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Multivariate analysis on students' cognitive assessment, attitude, and skill evaluation in problem-based learning

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Abstract

To improve the quality of education, the Ministry of Education and Culture of the Republic of Indonesia designed the "Merdeka" curriculum. With this curriculum, there are three learning outcomes, namely cognitive (knowledge), affective (character or attitude), and psychomotor (skills) domains. The learning that can be applied to the "MERDEKA" curriculum is the problem-based learning model. The significance of a variable in the learning process is very important to research to evaluate the learning process, especially in problem-based learning. Thus, the research objective of this study is to provide evidence of the significance of students' cognitive assessment, attitude, and skill evaluation in mathematics learning. This study is a quantitative research using two-way multivariable analysis of variance (MANOVA), to determine the significance of cognitive assessment (assessment of learning outcomes), character or attitude, and skills evaluation in three classes of VIII students using problem-based learning (PBL). A two-way MANOVA analysis was carried out with students' class and gender factors, using measurement variables: cognitive assessment, attitude, and skill evaluation. From the results of the analysis, it was found that problem-based learning can be applied to Mathematics classes because, with this learning, both male and female students, the student's cognitive assessment is equally good in the significance level 5%. The differences in attitude and skill evaluation occurred because of the uniqueness of male and female students.

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INTRODUCTION

Following the report released by The World Economic Forum (WEF) in 2020 at BBPPMPV BOE (2022), regarding current and future human skill needs, it is estimated that by 2025, as many as 85 million jobs will experience a shift in the division of work between humans and machines. Job demands in the digital era expect an increase in technology adoption, in addition to the five main skills: complex problem solving (complex problem-solving skills), critical thinking, creativity, human management skills, and the ability to coordinate with others. Moreover, the learning crisis, accompanied by the emergency condition of the COVID-19 pandemic, has dramatically impacted the transformation in education in Indonesia. Kurikulum Merdeka, as one of the Kementerian Pendidikan,

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Kebudayaan, Riset, dan Teknologi (Kemdikbudristek) efforts to overcome the learning crisis after the COVID-19 pandemic, has begun to be designed and implemented in ready schools (Nugraha, 2022). The urgency and the development of the curriculum have been reviewed by Sari et al (2024).

The MERDEKA curriculum learning policy has characteristics that emphasize creativity, problem-solving learning orientation, learning based on people's needs in global work, and a comprehensive evaluation system (Setyawati et al, 2023). It can be seen that the policies are in line with the work demands released by the WEF. There are three classifications of learning outcomes, namely cognitive or knowledge (Zhou et al., 2024), affective or character or attitude formation (Nielsen et al., 2024), and psychomotor (skills) domains (see (Huang et al., 2020) for the reference). Problem-Based Learning (PBL) is a learning model that emphasizes solving real problems as the center of learning. In the context of the Independent Curriculum, this approach allows students to take an active role in their learning. Problem-solving skills in the form of problem-solving learning are one of the lessons that are encouraged to be applied in the Merdeka curriculum. By using problem-solving learning in the classroom, it is hoped that knowledge, skills, and character formation can be boosted to improve the quality of students facing global challenges in education. Several studies have adopted the independent curriculum by implementing problem-solving learning, namely Heriyati (2022), Janainah et al (2024), (Saputri & Trihantoyo, 2022), (Aryanti et al., n.d.), and references therein. The problem-solving learning model focuses on problem-solving to strengthen students' thinking abilities so they can understand more basic knowledge from the material that has been presented. The problem-solving learning model is one of the applications of problem-based learning (PBL) with concrete steps. PBL uses problem-solving but is much more than just problem-solving. Problem-based learning is a curriculum-wide approach, it is a problem-first approach. So, students are involved in solving a problem using scientific methods. Based on this, students can identify problems directly, train their thinking skills, and hone their skills. On the other hand, learning that considers the teacher-student relationship improves cognitive ability and student learning attitudes (Ye & Wang, 2024). (Amalina & Vidákovich, 2023) found that cognitive and socioeconomic factors influenced the mathematical problem-solving skills of students. Also, teachers can certainly understand the unique attitude and skill evaluation of male and female students (see (Zurweni et al., 2022) and ((Horrell et al., 1990) for references).

Based on the background above, this research will thoroughly examine the significance of learning classes in terms of gender on cognitive assessment, attitudes, and skill evaluation. With quantitative statistical analysis, evidence will be provided regarding the significance of class differences between male and female students in the cognitive assessment, attitude, and skill evaluation in classes with problem-based learning. (Bayat & Tarmizi, 2012) and (Demirel & Dağyar, 2016) describe the influence of problem-based learning on cognitive assessment and attitude evaluation abilities. The relationship between student attitudes based on gender is significant to analyze to determine the character of students in the class based on gender (see (Zurweni et al., 2022) and ((Horrell et al., 1990) for references). Hence, the benefits and contribution of the study are as follows:

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a) Knowing the significance of cognitive assessment, attitude, and students' skills evaluation in problem-solving learning
b) Provide the scientific approach proof of the essential of problem-solving in the view of cognitive assessment, attitude, and students' skills evaluation
c) Knowing the significance of cognitive assessment, attitude, and students' skills evaluation in problem-solving learning based on gender.

RESEARCH METHOD

This research is a quantitative research using a two-factor multivariate analysis of variance (see Ntumi (2021) and Santis et al (2024) for references) with the dependent variables being cognitive assessment, attitude evaluation, and skill evaluation. We notate with y_1, y_2, and y_3. The factors chosen in this study are class and gender, namely male and female. We are interested choose the gender of the students because there are many different impacts of various teaching methods on the different genders ((Schreiber & Ashkenazi, 2024); (Henschel et al., 2023); for references). All students in 8^{th} grade were the population, and we applied the cluster random sampling and assigned 8B, 8C, and 8F for problem-solving learning. We test the significance of problem-solving learning for all of the class and investigate the effect of the dependent variables in terms of the gender of the students. We can see the design of the experiment of the research using a two-factor multivariate analysis of variance with the mean and the standard deviation as in Table 3.
The dependent variable measured in this research, namely:

1. Cognitive assessment. Cognitive assessments are carried out to measure students' understanding during the KBM process, on gradient material. Cognitive assessment is a learning achievement by the learning objectives to be achieved in this study through written tests. The data scale for cognitive assessment is an interval data scale. These dependent variables are instruments in the form of tests, i.e., in linear function material. The indicator of the cognitive assessment adopted the indicator of (Lepore, 2024), (Wu et al., 2024), and (2024). (Aragón et al., 2024).
2. Attitude evaluation. The assessment of attitudes or profiles of Pancasila students is measured during teaching and learning activities (KBM), including profiles of faith, creativity, critical thinking, and cooperation. The data scale in attitude evaluation is a qualitative data scale. The data scale for attitude assessment is a nominal data scale of 1 and 0, with the indicator of attitude followed by (Suherman & Vidákovich, 2024).
3. Skill evaluation. Skills evaluation is carried out on these learning outcomes by the learning objectives to be achieved, namely by performance/practical tests. The indicator of this variable, we follow (Caprioara, 2012). Skills assessment includes criteria:
    a. Carry out group activities and complete individual tasks well and correctly,
    b. Able to use student worksheets (LKPD) provided by the steps for using LKPD,
    c. Able to find appropriate alternative solutions in completing group assignments,
    d. Draw graphs of linear functions

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RESULTS AND DISCUSSION

The time for conducting the research can be seen in Table 1.

Table 1. The research stage

Month	Activity
Augustus 2023	Preparation
September 2023	Pre-observation
October 2023	Instruments preparation
November 2023	Treatment
December 2024	Data analysis
January 2024	Manuscript

By using a two-way MANOVA with the factors being class and gender; and the dependent variables are cognitive assessment (y1), attitude (y2), and skill evaluation (y3), this paper will provide supporting data evidence about the significance of class, gender, and their interaction to y1, y2, y3. Before we provide the core analysis of this paper, we will conduct a descriptive analysis of the research variables. The research sample was students of SMPN 04 Karanganyar, namely classes 8B, 8C, and 8F. From a gender perspective, Table 2 shows the distribution of male and female students.

Table 2. The number of research samples

Class	Boy	Girl
8B	12	20
8C	15	18
8F	15	15

From Table 2, it can be seen that the number of female students is greater than the number of male students, except in class 8F, where the number of male and female students is the same. From Table 2, the mean of the cognitive assessment (y1), attitude (y2), and skill evaluation (y3) measurement variables were then measured, namely as in Table 3.

Table 3. Cognitive assessment (y1), attitude (y2), and skill evaluation (y3) of students mean with standard deviation at the parenthesis

Gender	Class								
	8*B*			8*C*			8*F*		
	*y*1	*y*2	*y*3	*y*1	*y*2	*y*3	*y*1	*y*2	*y*3
Boy	85.83 (12.76)	75.69 (14.42)	94.79 (4.49)	71.53 (14.08)	97.77 (5.88)	95.60 (11.61)	84.00 (20.61)	59.20 (10.29)	64.87 (27.75)
Girl	87.25 (8.35)	78.33 (9.90)	93.13 (4.49)	75.56 (9.84)	97.22 (6.40)	92.67 (14.12)	93.33 (13.45)	73.73 (11.35)	90.13 (17.96)

From Table 3, in the view of the perspective of the class; in class 8B, the highest score was for skill evaluation for male students, namely 94.79 with a standard deviation of 4.49. In class 8C, the highest score was attitude evaluation for male students, namely 97.77 with a standard deviation of 5.88. Meanwhile, in class 8F, the highest score was for cognitive assessment for female students, amounting

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to 93.33 with a standard deviation of 13.45. From this descriptive distribution, it appears that the highest mean is distributed differently in the three classes. Next, to determine the significance of this average, a multivariate test and test of between-subjects effects will be carried out, as in Tables 4 and 5.

Table 4. Multivariate tests of Class, Gender, and Class*Gender

Effect	Pillai's	Wilks'	Hotelling's	Roy's	Sig.
Class	0.807	0.270	2.418	2.293	0.000*
Gender	0.107	0.893	0.120	0.120	0.020
Class*Gender	0.190 (0.007*)	0.811 (0.005*)	0.231 (0.004*)	0.226 (0.000*)	

* $p < 0.1, p < 0.05, p < 0.01$

The conclusions of Table 4 at the 5% significance level for the factors Class, Gender, and the interaction of Class and Gender (with the notation Class*Gender) are as follows:

1. For all multivariate measures Pillai's, Wilks', Hotelling's, and Roy's gave the same conclusion, namely that the mean cognitive assessment, attitude, and skill evaluation were significantly different in the three classes. This also applies at significance levels of 1%, and 10%
2. In all multivariate measures Pillai's, Wilks', Hotelling's, and Roy's gave the same conclusion, namely that the mean cognitive assessment, attitude, and skill evaluation were significantly different for male and female students. This also applies at the 10% significance level
3. On all multivariate measures Pillai's, Wilks', Hotelling's, and Roy's; Even though the Sig. values are different (see the numbers with * signs in brackets), and they provide the same conclusion, namely that there are significant differences in the interaction of class and gender on cognitive assessment, attitude, and skill evaluation. This applies at the 1% and 10% significance levels. These findings indicate that the mean cognitive assessment, attitude, and skill evaluation of male and female students is significantly different in three different classes.
4. The significance of factor interactions is that the effect of either factor does depend on the level of the other factor. Consequently, the effects can not be separated merely by analyzing the factor level means or the factor main effects Neter et al (1996). The two gender means signify that gender has effects on class. In other words, with the presence of the effects of class*gender interaction, we will then analyze it integrative by involving the output in Table 5.

From Table 5, it can be concluded that there is an interaction effect of class and gender on attitude evaluation and skill evaluation; while the interaction effect was not significant on cognitive assessment measurements. Cognitive assessment is not significantly different, because the value of significance level 0.05<Sig.= 0.530, it can be concluded that the cognitive assessment of male and female students in the three classes is not significantly different. With the influence of the interaction between class and gender on the two measurement variables, the analysis will become complicated, because the interaction is only significant for attitude and skill evaluation. To analyze this analysis, we start with descriptive statistical analysis and relate it to the inference results of Table 5.

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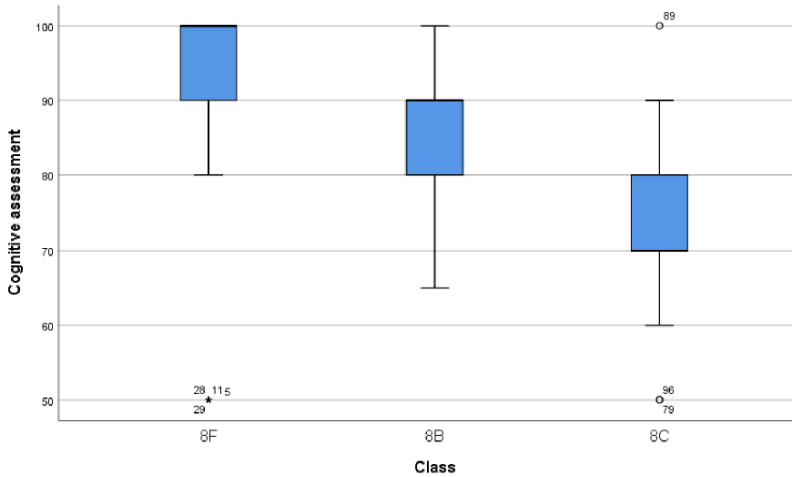
Table 5. Test of between-subjects effects

Source	Sum of Square	df	Mean Square	F	Sig.
Class					
Cognitive assessment	4313.569	2	2156.784	11.408	0.000
Attitude evaluation	15715.132	2	7857.566	81.308	0.000
Skill evaluation	5558.846	2	2779.423	11.849	0.000
Gender					
Cognitive assessment	576.431	1	576.431	3.049	0.084
Attitude evaluation	709.911	1	709.911	7.346	0.008
Skill evaluation	1098.286	1	1098.286	4.682	0.033
Class*Gender					
Cognitive assessment	242.061	2	121.031	0.640	0.530
Attitude evaluation	973.079	2	486.540	5.035	0.008
Skill evaluation	3869	2	1934.733	8.248	0.001
Error					
Cognitive assessment	16826.528	89	189.062		
Attitude evaluation	8600.958	89	96.640		
Skill evaluation	20877.233	89	234.576		
Total					
Cognitive assessment	673075.000	95			
Attitude evaluation	647711.450	95			
Skill evaluation	778782.000	95			

* $p < 0.01, p < 0.05, p < 0.1$

Cognitive assessment

Visually, cognitive assessment in the three classes can be described in a box plot like Figure 1. From the box plot, it appears that the cognitive assessment in the three classes tends to be different. The highest mean is in class 8F, whereas the lowest mean is in class 8C. In addition, in these two classes, there are several outliers, say, ID 29, 29, 11, and 5 in the 8F; ID 89, and ID 96, 79 in the 8C. These outliers indicate the larger dispersion of the cognitive assessment in both classes (8F and 8C).



Picture 1. Cognitive assessment boxplot

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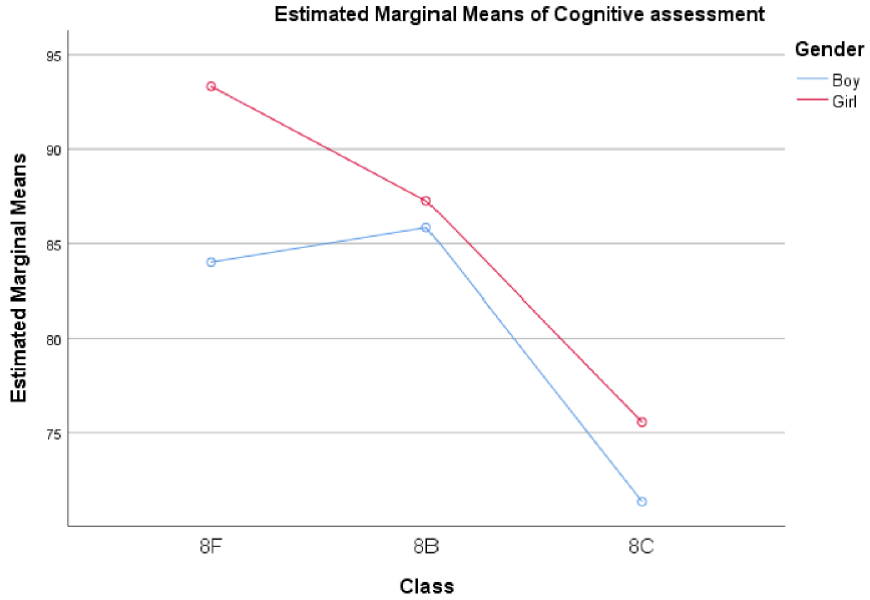
From two points of view in the form of class and gender, the mean cognitive assessment can be described in Figure 2. In Figure 2, the mean cognitive assessment of female students always appears to be above the mean cognitive assessment of male students. Regardless of gender, the mean cognitive assessment is significantly different in the three classes. Supported by the inference from Table 4, the cognitive assessment measurement variable, with the interaction between class and gender factors, is additive (see Netter et al (1996) for the definition of additive factor).

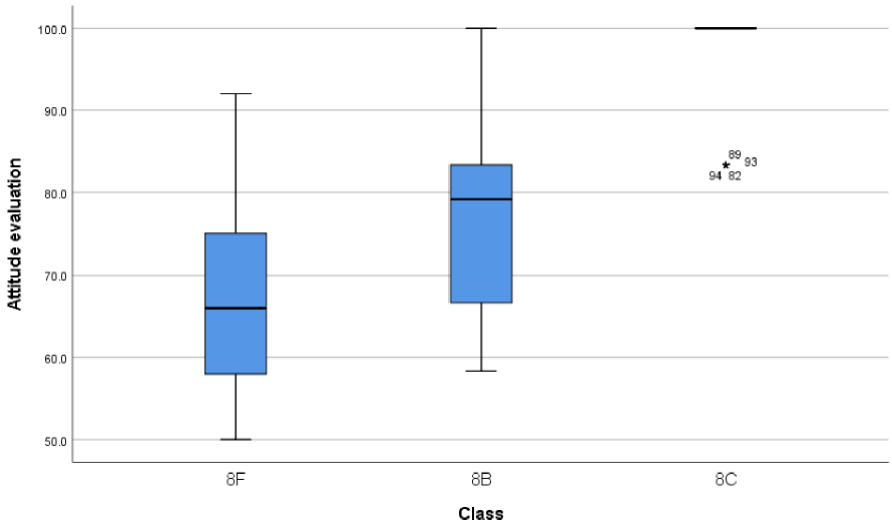


Picture 2. Cognitive assessment

The next analysis is on the attitude evaluation measurement variable.

Students Attitude

To find out the differences in the mean of attitudes and skill evaluations for which students and classes, we first carry out descriptive statistical analysis of Figures 3 and 4.



Picture 3. Attitude evaluation box plot

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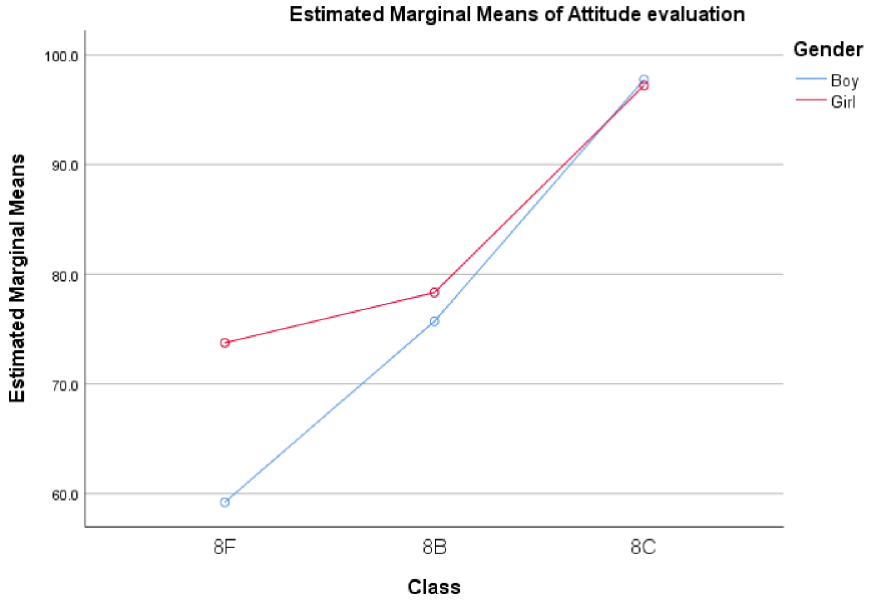
From the Box plot in Figure 3, it can be seen that the highest attitude evaluation is in class 8C, whereas the lowest attitude is in class 8F. There are several outlier data in class 8C (ID 82, 89, 93, 94, 93), indicating that some students have attitude evaluations that are not similar to the mean attitudes in the class. In the view of class and gender factors, the mean of attitude evaluation seems as in Figure 4. Similarly to the cognitive assessment measurement, the attitude evaluation of female students seems to be higher than that of male students, except in class 8C.



Picture 4. Attitude evaluation

To understand the Figure 4 with its inference analysis, we also use the Table 6.

Table 6. Pairwise Comparisons Attitude evaluation-Class dan Gender

Attitude evaluation	Mean Difference	Sig.
8F Boy		
8F Girl	-13.13*	0.024
8B Boy	-16.38*	0.005
8B Girl	-19.22*	0.000
8C Boy	-38.61*	0.000
8C Girl	-38.04*	0.000
8F Girl		
8B Boy	-3.25	0.982
8B Girl	-6.10	0.659
8C Boy	-25.48*	0.000
8C Girl	-24.92*	0.000
8B Boy		
8B Girl	-2.85	0.982
8C Boy	-22.23*	0.000
8C Girl	-21.67*	0.000
8B Girl		
8C Boy	-19.38*	0.000
8C Girl	-18.82*	0.000
8C Boy		
8C Girl	0.57	1.000

* $p < 0.01, p < 0.05, p < 0.1$

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Based on Table 6, we can deduce the following:

a. The attitude evaluation of class 8C male students is better than that of class 8F male students. Overall, the attitude evaluation for each gender in each class 8B, 8C, and 8F is significantly different. The differences were satisfied at significance levels of 1% and 10%.
b. The Attitude evaluation of male students in class 8C is better than female students in class 8F. Apart from class 8C male students, this pattern applies to female students in class 8C. The differences were satisfied at significance levels of 1% and 10%.
c. The attitude evaluation of male students in class 8C is better than male students in class 8B. The pattern also applies to the attitudes of female students in class 8C. The differences were satisfied at significance levels of 1% and 10%.
d. The attitude evaluation of male students in class 8C is better than female students in class 8B. This pattern also satisfied female students in class 8C. The differences were satisfied at significance levels of 1% and 10%.

Skill evaluation

Next, to determine the differences in the effects of male and female students' skill evaluations in the three different classes, we first carry out a descriptive statistical analysis in Figure 5.

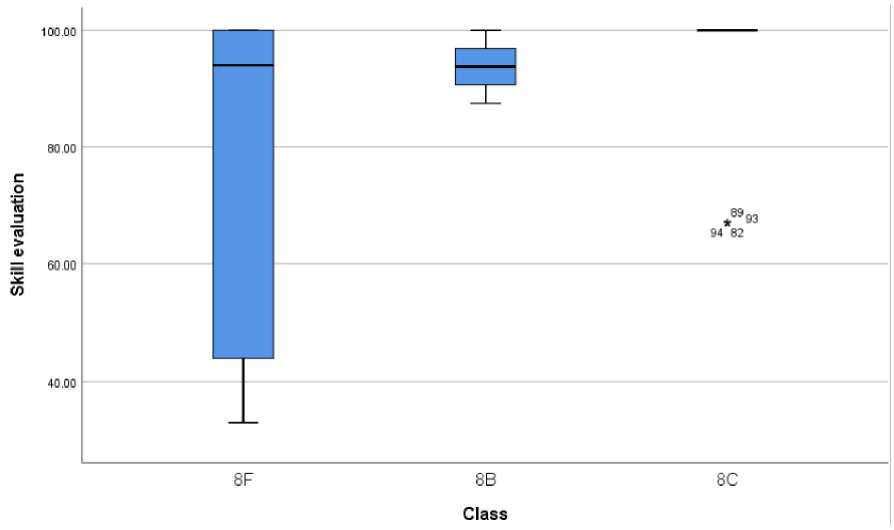

Figure 5. Skill evaluation box plot

From the box plot in Figure 5, it can be seen that the greatest diversity of skill evaluations is in class 8F, and conversely, the smallest mean diversity of skill evaluations is in class 8C. The outliers were detected in 8C, namely 89, 93, 82, and 94. This indicated the skill evaluation of those students below to the mean of the class. The mean skill evaluation can be depicted in Figure 6.

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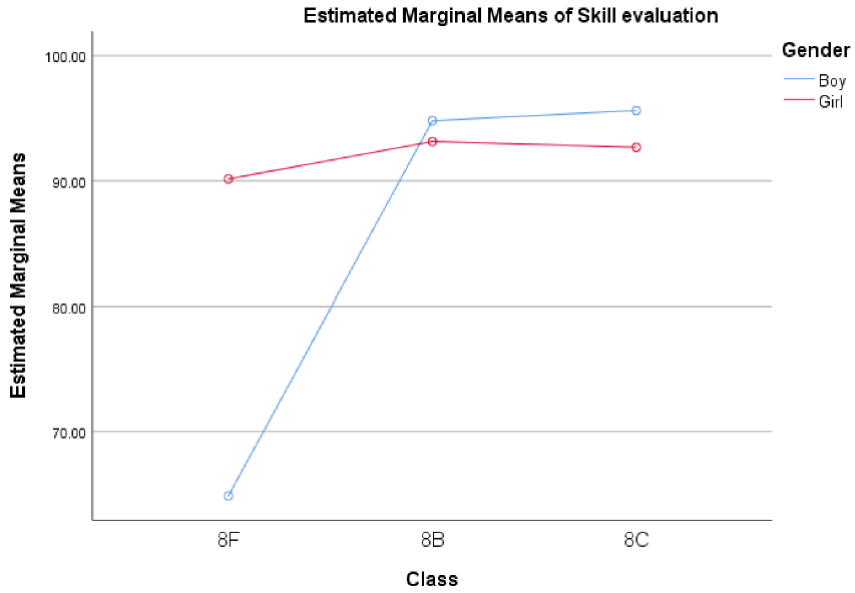

Figure 6. Skill evaluation

Using Figure 6 and Table 7, it appears that the only significant difference in the mean skill evaluation is in the skill evaluation of male students in class 8F. The skill evaluation of male students in class 8F is significantly different for each gender in three different classes. This difference is satisfied at the 1% and 10% significance levels. The best skill evaluation is for male students in class 8C. On the other hand, the lowest skill evaluation was for male students in class 8F.

Table 7. Pairwise Comparisons Skill evaluation-Class dan Gender

Skill evaluation	Mean Difference	Sig.
8F Boy		
8F Girl	-23.69*	0.035
8B Boy	-34.19*	0.001
8B Girl	-32.59*	0.000
8C Boy	-34.79*	0.000
8C Girl	-31.85*	0.001
8F Girl		
8B Boy	-10.50	0.830
8B Girl	-8.90	0.851
8C Boy	-11.10	0.749
8C Girl	-8.17	0.901
8B Boy		
8B Girl	1.60	1.000
8C Boy	-0.60	1.000
8C Girl	2.33	1.000
8B Girl		
8C Boy	-2.20	1.000
8C Girl	0.73	1.000
8C Boy		
8C Girl	2.93	0.999

* $p < 0.01, p < 0.05, p < 0.1$

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CONCLUSION

The conclusions from this study are as follows: a) Cognitive assessment, attitude, and students' skills evaluation in problem-solving learning were significantly different, b) In problem-solving learning; the cognitive assessment, attitude, and skill evaluation were significantly different for male and female students, c) In problem-solving learning; These findings indicate that the mean cognitive assessment, attitude, and skill evaluation of male and female students is significantly different in three different classes. Particularly, male and female students in classes 8B, 8C, and 8F have the same cognitive assessments in problem-based learning; male and female students in classes 8B, 8C, and 8F have significantly different attitudes and skill evaluations in problem-based learning.

From the conclusion above, it can be deduced that junior high school students tend to accept problem-based learning as a learning model in Mathematics classes. As for measuring attitude and skill evaluation, there are significant differences in effects in terms of class and gender of students.

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