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Awareness Learning Metacognitive And Critical Thinking Skill Senior High School Students Through Problem-Based Learning Combined With STEM

Gamar Shamdas

Tadulako University, Central Sulawesi, Indonesia
gamar.shamdas@gmail.com

Abstract

Awareness Learning Metacognitory (ALM) and thinking skills are the dimensions of knowledge and skills that each student should have on each level of education in Indonesia. Quantitative research using quasi-experimental methods aims to describe three things: the critical thinking abilities of biology-based senior high school students, and the critical thinking abilities of gender-based senior high school students, and the ALM senior high school students' critical thinking abilities through PBLs integrated with STEM. This study employs the Nonequivalent Control-Group Design. This study's sample consists of 220 students from seven classes at XI SMAN Model Terpadu Madani Palu in Indonesia.The researchers choose 64 students from two classes as sample. The researchers consider the homogeneity of students and their cognitive abilities in two classes. Hence, the researchers apply purposive sampling. Critical thinking skills data obtained through 12 reasoned multiple choice questions and ALM data obtained through questionnaire consisting of 30 questions. The outcomes showed that PBL joined with STEM fundamentally affected the decisive reasoning abilities of senior secondary school understudies in Science subjects contrasted with customary learning, even though gender was not affected by the PBL combined with STEM model. In addition, PBL combined with STEM has a significant effect on ALM. 87.5% of students who have ALM are in the good category and 12.5% is quite good. All ALM indicators are in good category except for Information Management Strategies which are in good category.

Keywords: Awareness Learning Metacognitive, Critical Thinking Skill, Based Learning Problems, STEM

Introduction

The modern era is closely associated with the significant development in all areas of human activity, no exception the development of science and technology. Hence, we need a strong generation that has many competencies to face and lead a complex global society. To meet the needs of this era, through a regulation issued by the Minister of Education and Culture of Indonesia No. 20 Year 2016 has delivered a message that metacognitive learning awareness (ALM) and thinking skills are dimensions of knowledge and skills that each student should have on each level of education (Permendikbud, 2016) and these two dimensions play an important role and determine student academic success (Mafarja & Zulnaidi, 2022; Özçakmak, 2021). According to (Devikaa & Singh, 2019) ALM helps students comprehend what they know, what they do not know, what they are learning, and how they learn. This helps them become effective, independent learners who have self-regulation skills, actively engage in learning, and succeed (Abdellah, 2015; Abdelrahman, 2020). On the other hand, decisive reasoning abilities as a component of higher-request thinking abilities are the abilities of investigating, assessing and deciphering an issue (Bellaeraa, Weinstein-Jonesa & T.Bakerb 2021; Fernando, Beatrice & Charlesa 2019) so that these abilities contribute significantly to improving students' comprehension and capacity to apply previous knowledge to new circumstances (ŽivkoviL·, 2016).

The ALM not just affects moral thinking and close to home development (Negi, Rajkumari & Rana, 2022) but also has an effect on academic performance (Fooladvanda, Yarmohammadian & Zirakbash 2017; Gul & Shehzad, 2012; Heaysman & Kramarski, 2022) because students with high ALM can use the right strategy and give logical reasons so that their problem solving tend to be correct (Cihanoglu, 2012) ans as a result, their learning outcomes will be better and more efficient (Ayazgok & Yalcin, 2014; Sindhwani & Rakhi, 2019). Then again, understudies with high decisive reasoning abilities will have higher scholastic capacities (Setiawati & Corebima, 2017) because someone who has critical thinking skill usually has analytical skill and curiosity, open mind and quest for truth (Barta, Fodor, Tamas & Szamoskozi, 2022). Furthermore, an understudy who thinks fundamentally can pose fitting inquiries, assemble important data, productively and innovatively sort through this data, reason coherently from this data, and reach solid and dependable resolutions (Özkana, 2010).

ALM and decisive reasoning abilities in understudies at all scholarly levels shift as certain reports uncovered that ALM students of university in Vilnius (Lithuania) are in medium category and college student of Tehran (Iran) in low category (Masoodi, 2019). In addition, students from several public universities of Punjab (Pakistan) have an extremely uplifting outlook towards decisive reasoning however their basic perusing abilities don't reflect decisive reasoning abilities (Din, 2020). While the decisive reasoning abilities of college understudies in the School of Humanities at Ferdowsi College of Mashhad, Iran reached the optimal category at a moderate level but not at a strict level (Khandaghi, Pakmehr & Amiri, 2011 2011). In Indonesia, the ALM student is in high, medium and low categories (Asy'ari, Mirawati, Zubaidah & Mahanal, 2022; Krisdianata & Kuswandono, 2022; Pammua, Amir, Tengku & Rizan, 2014) and students' critical thinking skills are also in the category high, medium and low (Hasanah, Sunarno & Prayitno, 2020; Hindun, Miharja, Permana, Setyawan & Fauzi, 2020; Lutfiyana, Ardini & Setyorini, 2021). Diversity in ALM and similar critical thinking abilities are also found among senior high school students in Palu, Central Sulawesi, in eastern Indonesia.

ALM is strongly influenced by study and learning factors (Altıoka, Başerb, & Yükseltürk, 2019; Schneider, 2001) because through learning, teachers can guide students to be more reliable thinkers, help understanding how to process information (Motlagh & Nasab, 2015), and teach various strategies so they can use newly acquired skills to improve its performance (Schraw, 2016). On the other hand, the process of guidance, collaboration among friends, extra tasks and feedback in every task is very influential on the students' capacity for critical (Jager, 2012) because learning in meaningful, fun, authentic and mutually supportive (Bağ & Gürsoy, 2021) assisted by technological facility can generate motivation and improve students' critical thinking (Cavus & Uzunboylub, 2009; Tang, Vezzani & Eriksson, 2020). The learning process which can generate student passion and building interactive activity in learning can be realized through the implementation of fun and not boring learning models (Davies et al., 2013; Flunger, Hollmann, Hornstra & Murayama, 2022; Wang & Tahir, 2020). Therefore it is advised to apply innovative learning models to encourage ALM (Sutarto et al., 2022; Tedjo, Teopilus, Hartani & Sulindra, 2022) and improve critical thinking skills (Lisa & Halpern, 2011).

Innovative learning which can work on understudies' ALM and the ability to think critically is problem-based learning (PBL) (Gholamia et al., 2016; Ismail, Harun, Zakaria & Salleh, 2018; Michael, 2015; Rijal, Mastuti, Safitri, Bachtiar & Samputri, 2021; Tarmizi & Bayat, 2010) since all PBL phases are potentially trigger superior activity in knowledge application and long-term knowledge retention (Yew & Goh, 2016). PBL is a holistic learning centered on students who are carried out by optimizing collaborative, contextual, integrated, self-contained, and reflective for the development of thinking, behaving, and acting professionals (Gwee, 2009) improve communication skills (Shamdas et al., 2023) and has a significant effect on self-regulated learning (Shamdas, 2023). Authentic problems which are relevant to the topic of the lesson are given through a series of guiding questions and resolved by the working group can provide opportunity for students to share their thought, mutual understanding and communicate with other friends so that these interactions will help them to improve their motivation (Bayat & Tarmizi, 2012). In addition, optimizing the role of elements of critical thinking such as asking questions, breaking down, orchestrating, deciphering, closing, thinking, applying, and utilizing instinct and creativity can facilitate students' ability to explore alternative solutions to problems so that the right solutions are found (Seibert, 2021). All student activity in the PBL is an implementation of cognitive function which can lead them to evaluate events from various points of view and be able to adapt to changing circumstances (Ersoy & Başer, 2014). However, studying science using technology; engineering and mathematics (STEM) on PBLs have a greater for students to search for many things related to the issues and solutions being studied.

Science, Technology, Engineering and Mathematics, or we can call it as STEM, is an integrated, interdisciplinary teaching approach (Tanenbaum, Grey, Lee, Williams & Upton, 2016) and student-centered, is an approach which can guide and help students use and develop knowledge and their skills about science and can develop the technical, creative, and critical thinking skills needed to work well so that, students can produce new products using their knowledge creatively innovative and experience in the fields of technology and engineering (Capraro, Capraro, & Morgan, 2013). STEM learning involves all students to work together so that they are encouraged to focus on real-world science problems related to subject matter, contemplating problem-solving processes, designing real solutions using technology and mathematics so that they can develop their own knowledge in the environment around them (Ejiwale, 2013) . According to the findings of other studies, STEM education has the potential to produce interactive, active learning in order to enhance students' comprehension abilities, problem solving skills, scientific literacy skills (Reyza, Taqwa, Ardiansyah & Nurhidayat, 2020), creative and critical thinking (Ati, Pramita, Santanapurba, Wiranda & Utami, 2021; Saputri & Herman, 2021; Saputri & Herman, 2022), increases academic achievement (Kong & Matore, 2022) as well as ALM (Kustiana, Suratno, & Wahyuni, 2020; Mariano, Figliano, & Dozier, 2021).

Based on the results of previous researches presented above, it is important to study the STEM approach integrated with PBL, especially in arousing ALM and improving critical thinking skills which have never been done for senior secondary school understudies in Palu City, particularly in Science learning. This sort of exploration is vital to apply in light of the fact that it can illuminate how to set off ALM and further develop understudies' decisive reasoning abilities utilizing innovation and math to plan arrangements of genuine issues in a coordinated way in Science learning. Furthermore, the discoveries got can be utilized as a reason for improvement research in Science learning. Teachers can also use the findings to plan lessons for other biology textbooks. The PBL-integrated STEM-based decisive reasoning abilities of secondary school science and the gender-based critical thinking skills of high school biology students, and the ALM of high school students studying biology through PBL-integrated STEM and categorize them are therefore the focus of this study.

Methodology

The type of quasi-experimental research using Nonequivalent Control-Group Design is research method applied pretest and posttest given in two observed groups and only experimental groups receive treatment (Creswell, 2014). The free variable in this research combines problem-based learning (PBL) and with STEM and variable bound is critical thinking and ALM. The research was conducted in SMAN Model Terpadu Madani Palu, Indonesia and chose 7 classes of class XI with 220 students listed by the year 2021-2022. The researchers choose 64 students from two classes as sample by applying purposive sampling with consideration of the number of samples and cognitive abilities of two students to relative homogeneous (source data: school documentation). Two observed classes were given biology lessons on plant tissue material which was preceded by a pre-test before learning and a post-test after learning. The experimental class using the STEM-integrated PBL model by applying the five stages of PBL adopted from Arends (2012) and conventional learning is given to the control class. Data on critical thinking skills were gathered from the posttest and ALM data obtained through a questionnaire given after the posttest was carried out.

The treatment instruments used in the study included lesson plans which contained learning implementation plans to measure the level of achievement of basic competencies using the PBL model combined with STEM, worksheets, tests of critical thinking skills, and assessment rubrics for critical thinking and questionnaires. Critical thinking skills are measured by 12 reasoned multiple choice questions because reasoned multiple choice questions can assess individual thinking skills spontaneously when recognizing the correct response (Coughlin & Featherstone, 2017; Ku, 2009). Reasoned multiple choice questions were developed from six indicators of critical thinking skills modified from Facione (2011) which were applied to the pre-test and posttest. The answers obtained were given a score of 0-5 according to the modified critical thinking skills rubric from Finken & Ennis (1993), i.e. a value of 0 = no answer, 1 = wrong argument, 2 = irrelevant argument to support the answer, 3 = a few concepts are mutually exclusive related and integrated, 4 = most of the concepts are interrelated and integrated and 5 = answers are accurate, clear, and precise and all concepts are interrelated and integrated. In addition, ALM data was obtained through a questionnaire containing 30 questions developed from eight indicators (Gregory, Dennison & Sperling, 1994). All things in the survey utilized a 5-point Likert scale going from Firmly Differ to concur unequivocally.

Pre-test and posttest scores as well as the results of the questionnaire were analyzed using analytical and descriptive statistics. The posttest average scores and the responses to the questionnaires given to the experimental and control classes were calculated using descriptive statistics. Data on critical thinking skills and ALM were tested for normality utilizing the Kolmogorov-Smirnov test and homogeneity tried utilizing the Levene test. If the data have a normal distribution and there is no difference in variance between groups, The independent t-test is then used to continue the analysis. Statistical data analysis using SPPS version 25.0. On the other hand, ALM description is calculated using the following formula:

$$\text{Awareness Learning Metacognitif} = \frac{\text{Achieved score}}{\text{Score maximum}}$$

The results obtained were converted into four categories according to the criteria used by Asy'ari, Ikhsan & Muhali (2019) which are shown in Table 1.

Table 1. Awareness Learning Metacognitif categories (Asy'ari et al., 2019).

Score Interval	Category
3.33 < MA ≤ 4.00	Very good
2.33 < MA ≤ 3.33	Good
1.33 < MA ≤ 2.33	Good enough
MA ≥ 1.33	Low

Each instrument was carried out for internal validity including construct validity and content validity (Chen & Rossi, 1987; Teglasi, 1998). It is assessed by two senior lecturers who are experts in evaluating biology education in the Biology Education study program FKIP Tadulako University, Indonesia. Content validity determines the extent to which the question items represent all subject matter and construct validity includes the quality of all instrument items based on variable operational definitions. The construct validity test was carried out by revising the learning tools based on expert advice. The validation results from the experts show that the instrument is valid. Empirical validity was carried out by testing 12 reasoned multiple choice test numbers and 30 statement items in a questionnaire distributed to 30 students from other schools. Tests were directed to decide the legitimacy and dependability of the instrument. Validity refers to the level of accuracy of measuring instruments and accuracy in performing measurement functions related to variable characteristics. Reliability is related to an index that indicates the extent to which a measuring instrument is reliable. The results of the analysis show that 12 reasoned multiple choice items in the test instrument and 30 statement items in the questionnaire instrument are included in the valid criteria.

Results and Discussion

The results and discussion on the use of the PBL model joined with STEM are presented in the following.

Decisive Reasoning Abilities for Senior Secondary School Understudies in Science Lesson

The critical thinking skill data obtained through posttest has been processed using an independent t-Test with the help of SPPS version 25.0. Normalization analysis Data and the consequences of the unmistakable measurable examination of the decisive reasoning abilities on the exploratory and control class understudies are introduced in Table 2 and Table 3 shows the results of the homogeneity analysis and the t test.

Table 2. Results of data normality analysis and descriptive statistical analysis

Class	**Kolmogorov-Smirnov**			**Descriptive Statistical Analysis**			
	Statistic	Df	Sig.	N	Mean	Std. Deviation	Std. Error Mean
Experiment Class critical thinking skills	.127	32	.200*	32	77.8750	4.14845	.73335
Control Class critical thinking skills	.143	32	.093	32	63.8125	4.76166	.84175

*. This is the true significance's lower bound..

The result of data normality analysis using Kolmogorov-Smirnov test in Table 2 informs that critical thinking skills data in the experiment class [D (32) = 0.127 p = 0.200] and the class control [d (32) = 0.143 p = 0.093] is normally distributed.

Table 3. Results of homogeneity analysis using levene's test and independent t-Test results

		Levene's Test for Equality of Variances		**t-test for Equality of Means**						
									95% Confidence Interval of the Difference	
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Critical thinking skills	Equal variances assumed	1.184	.281	12.59	62	.000	14.0625	1.11640	11.830	16.294
	Equal variances not assumed			12.59	60.85	.000	14.0625	1.11640	11.830	16.294

The Levene test results in Table 3 informed the differences in critical thinking abilities between the experimental and control groups is homogeneous [F (1.62) = 12.596, p = 0.281. In addition, the after effects of the investigation utilizing Free t-Test showed that critical thinking skills in the class control (m = 63.81, sd = 4.76) was significantly lower than the experimental class (m = 77.87, sd = 4.15), t (62) = 12.596, p <0.001.

Tables 2 and 3 show that the decisive reasoning abilities information in the trial class and the control class are typically circulated and homogeneous, allowing for independent T test inferential statistical analysis. The results obtained through t-Test are P <0.001 means Students' critical thinking abilities are significantly improved in the experimental class through the integration of the PBL model with STEM instruction in biological subjects especially plant tissue material. The problem-based learning process which leads students to examine the real problem has motivated students to conduct inquiry activities at the next stage. Observation and search literature through various available media trigger students' enthusiasm in seeking and exploring alternative solutions considered to be the best solution on identified issues. In addition, student creativity can be raised when students are asked to engage in their search results about the forms of plants of the plant which further are made into product through pictures produced as a result of group work. STEM in learning is carried out by students are conducting discussion in a group and collaborate using available technological media. This activity is very effective to stimulate students of critical thinking and learns to produce products. The discoveries in this study are generally in accordance with the consequences of past exploration which revealed that PBL and STEM can further develop mentalities, interests and characteristic inspiration for science and understudies' capacity convictions for science and arithmetic (Laforce, Noble & Blackwell, 2017). The results of other studies also report that integrated STEM in learning causes students to be able to answer questions, be able to solve problems, increase scientific literacy, creativity and learning outcomes (Pahrudin et al., 2021).

Gender Differences in the Critical Thinking Capabilities of High School Students

Data on gender-based critical thinking skills in the experimental class obtained through the post-test were processed using an independent t-test with the help of SPPS version 25.0. Data normality analysis and results of descriptive statistical analysis of students' critical thinking skills based on gender in the experimental class are presented in Table 4 and the results of the homogeneity analysis and t test are presented in Table 5.

Table 4. Results of data normality analysis and descriptive statistical analysis

Gender	Kolmogorov-Smirnov			Results of Descriptive Statistical Analysis			
	Statistic	Df	Sig.	N	Mean	Std. Deviation	Std. Error Mean
Female	.141	22	.200*	22	77.5455	4.14875	.88452
Male	.163	10	.200*	10	78.6000	4.27395	1.35154
*. This is a lower bound of the true significance.							

The result of data normality analysis using Kolmogorov-Smirnov test in Table 4 informed that data on female gender [D (22) = 0.141 p = 0.200] and male gender [d (10) = 0.163 p = 0.200] distributed normally.

Table 5. Results of homogeneity analysis using levene's test and independent t-Test results

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Gender	Equal variances assumed	.042	.840	-.660	30	.514	-1.05455	1.59675	-4.3155	2.2064
	Equal variances not assumed			-.653	7.022	.523	-1.05455	1.61525	-4.4620	2.3530

Table 5 displays the Levene test's findings, which indicate that the variance of female and male gender data is homogeneous [$F(1,30) = 0.660$ $p = 0.840$. In addition, the results of the analysis using independent t test showed that the male gender ($M = 78.6$, $SD = 4.273$) was not significantly different from the female gender ($M = 77.54$, $SD = 4.148$), $t(30) = 0.660$, $p > 0.05$.

The results of the data analysis presented in Tables 4 and 5 show that the posttest data for women and men are normally distributed and homogeneous so that inferential statistical analysis using the independent t test can be carried out. The results obtained through the t test were $p> 0.05$ meaning that there was no difference in the critical thinking skills of men and women after learning using the STEM-integrated PBL model. Equal opportunities are given to all students in participating in learning and each student follows every step of PBL as guided by the teacher. The togetherness of male and female students in this study was clearly seen when students conducted literature searches and exchanged information, and discuss the findings and accuracy of alternative solutions to the problems being studied. Conducive cooperation in groups is well maintained. It can be seen when female students write and complete assignments in the columns provided on the worksheet while male students describe plant tissues as assigned. Collaboration which is built in learning through the clear role of each student in their groups cause the problem identification and working process run according to the specified time. The findings in this study are relatively in line with the results of research which reports that gender is not affected by STEM, especially in thinking skills and teamwork (Kucuk & Sisman, 2020). The results of other studies also reported that there was no statistically significant difference between male and female grade 11 students in thinking skills in terms of originality of answers and fluency in completing tests (William, Okanson, Sahin & Abdelsamea, 2015) and gender had no significant effect significantly to the scientific reasoning abilities of grade 11 science students (Piraksa, Srisawasdi & Koul, 2014).

Awareness Learning Metacognitif of Secondary School Understudies in Science Lesson

Data on awareness learning metacognitif of secondary school understudies in science lesson were processed using an independent t-test with the help of SPPS version 25.0. Data normality analysis and results of descriptive statistical analysis of awareness learning metacognitif of high school students in biology lesson are presented in Table 6 and Table 7 displays the results of the homogeneity analysis and t test.

Table 6. Results of data normality analysis and descriptive statistical analysis

Awareness Learning Metacognitif	Kolmogorov-Smirnov			Results of Descriptive Statistical Analysis			
	Statistic	df	Sig.	N	Mean	Std. Deviation	Std. Error Mean
Experimental Class	.140	32	.115	32	75.6250	5.41652	.95751
Control Class	.122	32	.200	32	68.9375	5.91301	1.04528

The result of data normality analysis using Kolmogorov-Smirnov test in Table 6 reveals that the ALM data in the experiment class [D (32) = 0.140 p = 0.115] and the Control Class [D (32) = 0.122 p = 0.200] is normally distributed.

Table 7. Results of homogeneity analysis using levene's test and independent t-Test results

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Awareness Learning Metacog-nitif	Equal variances assumed	1.146	.289	4.71	62	.001	6.68750	1.41755	3.8538	9.5211
	Equal variances not assumed			4.71	61.52	.001	6.68750	1.41755	3.8534	9.5215

The Levene test results in Table 7 revealed that the ALM data variance for the experimental class and control class is homogeneous [F(1,62) = 4.718, p = 0.289. In addition, the results of the analysis using the independent t test (Table 9) showed that the ALM in the control class (M = 68.93, SD = 5.913) was significantly lower than the experimental class (M = 75.6250, SD = 5.4167), t (62) = 4.718, p < 0.001.

The results of the data analysis presented in Tables 6 and 7 show that ALM data in the experimental and control classes are normally distributed and homogeneous so that inferential statistical analysis using the independent t test can be carried out. The results obtained through the t test were p <0.001 meaning that learning using the STEM-integrated PBL model in the experimental class had a significant effect on students' ALM, especially in Biology subjects. The statistical test results obtained are supported by the results of the analysis based on the categorization as presented in Tables 8 and 9.

Table 8. Categories of metacognitive awareness learning in experimental and control classes

	PBL + STEM		Conventional		Category
	Total	**Percentage**	Total	Percentage	
Awareness Learning Metacognitif	-	-	-	-	Very good
	28	87,5	11	34,4	Good
	4	12,5	21	65,6	Good enough
	-	-	-	-	Low

The data in Table 8 shows that most students who taok part in STEM-integrated PBL learning have ALM in the good category and only a small number of students are in the pretty good category. In contrast to the control class with conventional learning. But none of the two classes reached the very good or low categories. The results obtained are supported by the data in table 9, namely the seven ALM indicators are in the good category and only the Information Management Strategies indicator is in the good enough category for learning with STEM integrated PBL. But in conventional learning, only the Procedural Knowledge, Debugging Strategies and Evaluation indicators are in the good category while the others are in the pretty good category.

Table 9. Categories of each ALM indicator in experimental and control classes

Metacognitif Awareness Learning Indicators	**PBL + STEM**			**Conventional**		
	Total Score	**Average**	**Category**	**Total Score**	**Average**	**Category**
Monitoring	312	2,4	Good	287	2,2	Good Enough
Declarative Knowledge	328	2,6	Good	298	2,3	Good Enough
Procedural Knowledge	245	2,6	Good	249	2,6	Good
Conditional Knowledge	329	2,6	Good	291	2,3	Good Enough
Planning	306	2,4	Good	290	2,3	Good Enough
Information Management Strategies	252	2,2	Good Enough	307	1,9	Good Enough
Debugging Strategies	269	2,8	Good	261	2,7	Good
Evaluation	279	2,9	Good	244	2,5	Good

PBL learning that concentrates on the learning process rather than learning outcomes and prioritizes contextual problems and problem solving gives students the opportunity to think about what they know and experience and then combine it with new knowledge to solve existing problems. Tasks like this can support students in developing their thinking processes by criticizing, evaluating, reflecting and finding solutions to problems. Students who have better ALM in learning using PBL combined with STEM will be more careful in acting and wise in providing solutions to a problem or making decisions. The findings in this study are relatively in accordance with the results of previous research which revealed that PBL has caused students to have more sophisticated and more metacognitive evaluation strategies in their thinking and they can assess progress and change strategies as progress is made (Anne, Holliday & Leary, 2011). The results of other studies reported that problem-based learning by posing various problems can improve students' metacognitive abilities because when they faced different problems they can generate creative ideas and further develop their thinking skills (Sart, 2014).

Conclusions

In this study, Metacognitive Awareness Learning and critical thinking skills through the application of PBL combined with STEM in senior high school students were conducted. The results showed that learning using PBL combined with STEM had a significant impact on high school students' capacity for critical thinking compared to conventional learning, although gender was not affected by learning using the PBL combined with STEM. In addition, PBL combined with STEM has a significant effect on Metacognitive Awareness Learning with the achievement which 87.5% of students have Metacognitive Awareness Learning in the good category and 12.5% is quite good. All indicators of Metacognitive Awareness Learning are in good category except for Information Management Strategies which are in good category.

Based on the findings obtained in this study, it is recommended to implement PBL combined with STEM in other schools. Spreading the benefits of implementing PBL combined with STEM needs to be carried out so that science teachers do not feel strange and odd to this combination of learning models. In addition, further research that examines the comparison of ALM and critical thinking skills between STEM-based PBL and other learning models also needs to be conducted. This research will be able to provide information about the advantages or disadvantages of PBL combined with STEM compared to other learning models. In addition, studies that examine the effect of PBL combined with STEM on other thinking skills also need to be carried out so that teachers can find out the benefits that can be obtained through implementing PBL combined with STEM in learning.

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