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THE DEVELOPMENT OF STUDENTS' MATHEMATICAL LITERACY PROFICIENCY

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Abstract

Improving the proficiency in mathematical literacy is one of the efforts to improve the human resources quality. Its development describes the students' strengths and weaknesses to support the improvement. The research tried to describe the development of students' proficiency in mathematical literacy, based on the school level and the students' gender. The research was a cross-sectional developmental study. The population was all of students ranging between 13 and 16 years old in the Province of Yogyakarta Special Region, Indonesia. In the sample were 1,001 students in the 8th, 9th and 10th grade, determined to use the combination of stratified and the cluster random sampling technique. The data were collected using 30 items. The data analysis was conducted by estimating students' ability through the item-response theory approach under the Rasch model and by using the parameters that had been adjusted to the international study item parameter under the concordance model for the linking score to interpret the students' development. The research results showed that there has been improvement of literacy proficiency among the 8th, 9th and 10th grade students. The development would generate higher scores utilizing multiple choice test items. There was a tendency that the school level, gender, the form of items, content, context, and process literacy would influence the mathematical literacy score. The efforts for improving proficiency in mathematical literacy were discussed.

Keywords: *ability development, mathematical literacy, PISA released items*, *cross-sectional developmental study*

Introduction

The efforts of improving the human resources quality, improving the literacy proficiency still becomes the focus of attention for all nations. Similarly, Indonesia as a developing country has also been pursuing the improvement of the human resources quality and that includes the students' proficiency in the schools. The proficiency development, especially that of the students, has still been pursued in order to overcome the learning results that have not been satisfying based on the results of TIMSS (Trends in International Mathematics and Science Study) (Mullis, Martin, Foy, & Arora, 2012; Mullis, Martin, Ruddock, O'Sullivan, & Preuschoff, 2009), PISA (Programme for International Student Assessment) (OECD, 2014) and the results of national study such as the national examination (Kemendikbud Balitbang, 2014; 2015; 2016) and to recollect the importance of mathematical literacy mastery that correlates to another proficiency such as the statistical ability (Lai, Tanner, & Stevens, 2011).

Literacy proficiency has been an international issue in education. The proficiency has been assessed by an international study of PISA. The objectives of PISA international study are to assess the students' knowledge and skills in the real world and to prepare the students in the long-life learning and the community participation (Shiel, Perkins, Close, & Oldham, 2007). The PISA international study might be implemented by the government to, for example, monitor the educational system (Stacey, 2011). In the PISA international study, there are three aspects of literacy that will be measured, namely the reading literacy, the mathematical literacy and the scientific literacy (OECD, 2014).

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Mathematical literacy relates to the individual ability in formulating, identifying, understanding and implementing the mathematical foundations in multiple contexts that an individual will need to deal with in the daily life problems (OECD, 2014). The mathematical literacy includes the mathematical reasoning, the mathematical concept, the mathematical procedure, and the mathematical fact and these aspects will be used for explaining and predicting a phenomenon by emphasizing the competencies of process, content and context. The process competencies in mathematical literacy are formulating, employing and interpreting (OECD, 2014). Then, the substances of the content that will be assessed include change and relationship, space and shape, quantity, uncertainty, and data. Next, the context proficiency relates to the personal, the occupational, the societal and the scientific context. In order to measure the context competencies, a researcher should implement several types of test items. Shiel, Perkins, Close and Oldham (2007) stated that the test item designs for the PISA assessment format were the multiple-choice (MC) and constructed response (CR) items. After the students' responses have been analyzed, the individual ability will be classified into 7 levels, starting from below Level, Level 1 to Level 6.

Kariuki, Kibet, Muthaa, and Nkonke (2012) stated that the lack of students' performance could be caused by teachers' and students' factor such as motivation, quality of teaching and learning, and teaching aids and material. The students' gender also influenced the performance in mathematics. The males' performance was higher than the females' performance (Hall, 2012; Zhu, 2007). However, these opinions are different than the results of a study by Ajali and Imoko (2015), who stated that there was indifferent achievement significantly between male and female. Furthermore, there is another factor that might influence the learning achievement namely the quality schooling (Bohlman & Pretorius, 2008).

There are multiple efforts that might be pursued in order to improve the literacy proficiency. These efforts are pursued by the government, the institutions and even the researchers themselves. Starting from the strategy for developing the literacy programs, the Indonesian government has implemented multiple principles, benefitted the local context, the local design, the participatory process, the action outcome (Department of National Education Indonesia, 1999), and benefitted the scientific approach (Nurhariyanti, Waluyo, & Wardono, 2015). Another effort that might be pursued is integrating the classroom literacy learning (Steihiliber, 2011) and suggesting the integration of mathematical literacy into other school subjects (Bowie & Frith, 2006).

Problem of Research

Within the learning process, mathematics should be mastered by the students gradually from one year to another. Similarly, the students develop the mathematical literacy proficiency gradually from one year to another. The expectation is that the students' literacy proficiency will be increasing over time. The development of literacy proficiency should be noticed in order to provide feedbacks for the teachers and the policymakers and to evaluate and perform the improvement toward the learning process that has been conducted and the importance of policy refinement including the curriculum for improving the students' mathematical literacy and educational literacy in general. Because multiple factors influenced the low students' achievement in learning mathematics such as school level, test type, and students' gender, the development of mathematical literacy is described based on the factors.

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Research Focus

The research was to describe the development of junior and senior high school students' mathematical literacy proficiency by considering the variables of school level, test type, and students' gender.

Research Methodology

Design

The research was an explorative descriptive research with the cross-sectional type of developmental research design. In the research, the researchers would like to describe the development of 8th, 9th and 10th grade students' mathematical literacy proficiency based on the data. The data was collected in 2015 and analyzed in 2017-2018.

Population and Sample

The population in this research was all of the junior high school students ranging between 13 and 15 years old and the senior high school students ranging between 15 and 16 years old in the Province of Yogyakarta Special Region, Indonesia. The sample collecting technique was the combination of the stratified random sampling technique and the cluster random sampling technique. The sample members in the research were the 8th and 9th grade students from junior high schools and the 10th grade students from senior high schools; the schools consisted of high-performance, moderate-performance and low-performance category based on the scores in the Mathematics National Examination. The number of the sample members was 1,001 students consisting of 155 students of 8th grade who were between 13 and 14 years old, 386 students of 9th grade students who were between 14 and 15 years old and 460 students of 10th grade students who were between 15 and 16 years old.

When collecting data, the researchers told the students about the research. The result of the test that was finished by the students was only to measure the students' proficiency in mathematical literacy. The result of the test wouldn't influence anything in relation to students' achievements and judgments. All of the students' identities were hidden to guarantee the objectivity of the research and students' safety and confidentiality.

Instrument and Procedures

The data were collected by administering the test. The test items in the test instrument were designed by adopting the PISA test items that had been released; the length of the test was 30 items. The PISA test items from 3 periods (2003, 2007 and 2011) that had been released were translated into Indonesian language and the contexts were replaced to the ones that govern in Indonesia. The validity of the test items had been validated while the reliability of the test items had been estimated.

The validity of the test instrument had been validated using the content validity that was conducted in order to identify the relevance and the representativeness of the instrument toward the domain under assessment. The validation toward the test instrument was conducted by consulting the text instrument to the experts (professional judgments) in relation to the domains of content and context and the domain of process in the PISA test-item models. The experts also provided feedbacks regarding the material truth, the composition of substances in each domain, the test item readability and the relevance between the test item context and the students in Indonesia.

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In order to estimate the reliability of the test in the form of essay or multiple choices with the dichotomous data, the researcher implemented the Cronbach's Alpha. The test was administered toward 30 students from the 7th Grade in the 1 State Junior High School Bantul, Yogyakarta, Indonesia. The index of reliability was equal to 0.707 and the standard error of measurement (SEM) was equal to 2.81. Based on the SEM score, the researchers implied that if the PISA test item model had been administered again then the score that the students would attain would be from $X_T - 2.81$ to $X_T + 2.81$.

Data Analysis

For the data analysis, the researcher estimated the students' literacy proficiency by implementing the item response theory under the Rasch model and by using the parameters that had been equalized into the international study test item with the concordance model for the linking score. The concordance was conducted by implementing the Mean and Mean Method and then the researcher interpreted the inter-year proficiency literacy development.

The steps of data analysis were as follows: (1) estimating the item parameters and the ability parameters by operating the Rasch model proposed by Masters (2010) both for the students' response from the multiple-choice test items and the dichotomous and polytomous constructed response test item with the assistance of CONQUEST program (Wu, Adam, & Wilson, 1997) and the calibration concurrent model for the 8th, 9th and 10th grade; (2) adjusting the test item parameters to the international test item parameters by means of Mean and Mean method (Hambleton & Swaminathan, 1985) until the researcher attained the adjustment of the item parameter to the international scale for the 8th, 9th and 10th grade and the results of the adjustment are displayed in Table 1; (3) implementing the adjustment equation from the second step in order to adjust the ability parameter for each grade; (4) performing a descriptive analysis in order to present the students' proficiency development for the 8th, 9th and 10th grade; and (5) categorizing the participants' proficiency in accordance with the data analysis within the PISA model for each classroom by using the estimation results of participants' ability.

To categorize the participants' proficiency based on the data analysis within the PISA model, the students' proficiency scale should be transformed using a mean that was equal to 500 and the standard deviation that was equal to 100. The results of the transformation then would be recoded into 7 levels that consisted of below level 1, level 1, until level 6 similar with what stated in the Technical Report (OECD, 2014). Utilizing the results of transformation and the categorization of literacy proficiency, the researcher monitored the development trend. The literacy development trend then was described by referring to the grade and by considering the variables of the school level, gender and item form.

Table 1. The adjustment of the proficiency parameter into the PISA international parameter.

Domain	Sub-Domain	International Mean of Difficulty Parameter	Mean of Difficulty Parameter Resulted in the Research	Beta	Equation of Proficiency Scale Conversion
General Mathematical Literacy Proficiency		-0.235	-0.446	0.211	0.021
Test Item Design	Multiple Choice	-1.287	-2.293	1.006	
	Constructed Response	0.567	0.520	0.045	

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Research Results

The development of students' mathematical literacy within 8th, 9th and 10th grade, overall, was presented in Figure 1.

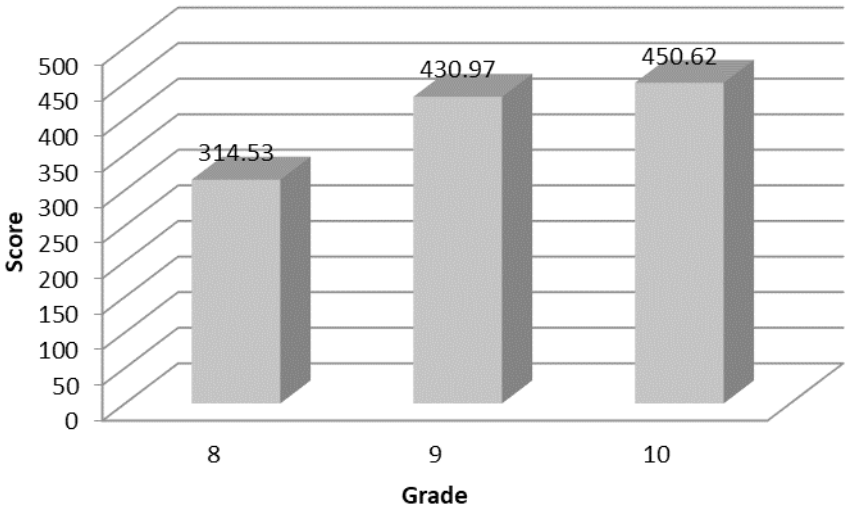

Figure 1. The development of students' mathematical literacy proficiency based on grade.

Based on Figure 1, the score of the 8th grade students' mathematical literacy is equal to 314.53, the score of the 9th grade students' mathematical literacy is equal to 430.97 and the score of the 10th grade students' mathematical literacy is equal to 450.62. These scores showed that there had been improvement in the students' mathematical literacy proficiency as the students got promoted to the higher grade. Then, the researchers elaborated the students' mathematical literacy proficiency according to the types of the test that had been administered. The test model PISA that had been administered consisted of the multiple-choice test items and the constructed response test items (the test items which answers were structured). Based on the type of the test, the description on the 8th, 9th and 10th grade students' mathematical literacy proficiency would be as follows.

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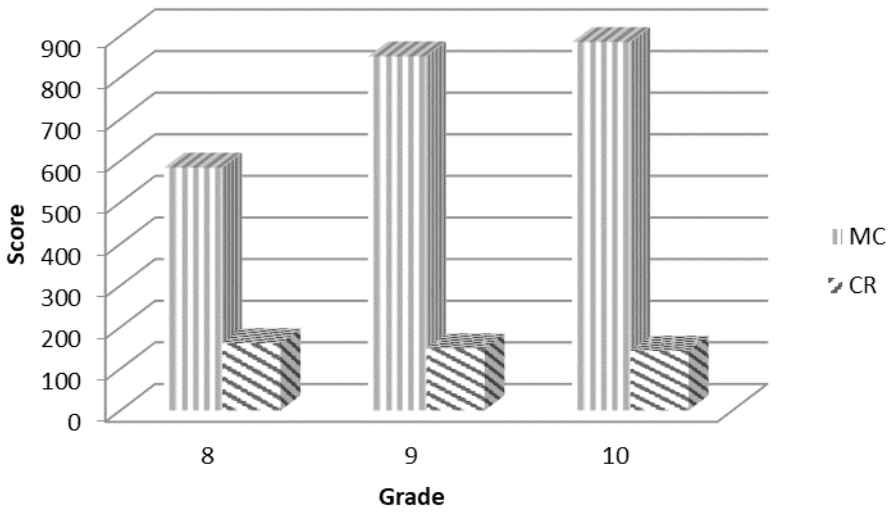

Figure 2. The development of students' mathematical literacy proficiency score based on the grade and test item type.

Based on Figure 2, there are differences among the students' mathematical literacy proficiency in completing the constructed response-type multiple choice (MC) test items. The 8th, 9th and 10th grade students are more inclined to complete the multiple-choice test items than the constructed response (CR) ones. It was found that the students got high scores after they completed the multiple choice test items; the score was higher than the international median which equals to 500. The situation was very contrast and significantly different from the time when they completed the constructed response test items in which they scored below 200. However, the 8th, 9th and 10th grade students had the similar mathematical literacy proficiency in completing the constructed response test items. The mapping on the students' mathematical literacy proficiency was analyzed based on the type of the test administered and differentiated based on the category of each school level (low, moderate and high). Based on the school level, the development of the students' mathematical literacy proficiency for the 8th, 9th and 10th grade students would be as follows.

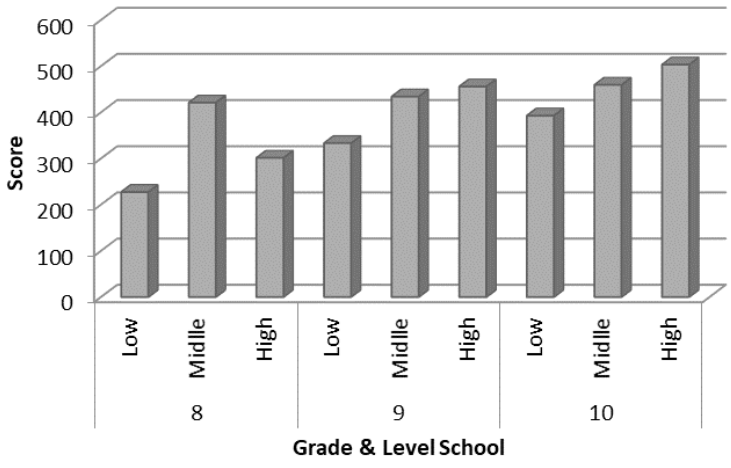

Figure 3. The development of students' literacy proficiency based on the grade and school level.

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Figure 3 explains the students' mathematical literacy proficiency based on the school level. The development of the 9th and 10th grade students improve along with the school level; the higher the school level, the more improved their development of mathematical literacy proficiency. The students' mathematical literacy proficiency in the high school level is better than that in the moderate school level; similarly, the students' mathematical literacy proficiency in the moderate school ability is better than that in the low school level. However, based on the figure above, the 8th grade students' mathematical literacy proficiency in the moderate school level is higher than that in the high school level. The mapping on the development of the students' mathematical literacy proficiency based on the grade and gender would be displayed in the Figure 4.

According to the results of PISA International Report (Technical Report), the data from the students' mathematical literacy proficiency were also presented based on the students' gender. Figure 4 showed that the female students' mathematical literacy proficiency is higher than the male students' mathematical literacy proficiency for the 8th, 9th and 10th grade. However, the higher the school level was the more equaled the male and the female students' mathematical literacy proficiency in the Province of Yogyakarta Special Region in Indonesia. Moreover, the development of the students' mathematical literacy proficiency based on the type of test and the school level altogether in the Figure 5.

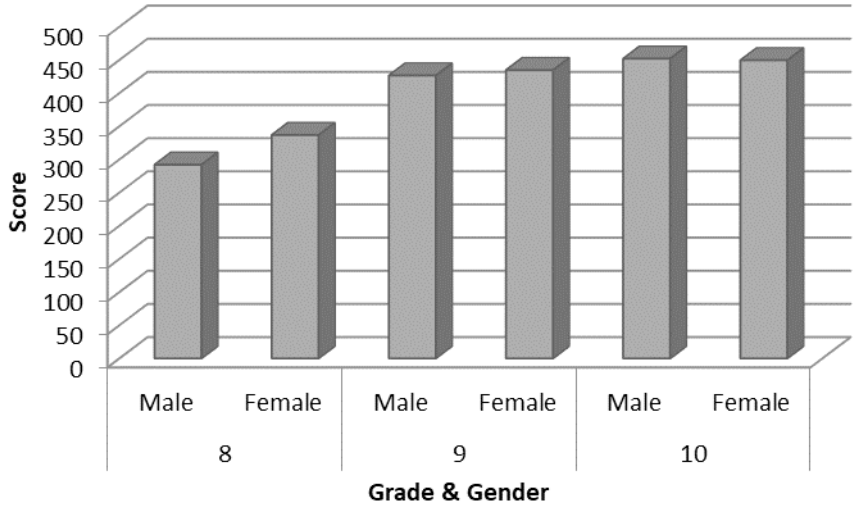

Figure 4. The development of students' literacy proficiency based on the grade and gender.

Figure 5 explained the students' mathematical literacy proficiency based on the school level for the multiple-choice test items and the constructed response test items. The 9th and 10th grade students' mathematical literacy proficiency had improved along with the school level both for the two types of the test items; the higher the school level was, the more improved the 9th and 10th grade students' mathematical literacy proficiency. The students' mathematical literacy proficiency is higher in the high school level than that in the moderate school level and, similarly, the students' mathematical literacy proficiency is higher in the moderate school level than that in the low school level both for the two types of the test items. However, based on the figure above, the 8th grade students' mathematical literacy proficiency in the moderate school level is higher than that in the high school level. The reason was that the moderate school level that had been sampled was the best moderate school and almost belonged to the high school level. In addition, the students' mathematical literacy proficiency in completing the constructed

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response test item in the low, moderate and high school level was lower than that in completing the multiple-choice test items.

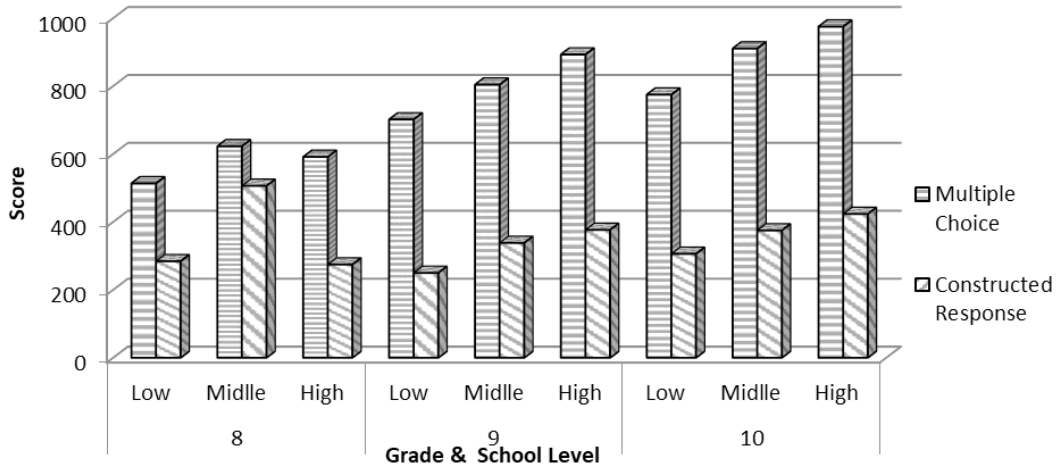

Figure 5. The development of students literacy proficiency based on the type of test, grade and school level.

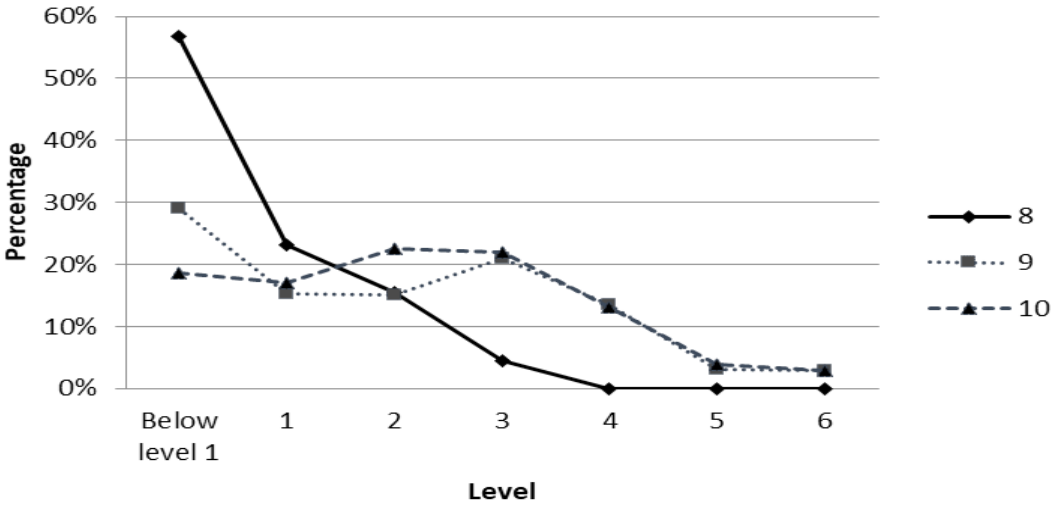

Figure 6. The level of students' mathematical literacy proficiency.

The development of the students' mathematical literacy proficiency based on the level of literacy proficiency is presented in the Figure 6. Based on that figure, most of the 8th grade students' mathematical literacy proficiency is Below Level 1 in comparison to the 9th and 10th grade students. Meanwhile, most of the 9th grade students' mathematical literacy proficiency is Below Level 1 in comparison to the 10th grade students. These findings showed that the 10th grade students' mathematical literacy proficiency was higher than that of the 8th and 9th grade students. However, there were only 10% of the total students who approached the Level 6 amongst the 8th, 9th and 10th grade students.

The mapping on the development of the students' mathematical literacy proficiency based on the combination of the type of test and the level of literacy proficiency is presented

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in Figure 7. There were more than 70% students of grade 8 and 9 who scored the literacy proficiency in the Level 6 under the multiple-choice test items. On the other hand, there were only more than 40% students who scored the literacy proficiency below the Level 1, while there were only few students who had scored the literacy proficiency in the Level 4, Level 5 and Level 6 under constructed response items.

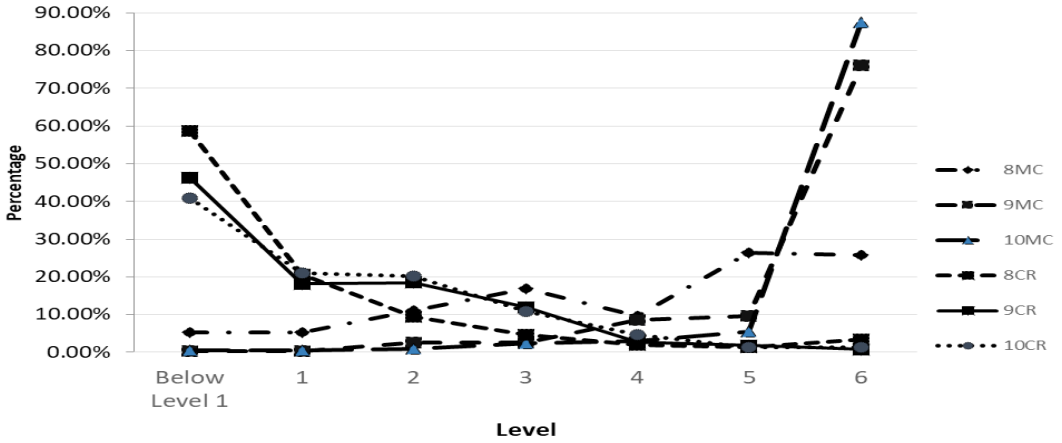

Figure 7. The level of literacy proficiency based on the type of test.

In addition to observe the pattern of development of students' literacy proficiency through graphics, the next step was to test the development of these abilities using statistical analysis. The analysis used for this purpose was analysis of variance (ANOVA), with the dependent variable that was literacy proficiency and the independent variables were the students' grades (8, 9, and 10). This analysis tested the null hypothesis that there was similarity means in literacy proficiency in grades 8, 9 and 10, with the alternative hypothesis at least one pair was different. The results of the analysis with significance level .05 are presented in Table 2. The results of this analysis indicate that *p*-value = .0001 <.05, which indicates the null hypothesis is rejected. This represents that there was average students' literacy proficiency of pairs that were not the same between grades.

Table 2. The analysis of variance result.

	Sum of Squares	*df*	Mean Square	*F*	*p*-value
Between Groups	140.674	2	70.337	66.731	.0001
Within Groups	1050.880	997	1.054		
Total	1191.554	999			

To know the different pairs, as well as the sequence of average of students' literacy proficiency, post-hoc analysis was carried out. In this research, post-hoc analysis was carried out with Scheffe-test. The full results are presented in Table 3. Based on these results it can be obtained that the average literacy proficiency of grade 8 was significantly lower than grade 9 and grade 10, but students' literacy proficiency of grades 9 and 10 was not different significantly. These results indicate that students' literacy proficiency from grade 8 to grade 9 increased significantly, while from grade 9 to grade 10 it didn't increase significantly.

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Table 2. The post-hoc result.

Multiple Comparisons						
(I) Grade	(J) Grade	Mean Difference (I-J)	Std. Error	p-value	95% Confidence Interval	
					Lower Bound	Upper Bound
8	9	-.9315173*	.0976629	.0001	-1.170931	-.692104
	10	-1.0887356*	.0953502	.0001	-1.322480	-.854991
9	8	.9315173*	.0976629	.0001	.692104	1.170931
	10	-.1572183	.0709166	.0860	-.331065	.016629
10	8	1.0887356*	.0953502	.0001	.854991	1.322480
	9	.1572183	.0709166	.086	-.016629	.331065

*. The mean difference is significant at the .05 level.

Discussion

The research results showed that in general there had been an improvement on the mathematical literacy proficiency from 8th grade to the 9th grade and to the 10th grade. However, the development from 9th grade to 10th grade was not significant. In relation to the test item design, the literacy proficiency development generated a higher score if it was measured by administering the multiple-choice test items than the constructed response test items. Regarding the school level, there was a tendency that the school level might influence the achievement of mathematical literacy score; the higher the school level was, the higher the mathematical literacy score that the students achieved would be. In relation to the gender, within the 8th grade, the female students achieved a higher score but in the 9th grade and the 10th grade, the achievement of literacy score was almost similar. The 8th grade students were more dominant in the "Below Level 1'" "Level 1" and "Level 2" category, while the 9th grade and the 10th grade students were more dominant in the "Below Level 1", "Level 1," "Level 2," "Level 3" and "Level 4."

There was an improvement of literacy from the 8th grade to the 9th grade and to the 10th grade. The higher the grade was, the higher the students' achievement was in the score of mathematical literacy proficiency. The achievement level of the students' mathematical literacy proficiency was also influenced by the grade. The reason was that the mathematics learning materials that the students studied in the 9th grade and the 10th grade are more abundant and containing many topics in accordance with the Standards of Content for the Educational Implementation issued by the government (Menteri Pendidikan Nasional Indonesia, 2006; Menteri Pendidikan dan Kebudayaan Republik Indonesia, 2015). As a result, the higher the students' grade was the more learning materials that supported the improvement of mathematical literacy proficiency would be.

The students' score of mathematical literacy proficiency would be higher if the score was assessed by administering the multiple-choice test items than the constructed response test items. The reason was that within the mathematical examination in the school, the teachers preferred to administer the multiple-choice test items more than the constructed response test items. The multiple-choice test items were administered in the mid-semester examination, the final examination, the school final examination, and even in the national examination.

The school-level indeed influenced the achievement of the students' mathematical literacy proficiency score. The schools that had a high achievement of national examination score also had a high score of mathematical literacy proficiency. These results might be caused

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by the situation that the schools with high achievement usually possessed better input of students, better learning process and, as a result, better learning achievement. These findings are in line with the opinion of Bohlmann and Pretoria (2008). The tendency that the students' mathematical literacy proficiency in the content of change and relationship, and of uncertainty and data was higher than that in the content of quantity, and of shape and space, both based on the grade and the school level which might be caused by multiple factors. The reason was that the material contents in the 8th grade and the 9th grade dominated by the content of change and relation and of uncertainty (Menteri Pendidikan Nasional Indonesia, 2006; Menteri Pendidikan dan Kebudayaan Republik Indonesia, 2015). In addition, the content of shape and space belonged to the material contents that had been difficult to study than the other contents based on the result of national examination (Balitbang Kemendiknas, 2014; 2015; 2016). Regarding the influence of gender towards the achievement, in this research, the 8th grade female students earned higher score than the 8th grade male students. However, the achievement of male and the female students in the 9th grade and the 10th grade was almost similar. These findings are in line with the opinion of Ajali and Imoko (2015) but are not quite similar to the opinion of Zhu (2007) and Hall (2012).

Low students' achievement should be a matter of attention. Several related studies might be conducted in order to overcome the low students' achievement. Since the school quality influences the quality of learning achievements (Bohlman & Pretorius, 2008), the improvement towards the learning quality and the learning assessment can be pursued through the integration of the literacy into the mathematics learning process (Steihilber, 2006) and other subjects.

Conclusions and Implications

The results of the research showed that in general there has been the improvement of literacy proficiency among the 8th, 9th and 10th grade students. The literacy development would generate higher scores if the development had been measured by means of multiple-choice test items. There was a tendency that the school level, gender, the form of items, content, context, and process literacy would influence the mathematical literacy score. The 8th grade, 9th grade and 10th grade students' literacy proficiency tends to improve although the literacy proficiency is still under the mean of mathematical literacy proficiency in the international study.

In relation to strengthening mathematical literacy proficiency, both the teachers and the researchers may develop a test instrument that contains literacy. The learning set contains the lesson plan, the student's worksheet and the assessment sheet. In terms of school assessment, the teachers should be benefited by the constructed response test items in that the students will be trained to perform critical thinking. By doing so, the quality of literacy learning process might be improved and the assessment system that has been applied might drive the students to learn about literacy.

Several strategies can be done to improve literacy skills, so that students' proficiency increase from year to year. The teaching and learning that train literacy can be carried out by teachers in schools, starting from elementary school. Of course, the teaching and learning literacy needs to be integrated with the curriculum. The various contexts of literacy need to be introduced to students, so that students get used to solve many problems. In addition to learning, the competence of teachers to train students' literacy in their schools needs to be considered. This is related to the teachers' role that is the spearhead of the literacy learning.

The future researches about literacy proficiency can be carried out by other researchers related to the results of this research. The students' difficulties in solving literacy problems need to be revealed in detail. Utilizing known difficulties students can follow up and determine strategies to overcome them. To identify whether learning that has been carried out by the teacher to integrate literacy is also important. The ability of the teacher to carry out learning

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that trains literacy also needs to be described. In addition, research related to the development of students' literacy proficiency starting from elementary school needs to be conducted, so that there is comprehensive progress starting from grade 1 to grade 12. These studies can then be a reference for policies to improve students' literacy skills at various levels of education.

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