to use scientific processes in situation. | 0.867 | 0.452 | - | - | 0.751 |
| SIA2: The ability to provide scientific explanations of phenomena using contextual evidence. | 0.905 | 0.482 | 0.020 | 23.718 | 0.819 |
| SIA3: The ability to think and solve problem. | 0.817 | 0.416 | 0.020 | 20.414 | 0.668 |
| 4. Application of science to contexts (ASC) | | | | | |
| ASC1: Application of knowledge and skills to solve problems and make decisions in contexts. | 0.808 | 0.404 | - | - | 0.654 |
| ASC2: Understanding and responding to science, technology, and society in contexts. | 0.944 | 0.506 | 0.022 | 23.497 | 0.890 |
| ASC3: Understanding the contexts. | 0.929 | 0.489 | 0.021 | 23.101 | 0.862 |

**Table 2** Estimated parameters and statistics of second-order CFA of scientific literacy model for general science student teachers at Rajabhat University.

| Latent variables | SC | bi | SE | t | $R^2$ | AVE | CR |
|---|---|---|---|---|---|---|---|
| Scientific Attitude | 0.788 | 0.379 | 0.041 | 9.238 | 0.621 | 0.800 | 0.923 |
| Understanding the Nature of Science | 0.826 | 0.318 | 0.042 | 7.668 | 0.682 | 0.866 | 0.942 |
| Scientific inquiry Ability | 0.860 | 0.261 | 0.040 | 6.567 | 0.739 | 0.746 | 0.898 |
| Applying science to contexts. | 0.825 | 0.321 | 0.039 | 8.277 | 0.679 | 0.878 | 0.951 |

Chi-square ($\chi^2$)=55.201 (df=43, p=0.100), Relative Chi-square ($\chi^2$/df)=1.284 (<2) RMSEA=0.027 (<0.05)
GFI=0.978 AGFI=0.961 CFI=0.997 NFI=0.987 NNFI=0.995 (>0.95) RMR=0.006(<0.04) SRMR=0.025 (<0.05)

Therefore, it concluded that the scientific literacy of general science student teachers at Rajabhat University comprises four main components: scientific attitude, understanding of the nature of science, scientific inquiry ability, and application of science in contexts where the scientific attitude component measured by three observed variables, namely SA1, SA2, and SA3, the component of understanding the nature of science measured by three observed variables: NOS1, NOS2, and NOS3, scientific inquiry ability component measured by three observed variables, namely SIA1, SIA2, and SIA3, and the component of application of science in contexts measured by three observed variables, namely ASC1, ASC2 and ASC3.It found that the scientific inquiry ability was the most important, followed by understanding the nature of science, application of science in contexts, and scientific attitude, respectively (standardized coefficient of weights were 0.860, 0.026, 0.825, and 0.788, respectively). When considering the weight of the latent variables, the importance of each component is as follows:

1) Scientific attitude is measured by the observable variables SA1, SA2, and SA3, with SA2 being the most significant, followed by SA1 and SA3 (standardized coefficient of weights were 0.936, 0.893, and 0.853, respectively).

2) Understanding of the Nature of Science, measured by the observable variables NOS1, NOS2, and NOS3, with NOS1 being the most significant, followed by NOS2 and NOS3 (standardized coefficient of weights were 0.863 0.849, and 0.849, respectively).

3) Scientific Inquiry Ability, measured by the observable variables SIA1, SIA2, and SIA3, with SIA2 being the most significant, followed by SIA1 and SIA3 (standardized coefficient of weights were 0.905, 0.867, and 0.817, respectively).

4) Application of science in context Measured from 3 variables, ASC2 was the most important, followed by ASC3 and ASC1 (standardized coefficient of weights were 0.944, 0.929, and 0.808, respectively).

The reliability values of Cronbach's alpha coefficient of latent variables, namely, scientific attitude, understanding the nature of science, scientific inquiry ability, and applying science to contexts, were 0.932, 0.889, 0.898, and 0.920, respectively. The measurement model of scientific literacy of general science student teachers at Rajabhat University is shown in Figure 2

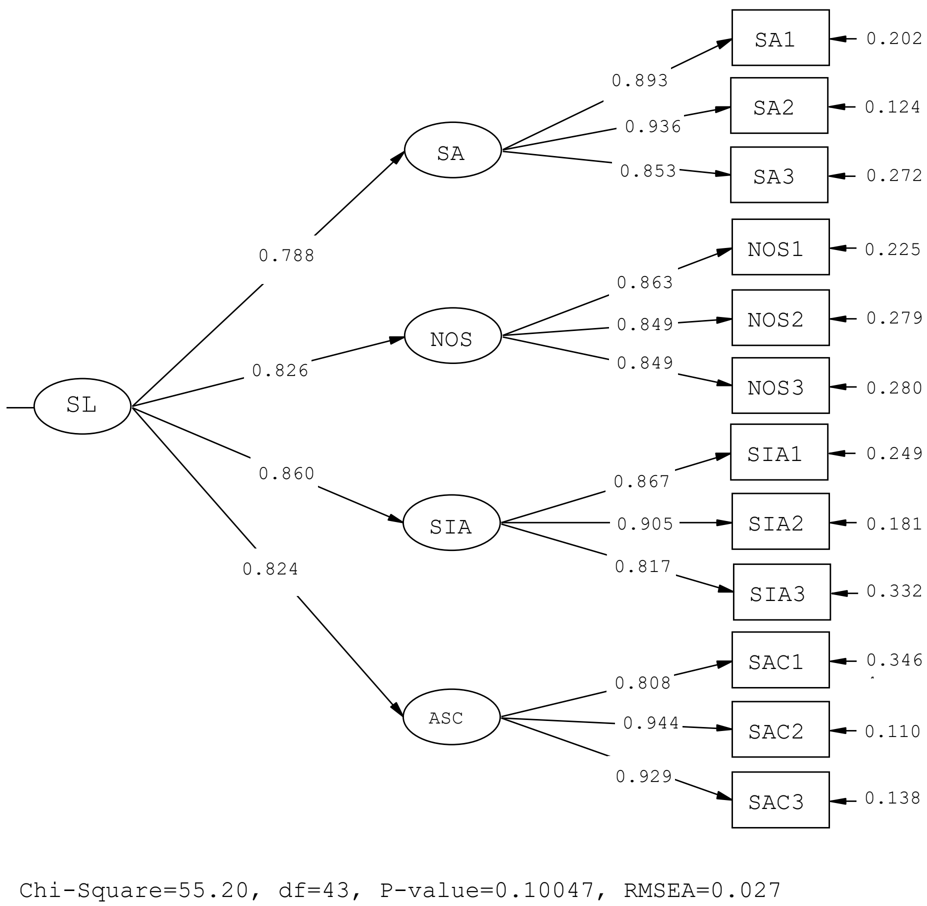


**Figure 2** Results of the second confirmatory factor analysis of the scientific literacy model for general science student teachers at Rajabhat University.

According to the research results, it found that the science literacy model of general science student teachers was consistent with the empirical data, which shows second-order confirmatory fidelity to the Scientific literacy of general science student teachers. It consists of four major components: scientific attitude, understanding the nature of science, scientific inquiry ability, and applying science to contexts, and the four major components can combine into a single component with structural validity.

## Discussion

The research found a second confirmatory component model of science literacy of general science student teachers consisting of 4 main components: scientific attitude, understanding the nature of science, scientific inquiry ability, and applying science to contexts, with all models being consistent with empirical data. The weights of the elements are arranged in descending order as follows:

1. Scientific inquiry ability: This ability was the most correlated with scientific literacy, probably because this ability was an essential factor affecting students' ability to acquire and create new knowledge on their own, consistent with Dirks and Knight (2016) and Wansudon et al. (2017) said that science teachers should engage in scientific inquiry and experimental design which will result in the ability to apply in context when working in schools. Students can use it to develop and design classroom activities. Including the application in daily life.

2. Understanding the nature of science: This element has a standard weight coefficient of elements with inferior values and close to that of the first component, indicating that understanding the nature of science plays an important role and is closely related to scientific intelligence, in line with Costa et al. (2021) which proposes the idea that the nature of science involves a process with various phases and includes the values and assumptions of scientific knowledge as well as the epistemology of science. Therefore, it should be given importance to promote understanding of the nature of science to student teachers. Supprakob et al. (2017) suggesting that Thailand should promote understanding of the nature of science for science teachers, especially science student teachers, to have the ability to integrate science learning and apply it to teaching in the classroom. This element is, therefore, essential to encourage student teachers to have more effective scientific inquiry capabilities.

3. Application of science in contexts: It is the ability that the component weight is close to the second component. Indicates that applicability is essential and relevant. If students can investigate science and understand the nature of science, good will result in application. Therefore, it is necessary to encourage student teachers to apply knowledge and skills in relevant contexts to be used to develop teaching in schools following the

context, which is consistent with Costa (2021), which suggests that using the scientific process in the resolution of problems, decision making and building an understanding of the universe including the application of scientific concepts, theories, and laws in interactions with the universe.

4. Scientific attitude: It has the lowest standard coefficient weight. However, it also has a relationship with high scientific intelligence. It indicates that the development of scientific intelligence due to scientific attitudes is a motive that drives a person to change their knowledge and skills towards practicing inquiry using scientific processes and methods willingly (Gauld, 1982).

## Recommendations:

Science education programs in local universities that encountered constraints of science literacy in science student teachers. These research results, especially the factors and indicators, have been adapted into a scientific literacy test for assessing student teachers. This assessment instrument should be tailored to the local context. The evaluation of scientific literacy among student teachers at each individual or university would perceive their strengths and weaknesses to develop instruction methods for promotion.

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