JPPIPA 9(Special Issue) (2023)

Jurnal Penelitian Pendidikan IPA
Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

Students' Information Processing Abilities and Cognitive Processes in Biotechnology Learning

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Received: August 18, 2023
Revised: November 10, 2023
Accepted: December 15, 2023
Published: December 31, 2023

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DOI: 10.29303/jppipa.v9iSpecialIssue.5021

Abstract: The learning outcomes in the independent curriculum expect students to have skills in processing and analyzing data and information. These skills are in line with the information processing abilities developed by Marzano (1993). This research aims to determine the level of students' information processing abilities in biotechnology learning and its relationship with students' cognitive processes. The data in this research were processed using PLS-SEM (Partial Least Square–Structural Equation Model) analysis. Based on the results of the analysis, the instruments used to test information processing abilities, level 1 retrieval and level 2 comprehension cognitive systems, metacognitive systems and self-systems are valid and reliable. However, the level 3 analysis and level 4 knowledge utilization cognitive systems showed invalid and unreliable results so no further evaluation was carried out at these two levels. The results of the inner model analysis show that increasing information processing abilities have a significant and linear relationship to increasing cognitive processes. The relationship between information processing abilities and cognitive processes from the highest respectively is students' comprehension (L2), self-system (L6), metacognitive system (L5), and retrieval (L1).

Keywords: Conventional biotechnology; Cognitive processes; Cognitive system; Independent curriculum; Information processing capabilities; Metacognitive system; Self-system.

Introduction

The independent curriculum was implemented as an effort to improve the quality of learning after the pandemic (Faiz et al., 2022). In this curriculum, student learning outcomes are divided into six phases which indicate the level of student learning progress and competency. The competencies expected in each phase are mutually continuous, so teachers must ensure students achieve the expected competencies. In class X, students are in phase E where students are expected to be able to speak, communicate, and reason according to goals and social context, as well as be responsive to global issues and provide problem-solving (Permendikbud, 2022). To achieve the expected competencies in this phase, students need to master the six process skills that have been summarized in the curriculum. Process skills include observing, questioning, and predicting, planning and conducting research, processing and analyzing data and information, evaluating and reflecting, and communicating results in the form of simple projects (Permendikbud, 2022).

The government gives teachers the freedom to organize learning activities in class but also recommends project-based learning (PjBL) to be used by teachers to help students practice and master these six process skills. In PjBL students are required to explore the knowledge they have and the reality that occurs around them also known as learning by doing (Liu et al., 2019). Activities in PjBL are student-centered and integrated with real-world problems, allowing students to store their new knowledge in long-term memory and integrate it into problem-solving (Indrawan et al., 2018)

How to Cite:
Tamba, Y.R., Rahmat, A., & Solihat, R. (2023). Students' Information Processing Abilities and Cognitive Processes in Biotechnology Learning. *Jurnal Penelitian Pendidikan IPA*, *9*(SpecialIssue), 598–606. https://doi.org/10.29303/jppipa.v9iSpecialIssue.5021

and provide students with the opportunity to reconstruct the knowledge they have to make it meaningful (Almulla, 2020). Apart from that, students are required not only to provide solutions but to apply the knowledge they have in a related project, whether in the form of a campaign or product (Indrawan et al., 2018; Simbolon & Koeswanti, 2020).

The material highlighted in this research is Biotechnology, which in the independent curriculum was renamed Biological Technology Innovation. Based on the results of interviews with teachers in several schools that use the independent curriculum, teachers find it difficult to organize lessons based on this material. Biotechnology material requires initial knowledge related to microorganisms, genetic material, and metabolic processes, especially fermentation. In the independent curriculum, students are not sufficiently equipped with this material, so teachers must organize learning activities in such a way that students' cognitive load is not too large. Apart from that, students must also have good information processing skills to be able to understand and use the knowledge they have to solve problems and create projects as intended in the independent curriculum.

Information processing ability is one of five standard categories that students must possess developed by Marzano (1993). Information processing abilities include students' ability to gather information, interpret information, sort relevant information, and apply the information obtained in solving problems or related projects (Marzano *et al*., 1993). This ability is in line with the competencies and skills needed by students to be able to meet learning outcomes in each phase, especially the highlight in this research is phase E in class X SMA.

Information processing abilities along with memory, attention, and concept formation fall within the framework of cognitive processes. This cognitive process emphasizes the knowledge that students have and how students obtain this knowledge and understanding. Through this process, students are also expected to be able to connect newly acquired information with previous information so that it becomes a more meaningful understanding (Yilmaz, 2011) and can store their knowledge in long-term memory and use their memories in various situations (Lutz & Huitt, 2003). Information processing abilities can help students regulate the cognitive load they receive so that students can organize the information they obtain into meaningful understanding (Rahmat et al., 2014).

If we examine the learning syntax in PjBL, information processing skills are not explicitly highlighted in each learning activity. So it is necessary to develop learning activities and worksheets that are integrated with information processing capabilities. This research aims to determine students' information processing abilities during biotechnology learning using project-based learning and its relationship with students' cognitive processes.

Method

This research is descriptive-correlational research where the researcher wants to see the relationship between information processing abilities and students' cognitive processes using PjBL. Information processing capability consists of 4 indicators, namely information identification (KPI1), information interpretation (KPI2), information relevance (KPI3), and information application (KPI4). The cognitive process consists of 3 systems, namely the cognitive system which consists of retrieval (level 1), comprehension (level 2), analysis (level 3), and knowledge utilization (level 4); the metacognitive system consisting of metacognitive (level 5) and self-system consisting of self-system (level 6). Each level in the cognitive process consists of several indicators as in Figure 1. Information processing abilities are tested using a questionnaire developed based on Marzano (1993) while students' cognitive processes are tested using multiple choice questions for the cognitive system and essay questions for the metacognitive system and self-system.

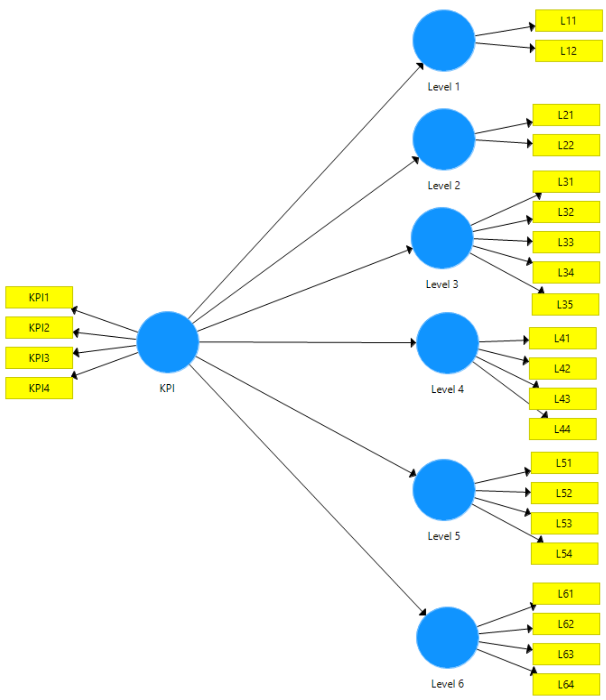

Figure 1. PLS-SEM Model Design

The assessment results were then analyzed using PLS-SEM (Partial Least Square–Structural Equation Model). This analysis is used to test the relationship between constructs by seeing whether there is an influence between the constructs. PLS-SEM analysis consists of outer model evaluation, inner model evaluation, and goodness of fit evaluation. The design of the PLS-SEM model can be seen in Figure 1.

Result and Discussion

Outer Model Evaluation

This evaluation was conducted to see the validity and reliability values of the instruments used. The results of the outer model evaluation can be seen in Table 1. Based on Table 1, it is found that the instruments used in the information processing ability variable, level 1 retrieval, level 5 metacognitive system, and level 6 self-system are valid with an AVE value > 0.5 and reliable with composite reliability value > 0.7 and Cronbach's alpha > 0.6. Level 2 comprehension is valid with an AVE value > 0.6. The Cronbach's alpha value is <0.6 so this variable instrument is not reliable, but the composite reliability level 2 value is >0.7 so this level can still be said to be reliable. At level 3 analysis and level 4 knowledge utilization, both AVE values are <0.6 so these two variables are invalid. Both composite reliability and Cronbach's alpha values also do not meet the requirements so these two levels are also not reliable. In PLS-SEM, variable instruments that are not valid and reliable can be eliminated.

Table 1. Results of Outer Model Evaluation

Variable	Composite Reliability	Cronbach 's alpha	AVE
Information Processing Skills	0.928	0.931	0.762
Level 1 Retrieval	0.879	0.741	0.786
Level 2 Comprehension	0.752	0.348	0.604
Level 3 Analysis	0.382	-0.173	0.230
Level 4 Knowledge Utilization	0.018	0.362	0.228
Level 5 Metacognitive Systems	0.837	0.745	0.564
Level 6 Self-system	0.838	0.757	0.565

The outer loading value is also looked at to determine the validity of the instrument for each indicator. The outer loading value can be seen in Table 2. Based on Table 2, all indicators for the information processing ability, retrieval, comprehension, metacognitive system, and self-system variables have an outer loading value of > 0.6, so this indicator is valid to show the relationship between the indicator and the variable. At level 3, 2 of the 5 indicators have valid outer loading values, while at level 4, there are no valid indicators. This is consistent with the results of the previous analysis in Table 1 so that the analysis and knowledge utilization variables are removed and not discussed for further analysis. The new PLS-SEM model can be seen in Figure 2.

Table 2. Outer Loading Values

Variable		Indicator	Outer loading
Information Processing Skills	KPI1	Identification	0.890
	KPI2	Interpretation	0.885
	KPI3	Relevance	0.900
	KPI4	Application	0.815
Retrieval	L_{11}	Recognizing	0.829
	L_{12}	Recalling	0.940
Comprehension	L_{21}	Integrating	0.834
	L_{22}	Symbolizing	0.715
Analysis	L_{31}	Matching	0.076
	L_{32}	Classifying	0.804
	L_{33}	Analyzing errors	-0.012
	L_{34}	Specifying	-0.032
	L_{35}	Generalizing	0.705
Knowledge Utilization	L_{41}	Decision making	-0.739
	L_{42}	Problem solving	-0.147
	L_{43}	Experimenting	0.068
	L_{44}	Investigating	0.582
Metacognitive Systems	L_{51}	Specifying Goals	0.735
	L_{52}	Process Monitoring	0.737
	L_{53}	Monitoring Clarity	0.826
	L_{54}	Monitoring Accuracy	0.700
Self-system	L_{61}	Examining Importance	.765
	L_{62}	Examining Efficacy	0.768
	L_{63}	Examining Emotional Responses	0.721
	L_{64}	Examining Motivation	0.750

Figure 2 shows that there is a slight change in the value of outer loading after levels 3 and level 4 were removed. Regarding information processing ability, the four indicators of information processing ability are valid with outer loading values between 0.823 – 0.898 > 0.70. These four indicators are closely related to each other. The highest outer loading value is found in the relevance indicator. This shows that student's ability to identify and interpret information is very good, so it also has a big impact on student's ability to connect information to meaningful understanding. This value also shows that changes in students' information relevance abilities have the greatest influence on students' overall information processing abilities. This is in line with research which states that the ability of information relevance depends on students' ability to understand and identify information (Yahaya, 2009). Faroun & Saja (2022) also state that this ability helps students determine relationships between information. To improve information processing abilities, teachers need to re-emphasize students' ability to identify and integrate information into a meaningful understanding. If students can identify the information needed, but students cannot integrate and analyze the relevance between the information needed and the knowledge they already have, then the identification process fails (Rini et al., 2017). This will certainly affect students' ability to apply information. Activities carried out using information processing capability indicators also provide various types of information. Variations of information that enter students' sensory memory will be processed through working memory into short-term memory and then stored in long-term memory (Jamaludin, 2022). This entire series of activities will also affect reducing students' cognitive load (Rahmat & Hindriana, 2014). The lower the cognitive load, the lower the mental effort that must be made in the cognitive process (Jan et al., 2010; Sweller et al., 2011).

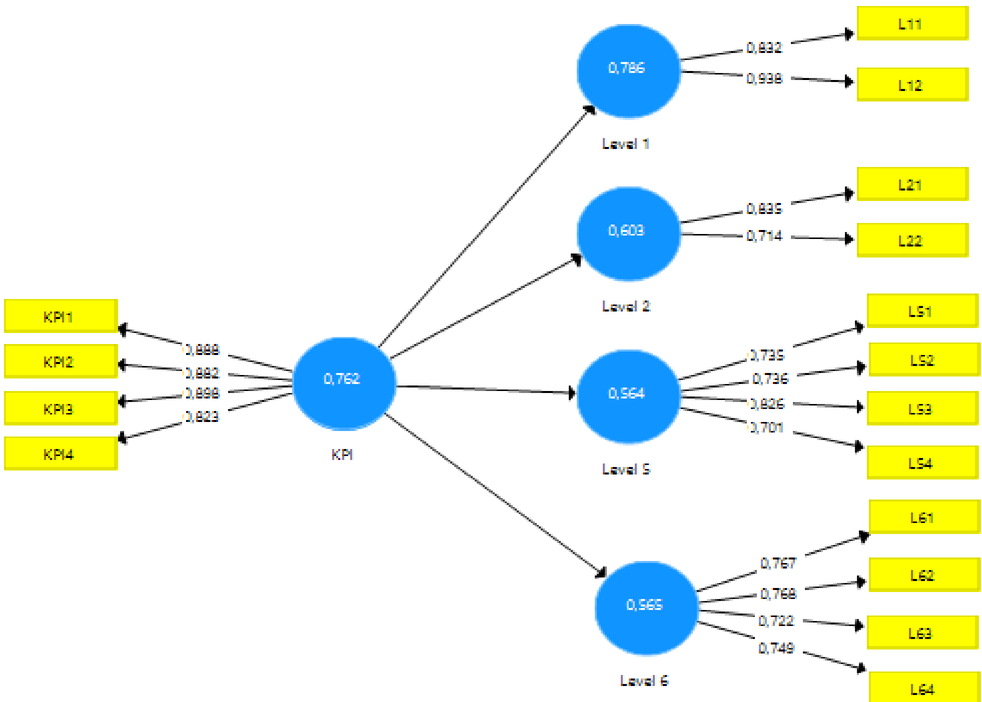

Figure 2. PLS-SEM Model
(Note: The value in the variable shows the AVE value; the value on the from line latent variable towards the indicator shows the outer loading value)

At level 1, both measurement indicators are valid with an outer loading value of 0.832 – 0.938 > 0.70. The recalling indicator shows the greatest relationship in the retrieval variable with a loading factor of 0.786. These results show that students' ability to recall the information they receive is higher than their ability to recognize information. Activities during learning with PjBL help students remember and store their memories in long-term memory. This follows the information processing model by (Van Blerkom, 2009) as shown in Figure 3. Information received through sensory memory will be processed in working memory which is included in short-term memory. This memory can last for 15-20 seconds without repetition (Sweller, 2006). Repetitive stimulation and various types of sensory input can help move information into long-term memory. During project-based learning activities, students receive stimulation from various directions, such as information obtained from the internet or books to fill in student worksheets, discussions with their group friends, direct practice in working on projects, and presentations of project results. This repeated stimulation is what allows students to remember this material well. This is in line with Gagne's information processing model, where increasing information processing abilities affects students' retrieval abilities (Suryana et al., 2022).

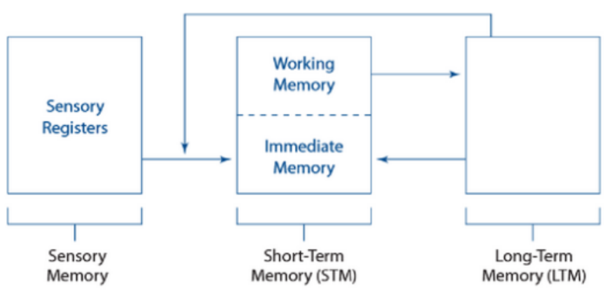

Figure 3. Information Processing Model (Van Blerkom, 2009)

At level 2, both indicators have an outer loading value of 0.714 – 0.835 > 0.70, so the indicators in this variable are also valid. The integrating indicator has the highest loading factor of 0.834. These results show that students' abilities in integrating information are higher than students' abilities in creating symbols. Biotechnology material is still quite abstract for students (Suryanda et al., 2020), so students experience difficulties in reasoning understanding, and integrating the information they get (Jumain et al., 2022; Nugraini & Amelia, 2023). However, the results of this study show that students' integration abilities are quite good.

At level 5 of the metacognitive system, this indicator is valid with outer loading values ranging between 0.701 – 0.826 > 0.70. Among the four measurement items, the monitoring clarity indicator shows the greatest relationship in the information processing ability variable with a loading factor of 0.826. This shows that changes to students' metacognitive systems will have a greater influence on students' abilities in monitoring clarity. The greater the student's awareness of the unclear material being understood, the greater the student's metacognitive abilities. These results follow research by Arifa et al., (2018) which found that activities in project-based learning can stimulate and train students' metacognitive abilities.

The indicator with the lowest loading factor on metacognitive variables is the monitoring accuracy indicator of 0.701. These results show that students lack confidence in confirming their understanding and cannot demonstrate their understanding through evidence. It is worth re-emphasizing that the essence of the project is observing. The lack of results in monitoring accuracy shows the lack of students' ability to observe the projects being implemented. Teachers must help students in monitoring accuracy so that students' metacognitive systems will also improve. Dewi & Sudiatmika (2023) in their research found that the low monitoring accuracy results were caused by several factors and one of them was that students did not adapt learning strategies. When students realize that they are having difficulty or are making mistakes, students must analyze the mistakes and look for ways to correct the mistakes. This is of course related to the ability to identify and apply student information. The better the information processing abilities, the better the student's metacognitive system.

At level 6 of the self-system, the self-system indicator is valid with an outer loading value between 0.722 – 0.768 > 0.70. Among the four measurement items, there were no significant differences between each variable. The indicators of examining importance and examining efficacy show the greatest relationship in the information processing ability variable with loading factors of 0.767 and 0.768 respectively. These results indicate that students' self-system abilities have a large influence on these two indicators. So teachers must emphasize these two indicators in learning activities. Improving students' self-systems will indirectly affect student learning outcomes (Toharudin et al., 2019). Variations in learning activities can be a stimulus to improve students' self-system abilities (Tuzzahra et al., 2022). Project-based learning can be a variation in learning activities, especially in improving social attitudes related to students' self-systems (Berhitu et al., 2020). Apart from that, the use of information processing activities in example-based learning can also help improve students' self-systems and student learning outcomes (Halimah et al.,2021).

Inner Model Evaluation

This evaluation was carried out to see the relationship between the variables in the study. This test will answer the research hypothesis that has been determined previously. This evaluation was carried out by looking at the t-statistic value and p-value of the path coefficient and testing the f-square value. If the t-statistic value is greater than 1.96 or the p-value is smaller than 0.05, then there is a significant influence between the variables. The f square value explains the influence of variables at the structural level with a low criterion of ≥ 0.02; ≥ 0.15 moderate; ≥ 0.35 high). The results of the inner model evaluation can be seen in Table 2.

Table 3. Results of Inner Model Evaluation

	Path Coefficient	T statistics (|O/STDEV|)	P values	f square
KPI > L_1	0.176	1.260	0.208	0.032
KPI > L_2	0.477	3.671	0.000	0.295
KPI > L_5	0.391	2.957	0.003	0.181
KPI > L_6	0.475	4.567	0.000	0.291

A positive path coefficient value means that the latent variable shows a positive influence direction. The higher the original sample value, the higher the influence that the information processing ability variable has on the cognitive process variable. Conversely, a low path coefficient value indicates a negative direction of influence (Hair et al., 2019). From the table above, it can be determined that information-processing abilities have a positive influence on all levels of the cognitive process. These results are in line with research by Faujiyati, (2021) who found that information-processing abilities show a linear relationship and are positively and strongly correlated with the cognitive system.

Based on Table 3, an increase in information processing capabilities has the highest influence on level 2 with an original sample value of 0.477 and significant p-values of 0.00. The T-statistical value of information processing ability at level 2 is 3.671 > 1.96, so the relationship between latent variables in this study is significant. However, increasing information processing ability in increasing level 2 has a moderate effect at the structural level with an f square value of 0.295. This result can be seen from the average score of students at level 2 which is only 36.80.

The outer loading value at level 1 described previously shows quite high results. However, subsequent test results showed that information processing abilities had a low influence on students' retrieval abilities with an f square value of 0.032. The t-statistic value of 1.226 < 1.96 and the p-value of 0.221 > 0.05 also show that there is no significant relationship between information processing abilities and students' retrieval abilities. So it is necessary to carry out further testing regarding the relationship between information processing abilities and students' retrieval abilities. In Gagne's information processing model, the final stage in learning activities is retrieval, after previously students store information through various stimuli (Suryana, 2022).

R square, Q square, Fit Model

Apart from the path coefficient value, the R square and Q square values are also considered in the evaluation of the inner model. The results of the R square and Q square tests can be seen in Table 4.

Table 4. R square dan Q square Values

	R square	Note	Q square	Note
Level 1 Retrieval	0.031	Low	0.003	Low
Level 2 Comprehension	0.228	Low	0.077	Low
L5 Metacognitive Systems	0.153	Low	0.073	Low
L6 Self-system	0.226	Low	0.084	Low

The statistical size R square describes the magnitude of the variation in endogenous variables that can be explained by the exogenous variables in the model. Based on the results of this processing, the influence of information processing abilities on the cognitive, metacognitive, and self-systems is relatively low.

The statistical measure Q square describes a measure of predictive accuracy, namely how well each change in an exogenous variable can predict the endogenous variable. This measure is a form of validation in PLS to state the suitability of model predictions. A q-square value above 0 indicates that the model has predictive suitability with qualitative interpretation values of 0 (low influence), 0.25 medium influence, and 0.50 (high influence). Based on the processing results above, the Q square value of the cognitive process variable provides low prediction accuracy.

The model fit value or model suitability is used to determine the suitability between the data correlation matrix and the estimated model correlation matrix. The results of this measurement are said to have acceptable suitability if the SRMR results are between 0.08-0.10. Based on the test results, the SRMR model estimation results were 0.129 > 0.10. These results indicate that this model does not have an acceptable fit.

Apart from that, model fit can also be seen from the Goodness of Fit Index value. The GoF Index can be calculated from a reflective measurement model. As for the categorization in the GoF Index, that is 0.1 is included in the low category, 0.25 is included in the medium category and 0.36 is included in the high category. Based on the calculation results, the GoF Index value shows a result of 0.323. This shows that empirical data can explain the measurement model with a moderate level of fit.

PLS-Predict

This analysis shows how good the predictive power of the proposed model is. PLS prediction functions as a form of validation of the strength of the PLS prediction test. To show that the PLS results have good predictive power, it is necessary to compare them with the basic model, that is the linear regression model (LM). The PLS model is said to have good predictive power if the RMSE (Root Mean Squared Error) or MAE (Mean Absolute Error) measure is lower than the linear regression model. A comparison of the RMSE and MAE values in the PLS and linear regression models can be seen in Table 5. Based on Table 5, it is known that several indicators have higher PLS RMSE and MAE values than the RMSE and MAE values in LM. This shows that the predictive power of this model is in the medium category.

Table 5. Results of PLS-Predict Analysis

	PLS		LM	
	RMSE	MAE	RMSE	MAE
L11	29.929	24.544	29.106	23.832
L12	26.665	22.314	26.947	22.275
L21	29.874	26.209	34.991	29.193
L22	48.552	44.482	50.346	43.878
L51	19.054	16.105	18.652	15.760
L52	22.268	18.123	22.972	19.295
L53	30.032	24.767	31.959	25.496
L54	32.298	27.469	32.425	28.569
L61	24.216	20.845	21.577	17.899
L62	17.088	13.774	19.296	14.516
L63	23.062	19.222	23.469	20.269
L64	30.168	26.585	31.947	26.922

Robustness Test

This test was carried out to determine the strength of the analytical model to maintain the analysis results against small changes during testing (Hair et al., 2017). The robustness test used in this research is the linearity test. This test aims to look at the relationship between variables by looking at the p-value. The test results show a linear influence between variables if the p-value is not significant (> 0.05). The results of this test can be seen in Table 6. Based on the table, it is found that there is a linear relationship between information processing ability and level 1, level 2, level 5, and level 6 of cognitive processes.

Table 6. Linearity Test Results

	Path coefficient	p-value
KPI -> L_1	0.117	0.382
KPI -> L_2	0.103	0.448
KPI -> L_5	-0.40	0.778
KPI -> L_6	-0.083	0.481

Based on a series of test results, it can be determined that research needs to be carried out again to obtain acceptable match results and have high prediction accuracy. However, the results of the robustness test show that there is a linear relationship between information processing abilities and cognitive processes at level 1, level 2, level 5, and level 6. Question creation in the cognitive process also needs to be considered so that all levels in the cognitive process are valid and reliable.

Conclusion

Based on the findings that have been presented, it was found that there is a significant and linear relationship between information processing abilities and project-based learning as well as information processing abilities and cognitive processes, especially at level 1, level 2, level 5, and level 6. Information processing abilities respectively -Can also improve students' comprehension abilities (L2), self-system (L6), metacognitive system (L5), and retrieval (L1).

Acknowledgements

Thank you to the supervisors who have guided me during the research, to the teachers and school principals as well as the students who have helped make this research process smooth.

Author Contributions

Conceptualization: Yusnita Renata Tamba, data curation: Yusnita Renata Tamba, Adi Rmat, Rini Sobayar, funding acquisition: Yusnita Renata Tamba, methodology: Yusnita Renata Tamba, Adi Rahmat, Rini Sobayar, writing-original draft: Yusnita Renata Tamba.

Funding

This research was independently funded by researcher.

Conflict of Interest

No conflict of interest.

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