The effect of problem-based learning to improve students’ metacognition skills in solving mathematical problems based on cognitive style

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Abstract. This paper aims to find out the effect of problem-based learning (PBL) to improve students’ metacognition skills in solving mathematical problems based on cognitive style. Aspect of metacognition skills in this study are planning, monitoring, and evaluating. Dimension of cognition style in this study are field dependent (FD) and field independent (FI). Participants in this study are 36 students in junior high school. The instrument in this study is 27 statements metacognition skills questionnaire to determine the level of metacognition skills and Group Embedded Figure Test (GEFT) developed by Witkin to find out the types of students’ cognitive styles. The statement was validated by 3 expert validators. The findings of the study revealed that problem-based learning (PBL) could be an effective learning model to improve metacognition skills in solving mathematical problems both of field dependent (FD) and field independent (FI) students.

1. Introduction
Mathematics subjects need to be given to all students starting from elementary school to equip students with the ability to think logically, analytically, systematically, critically, and creatively, as well as the ability to work together [1]. Mathematics is knowledge that a person can use to learn to think and know how someone thinks about a problem [2, 3]. The success of the mathematics teaching and learning process can be measured by the success of students in participating in mathematics learning activities [4]. Learning mathematics can be trained and developed with higher order thinking skills (HOTS) [5]. The ability to think at a high level is defined as a cognitive process at the highest level [6]. HOTS is related to thinking skills in analyzing, evaluating, and creating [7]. For example, to be able to solve problems, students must be able to analyze problems, think about solutions, implement solutions, and evaluate methods and solutions that have been implemented. One of the skills that must be possessed in HOTS is metacognition [8]. Students who have and use their metacognition optimally will be able to solve problems well [9].

Metacognition was introduced by Flavel and interpreted as a thinking process ability [10]. Metacognition is the ability to monitor one's own knowledge and control the process of drawing conclusions and information that is processed in a person's memory system [11]. One of the components in metacognition is metacognition skills [12]. Metacognition skills describe a person's knowledge of the strategies used to solve problems and optimize the knowledge they already have [13]. Metacognition skills consist of planning aspects, namely skills to plan problem-solving strategies and collect information related to problems, monitoring, namely monitoring the completion process with strategies...
and information that have been planned during planning, evaluating, namely checking whether the problem solving strategy used is able to solve problems in a manner effective and efficient [14].

A person's skills to solve problems are also influenced by cognitive style [15]. Cognitive style is a person's style to express how they think, feel, and remember information [16, 17]. Field independent (FI) and field dependent (FD) cognitive style are the most important dimensions of cognitive style [18]. Students with the FI cognitive style tend to see problems and objects as components or elements that are separate from the components or elements around them, while students with the FD cognitive style tend to see problems and objects as components or elements in general, not separated from the components and elements around them [18, 19]. FI students can see the objects of FI students who are more active and independent in the learning process, while FD students are more passive and dependent in the learning process [20].

Cognitive style also plays an important role in improving metacognition skills in problem solving [21]. There are differences in the problem-solving process based on the FI and FD cognitive styles, such as students with the FI cognitive style who are at a very high level as well as students with the FD cognitive style who are at a very high level, but students with the FI cognitive style who are at a high level, medium and low are better than students with a cognitive style of FD who are at high, medium and low levels [22].

Teachers must pay attention to students' cognitive styles and look for learning models that are in accordance with students' cognitive styles to suit the learning objectives [23]. Teachers also need to facilitate students so that students' metacognition skills can be trained and develop optimally so that students can solve problems well. One of the efforts that teachers can make to improve metacognition skills by paying attention to students' cognitive styles is by using problem-based learning (PBL). PBL can help students improve metacognition skills because it involves students actively in the process of problem solving through group work [24]. PBL creates a learning environment that can improve students' metacognition skills [25, 26]. If the teacher implements PBL in learning, students' metacognition skills will increase because PBL steps and activities implement a plan of steps to solve problems, reflect and evaluate the results of problem solving [27]. PBL can improve metacognition skills compared to ordinary learning and there are significant differences between the two [26]. Based on the explanation above, the purpose of this paper is to analyze the effect of problem-based learning (PBL) to improve students’ metacognition skills in solving mathematical problems based on cognitive style. Metacognition skills in this paper include planning, monitoring, evaluating and cognitive style in this paper include field dependent (FD) and field independent (FI).

2. Experimental method

This type of research is a quasi experimental research method. In this design, only one group are used to determine the effect of PBL on metacognition skills based on cognitive style. The group was given a pretest and posttest. The subjects in this study were 36 students of grade 8 (around age 13-14 years). Cognitive style tests use a standardized measuring instrument called The Group Embedded Figure Test (GEFT) which is use to obtain psychometric data developed by Witkin, et al. [28].

The metacognition skills test uses a standard measuring tool developed by Witkin, et al. to obtain psychometric data, namely The Group Embedded Figures Test (GEFT). GEFT tests students' ability to find simple picture patterns hidden within complex picture patterns. GEFT consists of 25 items which are divided into 3 parts, namely part I which is an exercise of 7 items, part II and III which are the core of 18 items. Each student thickens the exact shape of the simple picture hidden in the complex picture, then the student is given a score of 1 if he answers correctly. Students who score > 9 are classified as students with the FI cognitive style and subjects who score ≤ 9 are classified as students with the cognitive style of FD.

The metacognition skills test used a questionnaire validated by three validators to categorize students into very high, high, medium, low and very low levels of metacognition skills. This questionnaire examined students' skills in using their metacognition. This questionnaire consists of 27 statements
containing 14 positive statements and 13 negative statements using a Likert scale with 5 alternative answers. Determination of the score for the positive statement is very suitable (SS) = 5, suitable (S) = 4, doubtful (R) = 3, unsuitable (TS) = 2, very unsuitable (STS) = 1. While the score for negative statements are very unsuitable (STS) = 5, unsuitable (TS) = 4, doubtful (R) = 3, suitable (S) = 2, very suitable (SS) = 1. Each student puts a check mark on one of the available boxes accordingly. The data for the metacognition skills obtained are classified in the criteria based on Table 1.

| Table 1. Metacognition skills category |
|---------------------------------------|
| Formula                              | Score          | Category     |
| $X_i + 1.5sb_i < X$                   | $121.5 < X$    | Very high    |
| $X_i + 0.5sb_i < X \leq X_i + 1.5sb_i$| $94.5 < X \leq 121.5$ | High        |
| $X_i - 0.5sb_i < X \leq X_i + 0.5sb_i$| $67.5 < X \leq 94.5$ | Medium      |
| $X_i - 1.5sb_i < X \leq X_i - 0.5sb_i$| $40.5 < X \leq 67.5$ | Low         |
| $X \leq X_i - 1.5sb_i$                | $X \leq 40.5$  | Very Low     |

The data analysis technique used in this research is Analysis of Variance (ANOVA). ANOVA is used because there is only one dependent variable. Thus, the assumption underlying the univariate data analysis is that the dependent variable must be normally distributed.

3. Result and discussion

3.1. Metacognition skills category

The frequency and percentage of the number of students who reached the category of students’ mathematical metacognition skill level were calculated according to the range of scores determined in Table 2 for the categorization of students’ mathematical metacognition skills. The following table 2 presents the frequency distribution and percentage of students’ metacognition skills categorization before and after being given treatment.

| Table 2. Frequency distribution of students' metacognition skills scores before and after treatment |
|---------------------------------------------------------------|
| Score (X) | Category | Pretest F | % | Posttest F | % |
|-----------|----------|-----------|---|-----------|---|
| $121.5 < X$ | Very high | 0         | 0 | 2         | 5.56 |
| $94.5 < X \leq 121.5$ | High | 10        | 27.78 | 23 | 63.88 |
| $67.5 < X \leq 94.5$ | Medium | 26        | 72.22 | 11 | 30.56 |
| $40.5 < X \leq 67.5$ | Low | 0         | 0 | 0         | 0 |
| $X \leq 40.5$ | Very Low | 0         | 0 | 0         | 0 |

Based on Table 2 above, information was obtained that after being given treatment, there was a significant increase. The increase can be seen from students who are in the very high category increasing by 2 students, in the high category increasing by 13 students and in the medium category decreases by 15 students.

3.2. Mathematical metacognition skills data

Mathematical metacognition skills data were obtained from a questionnaire given to students before and after treatment. The description of the scoring results is presented in Table 3 below.
Table 3. Average score, standard deviation, theoretical maximum score, and minimum theoretical score of metacognition skills

| Cognitive Style       | Description          | Pretest | Posttest |
|-----------------------|----------------------|---------|----------|
| Field Dependent (FD)  | Average score        | 89.7    | 100.2    |
|                       | Standard deviation   | 11.7    | 11.9     |
|                       | Theoretical maximum  | 135     | 135      |
|                       | Theoretical minimum  | 27      | 27       |
| Field Independent (FI)| Average score        | 88.5    | 102      |
|                       | Standard deviation   | 10.4    | 11.9     |
|                       | Theoretical maximum  | 135     | 135      |
|                       | Theoretical minimum  | 27      | 27       |
| Total                 | Average score        | 89.1    | 101.2    |
|                       | Standard deviation   | 10.9    | 11.6     |

The total results of the descriptive analysis of the data on mathematical metacognition skills in Table 3 above indicate that the average score of students' math metacognition skills before being given treatment was 89.1. While the average score of students' metacognition skills after being given the treatment was 101.2. This data shows that there is an increase in the score of students' metacognition skills after giving treatment by 12.1. This indicates that the PBL model is effective in terms of metacognition skills.

This can also be seen from the average score of metacognition skills for FD students, there is an increase in the score of students' metacognition skills after giving treatment by 10.5, and the average score of metacognition skills for FI students, there is an increase in the score of students' metacognition skills after giving treatment by 13.5. So, the average score of metacognition skills still experienced an increase in the average pretest and posttest scores.

3.3. Hypothesis test results

Hypothesis testing uses paired-samples t-test to test the effect of PBL on metacognition skills and independent-samples t-test to test the effect of PBL on cognitive style FD and FI. Before being tested, the data have to fulfilled the assumption, that was normality test and homogeneity test. The normality test used in this study is Kolmogorov-Smirnov test. The homogeneity test used in this study is Levene Statistic test.

The result of the normality test are presented in Table 4 below.

Table 4. Normality and homogeneity test result

| Test     | Pretest | Posttest | Description |
|----------|---------|----------|-------------|
| Normality| 0.321   | 0.966    | Normal      |
| Homogeneity| 0.379 | 0.457    | Homogen     |

The normality assumption test for the Kolmogorov-Smirnov significance value was more than 0.05, namely 0.321 for pretest and 0.966 for posttest. The homogeneity assumption test for the Levene Statistic significance value was more than 0.05, namely 0.379 for pretest and 0.457 for posttest. This indicates that the assumption of univariate normality and homogeneity is fulfilled for the data after the treatment of PBL.

The result of paired-samples t-test are presented in Table 5 below.

Table 5. Paired-samples t test

| Paired Differences | t     | df | Sig. (2-tailed) |
|--------------------|-------|----|-----------------|
| Mean               | std. deviation | Mean | std. error | 95% confidence interval of the difference | lower | upper |
| Pretest - Posttest | -1.20833E1 | 7.76577 | 1.29429 | -14.71089 | -9.45578 | -9.336 | 35 | .000 |
Based on the hypothesis test using paired-samples t test, information was obtained that there was a significant difference between pretest and posttest because it has a significant value < 0.05, namely 0.000. In other word, PBL has a significant effect on metacognition skills.

The result of independent-sample t test are presented in Table 6 below.

**Table 6. Independent-samples t test**

|            | t   | df | Sig. (2-tailed) | Mean | Std. Error | 95% Confidence Interval of the Difference |
|------------|-----|----|----------------|------|------------|------------------------------------------|
|            | t   | df |                | Mean | Std. Error | Lower          | Upper          |
| Pretest    | .321| 34 | .750           | 1.17957 | 3.67781 | -6.29464       | 8.65377       |
| Posttest   | -.445| 34 | .659           | -1.76471 | 3.96302 | -9.81853       | 6.28912       |

In contrast to PBL, cognitive style does not have a significant effect on metacognition skills because it has a significant value > 0.05, namely 0.750 for pretest and 0.659 for posttest. In other words, PBL has a significant effect on the metacognition skills of both FD and FI students.

3.4. Metacognition skills for each aspect

Improvement of metacognition skills in students can also be seen through the percentage of each aspect of metacognition skills in students, which are presented in Table 4 below.

**Table 7. Average metacognition skills for each aspect**

| Cognitive Style       | Aspect | Pretest | Posttest |
|-----------------------|--------|---------|----------|
| Field Dependent (FD)  | Planning | 86.6  | 105.7   |
| Field Dependent (FD)  | Monitoring | 94.7  | 102.6   |
| Field Dependent (FD)  | Evaluating | 89.9  | 95.5    |
| Field Independent (FI)| Planning | 88.4  | 103.6   |
| Field Independent (FI)| Monitoring | 93.8  | 103.2   |
| Field Independent (FI)| Evaluating | 86.6  | 100.5   |
| Total                 | Planning | 87.6  | 104.6   |
| Total                 | Monitoring | 94.2  | 102.9   |
| Total                 | Evaluating | 88.2  | 98.1    |

Based on Table 4 above, it is known that on average each aspect of metacognition skills has increased. FD students experienced an increase in average aspects of planning increased by 19.1, aspects of monitoring increased by 7.9, aspects of evaluating increased by 5.6. Meanwhile, FI students also experienced an increase in the average planning aspect increased by 15.2, the monitoring aspect increased by 9.4, the evaluation aspect increased by 13.9. When viewed in general, the average aspect of metacognition skills has increased, the average planning aspect has increased by 17.0, the monitoring aspect has increased by 8.7, the evaluating aspect has increased by 9.9.

It can be seen that metacognition skills from pretest to posttest has increased. This is because PBL can improve metacognition skills, there are significant differences compared to ordinary learning [26]. PBL creates a learning environment that can improve students' metacognition skills [25, 26]. PBL consists of five stages starting with student orientation to actual problems and ending with a process of analysis and evaluation of learning outcomes so that PBL has the potential to improve metacognitive skills through authentic problems [29]. PBL steps and activities implement a plan of steps to solve problems, reflect and evaluate the results of problem solving [27]. PBL can also help students improve metacognition skills because it involves students actively in the process of problem solving through group work [24]. PBL also provides more opportunities for students to find information on various learning sources and the freedom to use various learning media, explore and process information obtained, solve problems and make decisions so that students can learn actively and try to construct their own knowledge, so that students are more active in looking for problem solving and understanding of what they are doing [30-31].
4. Conclusion
From the results of data analysis and findings, it can be concluded that problem-based learning (PBL) can improve students' metacognition skills both of field dependent (FD) and field independent (FI) students. Each stage of problem-based learning (PBL) learning is able to encourage students' metacognitive skills. Problem-based learning (PBL) can train metacognition skills moderately both of field dependent (FD) and field independent (FI) students.

References
[1] Depdiknas 2006 *Panduan Penyusunan Kurikulum Tingkat Satuan Pendidikan* (Jakarta: Badan Standar Nasional Pendidikan)
[2] Schoenfeld A H 1989 *J. Res. Math. Educ.* 20 338
[3] Richardson K, Schwartz C S and Reynolds A 2010 *Int. J. Math. Teach. Learn.* 1 21
[4] Izzati L R, Sutopo and Chrisnawati H E 2017 *J. Pendidik. Mat. dan Mat.* 1 110
[5] Kemendikbud 2018 *Buku Pegangan Penilaian HOTS Program Peningkatan Kompetensi Pembelajaran Berbasis Zona* (Jakarta: Kementerian Pendidikan dan Kebudayaan)
[6] Rahmadani D, Siagian P and Napitupulu E E 2020 *Int. J. Multicult. Multireligious Underst.* 7 310
[7] Anderson L W and Krathwohl D R 2001 *A taxonomy for learning, teaching, and assessing: A revision of Bloom’s Taxonomy of Educational Objectives* (New York: Longman)
[8] Sani R A 2019 *J. Phys.: Conf. Ser.* 1363 012058
[9] Izzati L R and Mahmudi A 2018 *J. Phys.: Conf. Ser.* 1097 012107
[10] Flavell J H 1976 *Metacognitive Aspects of Problem Solving* (Hillsdale, NJ: Lawrence Erlbaum)
[11] Patuddin, Budayasa I K and Lukito A 2019 *J. Phys.: Conf. Ser.* 1218 012025
[12] Flavell J H 1979 *American Psychologist* 34 906
[13] Trisna B N, Budayasa I K and Siswono T Y E 2018 *J. Phys.: Conf. Ser.* 947 012072
[14] Schraw G and Dennison R 1994 *Contemp. Educ. Psychol.* 19 460
[15] Muhtarom, Sugiyanti, Utami R E and Indriana K 2018 *J. Phys.: Conf. Ser.* 983 012118
[16] Lusweti S L, Jacinta K and Helen M 2017 *J. Educ. Pract.* 8 10
[17] Saxena S and Jain R K 2014 *International J. Acad. Res. Psychol.* 1 6
[18] Al-Salamah E M 2011 *Int. Educ. Stud.* 4 189
[19] Onyekuru B U 2015 *J. Educ. Pract.* 6 76
[20] Karamaerouz M J, Abdi A and Laci S 2013 *Univers. J. Educ. Res.* 1 298
[21] Vendiagrys L, Junaedi I and Masrurkan 2015 *Unnes J. Math. Educ. Res.* 4 34
[22] Izzati L R and Mahmudi A 2019 *J. Phys.: Conf. Ser.* 1157 032089
[23] Pramusinta Y, Setyosari P, Widiati U and Kuswandi D 2019 *J. Educ. Gift. Young Sci.* 7 999
[24] Danial M 2010 *Chem.: J. IIm. Kim. dan Pendidik. Kim.* 11 1
[25] Birgili B 2015 *J. Gift. Educat. Creat.* 2 71
[26] Haryani S, Masufah, Wijayanti N and Kurniawan C 2018 *J. Phys.: Conf. Ser.* 983 012174
[27] Buku M N I, Corebima A D and Rohman F 2016 *Int. J. Acad. Res. Dev.* 1 58
[28] Witkin H, Moor C A, Goedenough D, Cox P W 1977 *Rev. Educ. Res.* 47 1
[29] Fitriyani R, Corebima A D, and Ibrohim 2015 *J. Pendidik. Sains* 3 186
[30] Priyanti D, Marpaung R R T, and Achmad A 2018 *J. Biotedidik Wahana Ekspresi Ilm.* 6 1
[31] Aisyah S and Ridlo S 2015 *Unnes J. Biol. Educ.* 4 22