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Construction of structural correlation of quantitative literacy and critical thinking, and factors affecting them in students of pre-service biology teachers

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Abstract

Quantitative literacy and critical thinking skills contribute to the skill of pre-service biology teachers to teach 21st-century learning. This study aims to describe the construction of structural correlation between quantitative literacy and critical thinking skills, and factors affected them among South Kalimantan pre-service biology teachers. The researchers employed a quantitative correlational research method. The samples were 245 biology education students in South Kalimantan province. The instrument used for this study was a test instrument and a questionnaire. The data analysis techniques used were partial least square, structural equation modeling, and Spearman correlation test to evaluate structural models and hypothesis testing. The results of this study indicated that there is a significant relationship between quantitative literacy ability and critical thinking skills of students of pre-service biology teachers in South Kalimantan. There is a significant influence from the factors that affected students' critical thinking skills and quantitative literacy, except age.

Keywords: quantitative literacy, critical thinking, students of pre-service biology teachers

INTRODUCTION

Quantitative literacy and critical thinking are competencies that must be possessed by students to meet today's global challenges. Quantitative literacy is a person's habit of thinking mathematically to understand numerical information. Contextually quantitative literacy can be understood as the ability to interpret data and reason numerically in everyday life (Speth et al., 2010). Association of American Colleges and Universities defines quantitative literacy as competence, the ability to form habits from thought, and the capacity of working with numerical data with ease (Association of American Colleges and Universities, 2009). Quantitative literacy is a habit of thinking that links an understanding of mathematics with decisions in everyday life. Quantitative literacy will indeed have a lot to do with numbers, diagrams, charts, and even formulas or formulations. However, this quantitative literacy is also as important as the reading and communication skills (Crauder et al., 2015).

The application of quantitative literacy in everyday life can help solve problems that are numerical/quantitative in the workplace and daily life. Quantitative literacy can facilitate decision-making based on quantitative data (Lee-Post, 2019). Quantitative literacy is required for undergraduate students and pre-service biology teachers in order to organize and analyze data in research. However, some research results showed that students have low quantitative literacy and need to improve. Research conducted by Ardiansyah and Diella (2017) showed that the quantitative literacy of biology pre-service teachers at one of the tertiary institutions in Indonesia (Siliwangi University) is still low. This demonstrated that the quantitative literacy ability of biology education students is still low. This is because the learning process does not integrate quantitative literacy, and the lack of facilities to

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Contribution to the literature

- This study can provide specific information on the correlation between critical thinking and quantitative literacy in students' pre-service biology teachers.
- This study describes the construction of the structural correlation between critical thinking and quantitative literacy, as well as several factors that influence it simultaneously.
- The structure construction model of the correlation that is described based on the results of analysis using PLS-SEM can provide a reference for what factors influence critical thinking and quantitative literacy so that these factors can be considered in training these two skills.

familiarize students with quantitative literacy, even though several courses in biology education have the characteristics of practicing quantitative literacy in the learning process.

In addition to quantitative literacy, critical thinking skills is a necessary skill that must be taught. Critical thinking is needed to evaluate the quantitative data presented and claim conclusions based on this data, which is also contributed to the public in everyday life (Best, 2008). In addition, Cao Thi et al. (2023) explain that educators, study time, interest, and students' self-confidence also affect quantitative literacy. So that other skills apart from critical thinking can be trained together with quantitative literacy. For example, creative thinking can be trained by applying the concept of quantitative literacy (Agustina et al., 2021). However, in quantitative literacy and critical thinking, several indicators are in common (Asknes, 2017). Further, Lauermann (2021) explains that in the learning process, quantitative literacy can be included in the learning process to train critical thinking skills.

Critical thinking is the process of evaluating claims and arguments that someone believes are true and having the ability to formulate good arguments regarding these claims (Epstein, 2006). Fisher explained the definition of critical thinking, namely the attitude of someone who tends to consider wisely a problem, conclusion, or subject based on evidence or arguments that support it (Fisher, 2011). Critical thinking is important for making logical judgments about what to believe and what to do. This is crucial for consistently successful decision-making so that the desired goals are achieved (Facione & Gittens, 2016). Students must also possess critical thinking skills to be able to solve complex problems; hence, these are abilities that students need to join the workforce (Anderson & Good, 2020).

Saefi et al. (2016) reported that most prospective biology teacher students at the State University of Malang, Indonesia, have moderate and low critical thinking. In line with this, Rasis and Paidi (2021) also reported that the critical thinking skills of biology students at Yogyakarta State University Indonesia were also in the moderate category, while Anwar's research results indicated that the critical thinking skills of first-semester biology students at a number of Indonesian universities still show low indications (Anwar et al., 2020). This demonstrates the need for efforts to improve critical thinking skills in biology education students. One of these efforts is the use of learning models that can train critical thinking skills (Arsih et al., 2021; Hasanah et al., 2016; Nur et al., 2023).

Quantitative literacy abilities can support critical thinking skills. Critical thinking is needed to evaluate the quantitative data presented and draw conclusions based on this data, which is also presented to the public in everyday life (Best, 2008). Quantitative literacy is linked with critical thinking. Asknes's (2017) research demonstrated that practicing quantitative literacy can enhance students' critical thinking. Both critical thinking and quantitative literacy are based on examining and evaluating evidence, finding implications and consequences, forming conclusions, and expressing knowledge. Quantitative literacy can be developed in the classroom through daily learning by applying quantitative concepts to students' critical thinking (Asknes, 2017; Lauermann, 2021). Several factors can affect students' quantitative literacy and critical thinking. The results of the study showed that several factors influence quantitative literacy, namely interest in mathematics, motivation, length of study, numeracy habits, and curriculum while studying at senior high school (Garcia & Pintrinch, 1992; Mercader et al., 2018; ULM, 2020; Wong & Wong, 2019; Woolcott et al., 2019). In line with this, the ability to think critically is also influenced by several factors. The results of the study showed motivation, length of study, age, and curriculum when pursuing senior secondary education (Aycicek, 2021; Bahr, 2010; Biology Education ULM, 2020; Garcia & Pintrinch, 1992).

Students of the biology education study program at Lambung Mangkurat University, high school of teacher training and education (STKIP) PGRI Banjarmasin, and Tadris biology of Antasari State Islamic University Banjarmasin are partly pre-service biology teachers. In accordance with the learning outcomes of graduates determined by the Indonesian Biology Education Consortium, graduates of biology education must have the ability to plan, design, implement, and evaluate biology learning (ULM Biology Education, 2020). This ability can be supported by critical thinking and quantitative literacy abilities. Research on the relationship between quantitative literacy and critical

Table 1. Distribution of the study population

No	College	Number of biology education students	Percentage (%)
1	Lambung Mangkurat University	337	61
2	Antasari State Islamic University Banjarmasin	140	25
3	STKIP PGRI Banjarmasin	78	14
Total		555	100

thinking that has been reported by Asknes (2017) is limited to nursing students. The results of this study indicated that quantitative literacy has the opportunity to improve critical thinking skills. This research has not included the influence of other factors on the quantitative literacy and critical thinking of biology education students. Even though the integration of mathematical abilities in the inquiry process in biology learning can form quantitative literacy abilities (Baumgartner et al., 2015), this is in line with the results of research of Harianto et al. (2017), Nuraeni et al. (2015), and Nuraeni and Rahmat (2019), which shows the integration of mathematics in several biological topics such as data presentation and calculations on reactions in physiology and comparison of anatomical size data of organs in plants. In the learning process, the presentation of data and mathematical calculations can train students' quantitative literacy (Amin et al., 2020; McNeal & Mierson, 1999; Nguyen et al., 2017). Quantitative literacy and critical thinking are important to support the competence of pre-service biology teachers. However, research on the relationship between critical thinking and quantitative literacy in biology students in South Kalimantan has never been done. Research on influencing factors for quantitative literacy and critical thinking of students of pre-service biology teachers in South Kalimantan has also never been reported. Structural relationships among these two abilities is important to conduct research so it can be used as a consideration in the formulation of curriculum and the selection of learning models that will be used. Currently, consideration of the use of more learning models is based on achievement learning based on aspect knowledge. A learning model used with consideration aspect general abilities or skills is still limited to training a single certain skill. Thus, it is important for further research related to influencing factors of these two abilities on more specific students, that is, students of pre-service biology teachers.

The correlation between quantitative literacy and critical thinking skills of pre-service teacher students is important to examine. The existence of knowledge about these relationships can be a basis for consideration in the application of a learning model so that several skills can be taught to students at the same time in one lesson. As Stehle and Peters-burton (2019) exemplified, the STEM model can support the development of several 21st-century skills. Research by Supratman et al. (2021) shows that different learning models can influence biology students' creative and critical thinking. Hariyanto et al. (2022) reports that critical thinking and social skills can be applied to learning models and contribute to student character. Practicing several skills to students at once in one lesson is expected to make the learning process can achieve the goal effectively and efficiently. Based on this, this study aims to describe the correlation between quantitative literacy and critical thinking as well as the factors that influence these two variables in the students of pre-service biology teachers in South Kalimantan.

METHODOLOGY

Research Design, Population, and Time of the Study

The current research employed a quantitative correlational research. This research was conducted at Lambung Mangkurat University, STKIP PGRI Banjarmasin, and Antasari State Islamic University Banjarmasin. The research subjects were biology education students at Lambung Mangkurat University, STKIP PGRI Banjarmasin, and Antasari State Islamic University Banjarmasin. The data collection process was carried out in April 2022.

The subjects of this study were biology education students at universities in South Kalimantan province, Indonesia. The total population in this study was 555 students from three universities in South Kalimantan with the details and percentages provided in **Table 1**.

The sample in this study was 245 students, or 44% of the total population. 149 respondents came from Lambung Mangkurat University, 34 students from STKIP PGRI Banjarmasin, and 61 students from Antasari State Islamic University Banjarmasin. Samples were asked to complete a questionnaire and answer questions about critical thinking and quantitative literacy. The sample came from students in semester 3 to semester 8. This was because the sample had to take general biology/basic biology courses to master basic biology concepts, which became material concepts in preparing critical thinking instruments and quantitative literacy. The instrument was tested on biology education students from South Kalimantan from semester 3 to semester 6. Students sampled for the instrument test were no longer involved as samples in this study.

Variables

The main variables in this study were quantitative literacy and critical thinking skills. The latent variables in the PLS-SEM analysis were critical thinking skills, quantitative literacy ability, study period that has been

Table 2. Research variables & indicators

Variable	Indicator	Code	Source
Quantitative literacy ability (QLA)	Interpretation	QL 1	Association of American Colleges and Universities (2009)
	Representation	QL 2	
	Calculation	QL 3	
	Assumption	QL 4	
	Application	QL 5	
	Communication	QL 6	
Critical thinking skills (CTS)	Interpretation	CTA 1	Facione and Gittens (2016)
	Analysis	CTA 2	
	Evaluation	CTA 3	
	Inference	CTA 4	
	Explanation	CTA 5	
	Self-regulation	CTA 6	
Age (A)	Age category of respondents	A 1	Wheeler (2017) & WHO (2015)
	Age begins to think critically & think mathematically	A 2	
Study period that has been taken (SP)	Study period that has been taken at tertiary institution that has been taken	SP 1	Toppin and Chitsonga (2016)
	Study period that has been taken at upper secondary level	SP 2	
	Study period that has been taken at junior secondary level	SP 3	
Curriculum & learning process (CLP)	Learning model	CLP 1	Crissien-Borrero et al. (2019)
	Material content	CLP 2	
	Competence	CLP 3	
Motivation (Mot)	Extrinsic factors	Mot 1	McCord and Matusovich (2013)
	Intrinsic factor	Mot 2	
	Interest to learn	Mot 3	
Interest in mathematics (IIM)	Interested in mathematical problems	IM 1	Stevens and Olivárez, 2005 & Wei et al. (2014)
	Feeling of pleasure when working with quantitative data	IM 2	
	Provide time to work with quantitative data	IM 3	
	Passion when working with quantitative data	IM 4	
Habit of mathematical thinking (HMT)	Working systematically with quantitative data	HMT 1	Ario (2015), Levasseur and Cuoco (2003), & Lim and Selden (2009)
	Regularity in analyzing mathematical data	HMT 2	
	Linking between formulas or formulas in mathematics	HMT 3	
	Representation of description in form of a presentation of mathematical data	HMT 4	
	Looking for other alternatives in solving mathematical problems	HMT 5	

taken or time-spent studying, curriculum and learning process, motivation, interest in mathematics, mathematical thinking habits, and age. The exogenous variables were study period or time spent studying, curriculum and learning process, motivation, interest in mathematics, mathematical thinking habits, and age, while endogenous variables were critical thinking skills and quantitative literacy ability. Study period that has been taken, interest in mathematics, habits of mathematical thinking, and age were variables exogenous from endogenous variable quantitative literacy. The interest in mathematics can motivate someone always to involve quantitative data daily to support numeracy behavior and quantitative literacy ability. Regarding the curriculum and learning process, motivation, age, and study period that has been taken were variables exogenous from the endogenous variable of critical thinking skills. Curriculum can determine competency, material content, and learning process. The learning process with a strategy involving active students equipped with a problem-solving process will train students to think critically.

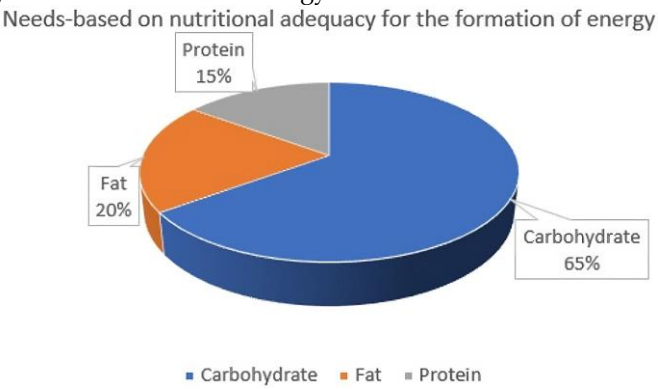
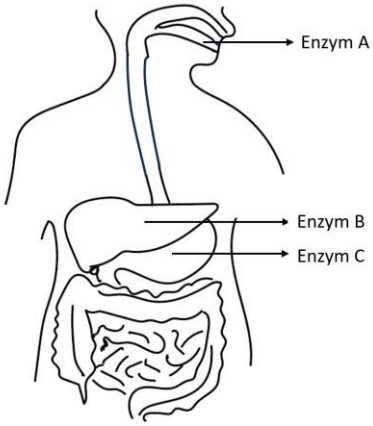
Complete variables and indicators can be seen in **Table 2**.

Data Collection Instruments and Research Procedures

The instrument used in this study was a questionnaire to collect demographic data on respondents that predicted related to quantitative literacy and critical thinking. The demographic data that was measured and predicted was a factor related to critical thinking skills, namely motivation, study period, age, and curriculum when studying senior high school. The demographic data that was measured and predicted was a factor related to quantitative literacy ability, namely interest in mathematics, motivation, study period that has been taken, habits of mathematical thinking, and curriculum when studying senior high school. The other factors that were predicted to affect the ability of quantitative literacy and critical thinking were motivation and interest in mathematics. This factor was also measured using the questionnaire.

Quantitative literacy ability data was measured using a test instrument with reference to indicators developed by Association of American Colleges and Universities (2009). Critical thinking skills data was measured using instruments with reference to indicators developed by Facione and Gittens (2016). The type of data in this study

Table 3. Examples of questions on quantitative literacy & critical thinking

Variable	Indicator	Example of question
Quantitative literacy	Interpretation	A person's daily nutritional needs for energy formation can be seen in following diagram.  If a person must consume 40 grams of fat per day, the most appropriate statement about the weight of protein he must consume in one day is ... A. Protein is the least amount of nutrients needed, namely 30 grams. B. The weight of protein in grams needed is minor than carbohydrates and fats. C. 15% of the total weight of all nutrients. D. Body needs 15 grams of protein according to the proportions on the pie chart. E. The protein needed in one day is 20 grams.
Critical thinking	Interpretation	 Based on picture above, if you see location, where enzyme reaction occurs, then correct statement is ... A. Enzymes A, B, and C work optimally at the same pH. B. Enzyme C works optimally at a lower pH than enzyme B, while enzyme A works optimally at a lower pH than B. C. Enzyme B works optimally at a lower pH than enzyme C and enzyme A. D. Enzymes A and C work at the same pH and higher than the pH of enzyme B. E. Enzyme C works optimally at a lower pH and enzymes A and B.

was quantitative data. Quantitative literacy and Critical thinking instruments use questions in the form of multiple choices. Each indicator consists of two questions. **Table 3** shows an example of questions to measure interpretation indicators on quantitative literacy and critical thinking.

The items on the data collection instrument were validated on a sample of 100 students by measuring the correlation. The instrument reliability was measured by measuring Cronbach's alpha value. The item analysis was carried out using SPSS 26 application. The value of the r-table is 0.195. The results of the validity analysis showed that the 32 items of the instrument were valid, with the lowest correlation coefficient value of 0.657 and the highest of 0.957. Measurement of instrument reliability also showed that the instrument is reliable, with the highest value of 0.950.

The stages of the procedure in this study were

(1) preparing research instruments,

(2) validating research instruments,

(3) collecting data by conducting surveys and distributing questionnaires to research subjects,

(4) measuring critical thinking and quantitative literacy abilities in research subjects, and

(5) performing data processing and data analysis.

In the preparatory stage, we asked for approval to carry out the research from the biology education study

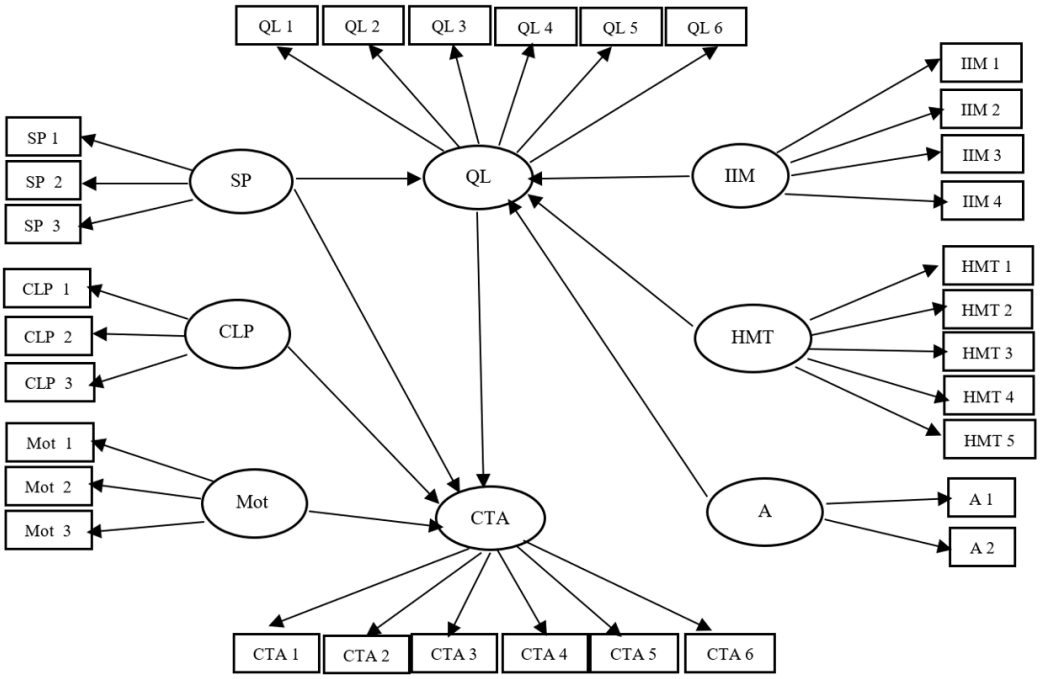


Figure 1. Initial design of the relationship model between variables (Source: Authors' own elaboration, using SmartPLS software)

program coordinators at ULM, STKIP PGRI Banjarmasin, and UIN Antasari. An explanation regarding the research variables, the instruments developed to measure the variables, and the research protocol being implemented also accompany the request for approval. After obtaining approval from the study program coordinators, we explained to students that these students were selected as respondents in this study because of their capacity as prospective biology teachers. The students were asked to fill out the questionnaire voluntarily. Student identities and responses are kept confidential and anonymous. Respondents are allowed to ask questions before answering and completing the questionnaire.

Data Analysis

The data analysis technique in this study was carried out to measure the measurement model through construct validity by measuring the validity and reliability of the indicators (outer model). The data analysis was also carried out for the measurement/evaluation of structural models and to determine the effect of latent variables on the main variables. The analysis was carried out using partial least square (PLS). PLS is an equation model of structural equation modeling (SEM) with an approach based on variance or component-based structural equation modelling.

The initial design of the structural model design path diagram prior to model measurement can be seen in **Figure 1**. **Figure 1** shows the relationship between the structure of the variables. There are eight latent variables, namely critical thinking skills, quantitative literacy ability, study period that has been taken, curriculum and learning process, motivation, interest in mathematics, mathematical thinking habits, and age. The exogenous variables were study period has been taken, curriculum and learning process, motivation, interest in mathematics, mathematical thinking habits, and age. The endogenous variables were critical thinking and quantitative literacy. Each latent variable consisted of several manifest variables or indicators.

Correlation data analysis between the main variables (quantitative literacy and critical thinking) was carried out using the Spearman correlation test. This test was used as an alternative test (non-parametric). This is due to the results of the data normality test as a prerequisite test using the Kolmogorov-Smirnov test showed that the data was not normally distributed. The other prerequisite test was the homogeneity test, with the Levene test showing that the data on both variables were homogeneous. Kolmogorov-Smirnov test, Levene test, and Spearman correlation were performed using IBM SPSS statistics 26.

Research Hypothesis

The hypothesis in this study are:

- There is a correlation between quantitative literacy ability and critical thinking skills.
- There is an effect of study period that has been taken on quantitative literacy ability.
- There is an effect of age on the quantitative literacy ability.
- There is an effect of interest in mathematics on quantitative literacy ability.

Table 4. *Outer loading* & *cross loading* values

Indicator	Outer & cross loading values	Another highest score on other indicators	Information	
			Convergent validity	Discriminant validity
KBK_1<-Critical thinking skills	0.950	0.892	Valid	Valid
KBK_2<-Critical thinking skills	0.920	0.864	Valid	Valid
KBK_3<-Critical thinking skills	0.871	0.838	Valid	Valid
KBK_4<-Critical thinking skills	0.907	0.777	Valid	Valid
KBK_5<-Critical thinking skills	0.854	0.749	Valid	Valid
KBK_6<-Critical thinking skills	0.919	0.863	Valid	Valid
KBM_1<-Habit of thinking mathematically	0.946	0.929	Valid	Valid
KBM_2<-Habit of thinking mathematically	0.863	0.847	Valid	Valid
KBM_3<-Habit of thinking mathematically	0.926	0.898	Valid	Valid
KBM_4<-Habit of thinking mathematically	0.941	0.928	Valid	Valid
KBM_5<-Habit of thinking mathematically	0.867	0.815	Valid	Valid
KPP_1<-Curriculum & learning process	0.961	0.826	Valid	Valid
KPP_<-Curriculum & learning process	0.903	0.809	Valid	Valid
KPP_3 <-Curriculum & learning process	0.948	0.732	Valid	Valid
KLK_1<-Quantitative literacy ability	0.748	0.669	Valid	Valid
KLK_2<-Quantitative literacy ability	0.954	0.815	Valid	Valid
KLK_3<-Quantitative literacy ability	0.938	0.833	Valid	Valid
KLK_4<-Quantitative literacy ability	0.934	0.826	Valid	Valid
KLK_5<-Quantitative literacy ability	0.901	0.811	Valid	Valid
KLK_6<-Quantitative literacy ability	0.876	0.732	Valid	Valid
MTM_1<-Interest in mathematics	0.945	0.914	Valid	Valid
MTM_2<-Interest in mathematics	0.904	0.880	Valid	Valid
MTM_3<-Interest in mathematics	0.944	0.907	Valid	Valid
MTM_4<-Interest in mathematics	0.946	0.937	Valid	Valid
MS_1<-Study period that has been taken	0.948	0.931	Valid	Valid
MS_2<-Study period that has been taken	0.440	0.153	Invalid	Valid
MS_3<-Study period that has been taken	0.480	0.241	Invalid	Valid
Mot_1<-Motivation	0.949	0.868	Valid	Valid
Mot_2<-Motivation	0.952	0.873	Valid	Valid
Mot_3<-Motivation	0.948	0.859	Valid	Valid
U_1<-Age	0.878	0.205	Valid	Valid
U_2<-Age	0.908	0.217	Valid	Valid

- There is an effect of mathematical thinking habits on quantitative literacy ability.
- There is the effect of study period has been taken on critical thinking skills.
- There is an effect of age on critical thinking skills.
- There is the effect of the curriculum and learning process on critical thinking skills.
- There is an effect of motivation on critical thinking skills.

RESULTS

Model Measurement Evaluation Results

Model measurement evaluation was carried out by calculating the value of convergent validity and discriminant validity for each indicator. Convergent validity can be seen from the results of outer loading calculations and discriminant validity from the results of calculating the cross-loading value of each indicator. Both calculations used the SmartPLS 3.0 application. The results of calculating the outer loading and cross-loading values for each indicator on the variable can be seen in **Table 4**. Based on results of calculating the outer loading value in **Table 4**, the two indicators of variable of the study period that has been taken are invalid. This is due to the outer loading value of the two indicators is less than 0.7. The results of the cross-loading measurements showed that the values for all indicators are higher than the cross-loading values for other indicators connected to each of the indicators in question. Therefore, it can be concluded that all indicators have valid discriminant validity. Discriminant validity also needed to be measured at variable level by looking at cross-loading value of each variable. Results of calculating cross-loading value of each variable can be seen in **Table 5**.

Another validity besides convergent and discriminant validity, which also needs to be known, is construct validity. The construct validity can be determined by calculating the average value of the extracted variance (AVE) for each variable. In addition, to construct validity, model measurement also needs to look at the condition of composite reliability and

Table 5. Average value of extracted variance (AVE), composite reliability, & Cronbach's alpha

Variable	Construct validity		Reliability		Discriminant validity		
	AVE value	Information	CRV/CA	Information	CLV	AHV	Information
Habits of mathematical thinking	0.827	Valid	0.947	Reliable	0.909	0.000	Valid
Critical thinking skills	0.818	Valid	0.955	Reliable	0.904	0.595	Valid
Quantitative literacy ability	0.800	Valid	0.949	Reliable	0.894	0.805	Valid
Curriculum & learning process	0.880	Valid	0.931	Reliable	0.938	0.914	Valid
Study period that has been taken	0.441	Invalid	0.633	Not reliable	0.901	0.707	Valid
Interest in mathematics	0.874	Valid	0.952	Reliable	0.935	0.903	Valid
Motivation	0.901	Valid	0.945	Reliable	0.949	0.913	Valid
Age	0.798	Valid	0.747	Reliable	0.893	0.201	Valid

Note. CRV/CA: Composite reliability value/Cronbach's alpha; CLV: *Cross loading* value; & AHV: Another highest value on other variables

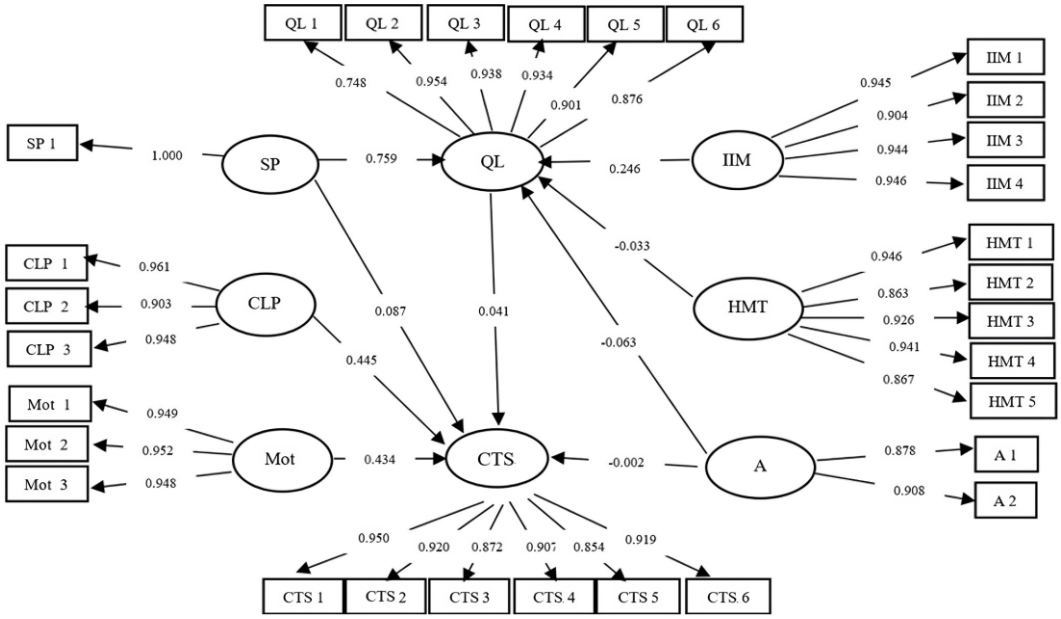


Figure 2. Design of the new structural model (Source: Authors' own elaboration, using SmartPLS software)

Cronbach's alpha value to determine the construct reliability of each variable. The results of calculating the AVE value, composite reliability, and Cronbach's alpha value are given in **Table 5**.

Based on the measurement results for each indicator, there are two indicators of variable of the study period that has been taken, which are invalid and unreliable. These indicators were not included in the model design and hypothesis testing (inner model), so the preparation of a new structural model was carried out.

Design of a New Post-Measurement Structural Model

The design of the new structural model was prepared based on the results of construct validity and reliability, convergent validity, and discriminatory validity. In the design of the new structural model, two indicators of variable of the study period has been taken experience reduction. The design of the new structural model is shown in **Figure 2**.

Structural Model Testing (Inner Model) and Hypothesis Testing

Structural model testing was seen from the original sample value (OS), t-count, and p-value, as well as the value of r^2. OS value, t-count, and p-value to see influence of latent variables (sub-variables on main variable). The values can be seen in **Table 6**, and value of r^2 between the main variables can be seen in **Table 7**.

Based on **Table 6**, it is known that age does not have a significant effect on critical thinking skills and quantitative literacy ability. This is because the t-score is smaller than the t-table value.

Based on the testing structural model (*inner model)*, the final model structure of the relationship between variables can be compiled, as shown in **Figure 3**.

Figure 3 shows that all indicators for each variable have an outer loading value of more than 0.7, so the indicator is valid for measuring each variable. The structural model in **Figure 3** also shows the effect of exogenous variables on endogenous variables

Table 6. Results of measuring the relationship between variables

Relationship between variables	OS	t-score	t-table	p-value	Information	Hypothesis testing decisions
Quantitative literacy ability->Critical thinking skills	0.123	2.570		0.010	Effect	Accepted
Habits of mathematical thinking->Quantitative literacy ability	0.126	2.278		0.011	Effect	Accepted
Curriculum & learning process->Critical thinking skills	0.450	8.696		0.000	Effect	Accepted
Study period that has been taken->Critical thinking skills	0.061	3.864		0.000	Effect	Accepted
Study period that has been taken->Quantitative literacy ability	0.656	15.323	1.966	0.000	Effect	Accepted
Interest in mathematics->Quantitative literacy ability	0.324	3.164		0.002	Effect	Accepted
Motivation->Critical thinking skills	0.430	9.151		0.000	Effect	Accepted
Age->Critical thinking skills	0.011	0.711		0.478	No effect	Rejected
Age->Quantitative literacy ability	-0.003	0.065		0.948	No effect	Rejected

Table 7. R square value of quantitative literacy ability & critical thinking skills

Variable	R square	Adjusted R square
Critical thinking skills	0.893	0.892
Quantitative literacy ability	0.894	0.893

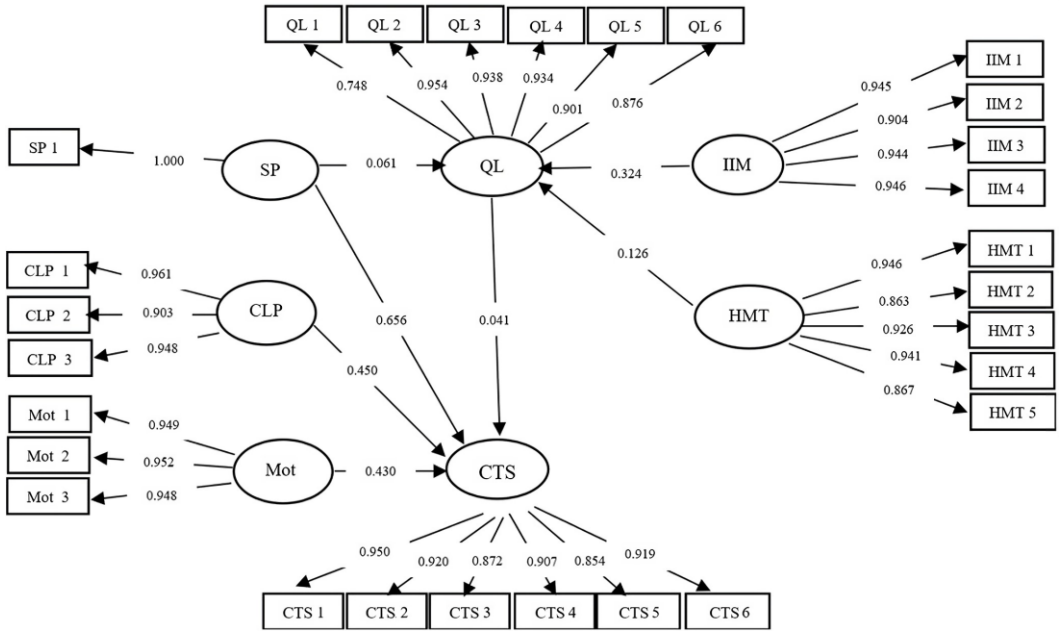


Figure 3. Final model structure (Source: Authors' own elaboration, using SmartPLS software)

Table 8. Results of the data normality test with the Kolmogorov-Smirnov test

Variable	n	Sig	Information
Quantitative literacy ability	245	0.000	Data distribution was not normal
Critical thinking skills	245	0.000	Data distribution was not normal

Relationship Between Quantitative Literacy and Critical Thinking

The prerequisite test was carried out by testing the normality of the data using the Kolmogorov-Smirnov test. The results of the data normality test can be seen in **Table 8**.

Another prerequisite test was carried out by testing the homogeneity of the data. The test used was the Levene test. The results of the data homogeneity test is given in **Table 9**.

Based on the normality test results and data homogeneity, the data was not normally distributed, so the correlation test used was a non-parametric test. The correlation test used to determine the value of the correlation coefficient and the significance of the correlation was the Spearman correlation test (Sedgwick, 2014). Spearman correlation test results can be seen in **Table 10**.

Table 9. Results of data homogeneity testing with Levene test

	n	Sig	Information
Score	245	0.147	Homogeneous data

Table 10. Spearman correlation test results

Variable	Correlation coefficient	Sig. (2-tailed)	Information
Quantitative literacy ability & critical thinking skills	0.703	0.000	A significant correlation

Based on the results of the Spearman correlation test, there is a significant relationship between quantitative literacy ability and critical thinking skills. This can be concluded from the sig value, which is less than 0.05.

DISCUSSION

Evaluation of Model Measurements

PLS-SEM analysis can be used to design the structure of a factor or indicator model that influences a variable so that PLS-SEM can describe the factors that influence a variable simultaneously. PLS-SEM can also be used to measure the effect of a variable on other variables. PLS-SEM analysis can be carried out using the smartPLS application (Sarstedt et al., 2014; Teo & Noyes, 2011). Analysis with PLS-SEM uses two main stages, namely, evaluation of model measurements (including measures of construct validity and reliability, convergent validity, and discriminant validity) and structural model evaluation. In this study, there were two indicators for the study period that did not meet the validity criteria, both convergent validity and construct validity as well as the reliability. These indicators are unable to measure latent variables; thus, these indicators must be discarded, and a new model structure must be developed so that they can measure variables can proceed to the structural evaluation analysis of the model (Gaskin & Lowry, 2014; Hair et al., 2017; Sarstedt et al., 2014).

The relevance of indicators to variables is important because indicators will measure variables. In addition, the very high level of data similarity as the responses of respondents can also affect the results of data analysis (van Gelder & Vrijling, 1998). In indicator 1 and indicator 2 of the study period has been taken as the variable, the items measured are the study period at the junior high and high school levels. This has the potential to generate very similar responses and weaker relevance to measurement indicators for pre-service biology teachers in South Kalimantan.

Structural Model Testing (Inner Model) and Hypothesis Testing

The results of testing the hypothesis regarding the correlation between quantitative literacy ability and critical thinking skills of pre-service biology teachers in South Kalimantan showed that there is a correlation between the two variables. This can be seen from the significance value of the test results, which is 0.000, which is smaller than the significance level of 0.05, and the correlation coefficient of 0.703 (Knapp, 2018; Shi & Conrad, 2009). This is in line with the results of Asknes' (2007) research on nursing students, which showed that quantitative literacy can improve students' critical thinking skills. Best (2008) explained that quantitative literacy ability has the potential to be improved and used to increase students' critical power. Jain and Rogers (2019) also explained that numeracy literacy ability could foster critical power to evaluate existing information. Asknes (2017) further explained that critical thinking and quantitative literacy have the same basis, namely focusing on analyzing and evaluating evidence, identifying implications and consequences, drawing conclusions, and communicating information. This show that quantitative literacy can improve critical thinking, so there appears to be a relationship between the two. The results of another study reported by Burdette and McLoughlin (2010) show that quantitative literacy and critical sociology thinking can be improved simultaneously by using demographic census data in learning.

The results of structural model testing and hypothesis testing showed that age did not have a significant effect on critical thinking skills and quantitative literacy ability, in contrast to the research report by Shirazi and Heidari (2019), who reported that age is an important variable related to critical thinking. Other reports published by Lechner et al. (2021) explained that based on the results of NEPS survey, there were differences in quantitative abilities based on age groups. Lechner further explained that the numeracy abilities of adults can change even for three to six years. The difference in the results of this study with several previous research reports is due to the age grouping categories used in this study. The use of the age category from WHO causes the data obtained from the respondents to be uniform because the respondents come from the same age group, namely the age of undergraduate students. The use of WHO age category causes the average respondent to be in the same age range. This affects the results of the data analysis (Allen, 2017).

The results of hypothesis testing indicate that there is an effect of curriculum and learning on students' critical thinking skills. This variable has the most influence. This is in line with several publications that report the influence of curriculum, learning processes, and learning management on critical thinking skills. The curriculum will determine competence, material content, and the learning process. The learning process with a strategy involving active students equipped with a problem-solving process will train students to think critically. Active student involvement accompanied by problem-solving exercises with the model used in learning will train students to think critically. Active

learning can facilitate students' physical and emotional involvement with the material so that it can encourage students to engage in relevant discussions and evaluations. The active learning model also provides opportunities for students to gain direct experience and can confront students with problems so that students can be trained to think critically in solving problems (Changwong et al., 2018; Heard et al., 2020; Nelson & Crow, 2014; Soltani et al., 2021). In the learning process in tertiary institutions, especially in biology education study programs, critical thinking skills will support CPL study programs, where one of the competencies that must be possessed by pre-service biology teachers is being able to solve problems in learning biology (Biology Education ULM, 2020)

Another factor that has a significant influence on critical thinking skills is motivation. In line with the results of Wichadee (2014), Wichadee's (2014) research, which reported that learning behavior and motivation can affect critical thinking skills. Learning motivation can encourage students to be active and focus on existing problems, so they can train critical thinking skills (Riggs & Hellyer-Riggs, 2014). Learning motivation influences learning interest. This causes motivation to become an important factor in determining learning success. High motivation can cause learning to run smoothly, and students have a higher interest in solving problems so that they can train their critical thinking skills (Sari et al., 2021).

A significant factor influencing quantitative literacy is interest in mathematics. In line with these results, the publication of Tunstall and Bosse (2016) reported that interest in and interest in mathematics can influence quantitative literacy. Interest in mathematics will make someone deliberately expose himself to quantitative data in everyday life. This will lead to calculating behavior and stimulate their numeracy skills and mathematical abilities. A person with a high interest in mathematics has the opportunity to increase his/ her mathematical activity in everyday life so that their quantitative literacy will also be trained (Fisher et al., 2012).

The factor that has the greatest influence on quantitative literacy is the study period that has been taken. The contents of the material in the biology curriculum have the potential to train quantitative literacy (Speth et al., 2010). The longer students study, the greater the opportunity to deal with quantitative data. In the learning process, students who study longer have more opportunities to solve problems with numerical data. Biology students are students of the natural sciences. So there is a great opportunity to deal with quantitative data. The learning process has the potential to train their quantitative literacy. As a result, the longer students study, the more opportunities they have to practice quantitative literacy (Kidron & Lindsay, 2014).

In line with the interest and study period that has been taken, the habit of thinking mathematically also has an influence on the quantitative literacy of pre-service biology teacher students in South Kalimantan. The habit of mathematical thinking will confront students in solving problems related to numerical data in everyday life. The ability to solve these problems mathematically will bring productivity to students to think mathematically. So that students will be accustomed to devoting both emotional and cognitive potential to solving problems based on quantitative data. This has the potential to improve students' mathematical abilities (Dwirahayu et al., 2017).

There is a lot of numerical information that needs to be interpreted and a lot of data in the form of numbers that needs to be understood in everyday life. In order for this problem to be resolved, quantitative literacy needs to be integrated into courses (Speth et al., 2010). Undergraduate students in tertiary institutions can utilize numerical data to develop quantitative literacy (Klug et al., 2017). Educators or lecturers also need to provide assignments in the form of mathematical data analysis so that they can train students' critical thinking and literacy abilities (Nel, 2020). One of the learning forms that can be integrated with mathematical thinking skills is learning biology (Batzel et al., 2012; Hester et al., 2014).

CONCLUSIONS

The results of this study indicated that there is a significant correlation between quantitative literacy ability and critical thinking skills of pre-service biology teachers in South Kalimantan. In addition, there is a significant effect from the curriculum and learning process, motivation, and study period that has been taken on students' critical thinking skills. The results of hypothesis testing also showed that there is an effect of mathematical thinking habits, interest in mathematics, and study period on students' quantitative literacy ability. The factor that does not have a significant effect on students' quantitative literacy and critical thinking skills is age.

Research Limitations

The limitation of this study is that the sample for collecting data on the age variable comes from a group of the same age categories. This could potentially lead to bias in data analysis and could impact hypothesis testing.

Recommendations

In further studies, it is necessary to measure the age variable of subjects of various ages or by using different age categories so that the respondent's data is more diverse.

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