The Effect of Enrichment Program on the Achievement of Vocational High School Gifted Students in Mathematics Competitions

Masithoh Yessi Rochayati[1], Masithoh Yessi Rochayani[2]*
[1]SMK Negeri 1 Turen, Indonesia
[2]Department of Statistics, Universitas Diponegoro, Indonesia
*yessirochayani@lecturer.undip.ac.id

Abstract

The group of gifted students is a group of students who need special services in learning. SMK Negeri 1 Turen, is one of the schools in Malang Regency that has a platform for gifted students, in the form of a mathematics olympiad team. Every year there are beginner students who join the mathematics olympiad team. Therefore, matriculation is needed for them to catch up on the material they are missing. This research was conducted to find out how many enrichment program meetings are needed for beginner students to equalize their abilities with experienced students. The participants in this study were 10 students, consisting of 6 beginner students and 4 experienced students. Based on the Mann-Whitney test, the results of this study indicate that a long-term enrichment program (17 meetings) has a significant effect on students' achievement in mathematics competitions.

Keywords: Enrichment program, Gifted student, Mathematics competition

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INTRODUCTION

One group of students who have special needs in learning is a group of gifted students (Ikhwanudin et al., 2019). There are many different interpretations of the term giftedness, depending on the researcher's area of expertise, focus of study, and current trends of the time (Türkman, 2020). Gifted students (in the academic field) occupy an essential position because gifted students already have extra motivation and skill to learn and act in class, and can think and learn topics faster than their friends (Uçar, Uçar, & Çalişkan, 2017).

Formal educational institutions need to provide programs for gifted students so that they can develop their abilities (Kahraman & Bulut Bedük, 2016). Special services for gifted students aim to optimize their thinking skills so that later they can become excellent human beings who can play a role in the development of Indonesia to become a developed country and can compete with other developed countries (Haryanto & Pujaningsih, 2008). This is in line with article 5 verse 4 of the Law of the Republic of Indonesia Number 20 of 2003 which states that citizens who have potential intelligence and special expertise are right to get special education.

SMK Negeri 1 Turen is one of the Vocational High Schools in Malang Regency which has a forum for students who are skillful in mathematics. Math-gifted students are gathered into a mathematics olympiad team and given training for a month before the competition. Recruitment of students in the mathematics olympiad team is carried out annually and is based on student interests, teacher recommendations, achievements in mathematics, and recent summative exam scores. This recruitment is carried out once a year, and every year there are beginner students who join the mathematics olympiad team. Therefore, matriculation is needed for beginner students to catch up on the material they are missing. This research will investigate how many meetings so that beginner students have the same abilities as experienced students.

In the enrichment program, students are trained to work on non-routine questions, such as questions in the HOTS category. HOTS stands for Higher Order Thinking Skills. Based on Bloom's Taxonomy revised by Anderson et al. (2000), HOTS includes the activities of analyzing, evaluating, and creating. Meanwhile, according to Krulik et al. (2002), the thinking processes included in the HOTS category are critical thinking and creative thinking. Based on these two definitions, it can be concluded that HOTS questions are questions that require activities to analyze, evaluate, or create which require critical and creative thinking skills. Table 1 below presents examples of routine and non-routine Mathematics questions on Sequences and Series.

Table 1. Examples of Routine and Non-Routine Problems

Routine Problem	Non-Routine Problem
The value of $\frac{1}{16}+\frac{1}{8}+\frac{1}{4}+\cdots+16$ is …	The value of $\frac{1}{1+7^{-15}}+\frac{1}{1+7^{-14}}+\frac{1}{1+7^{-13}}+\cdots+\frac{1}{1+7^{13}}+\frac{1}{1+7^{14}}+\frac{1}{1+7^{15}}-\frac{3}{2}$ is … .
Source: Final Evaluation Questions Chapter 5 Math Textbook for SMK/ MAK Grade X	Source: Questions for the Preliminary Round of the Vocational High School Math Competition in 2022

In this study, gifted students who were members of the Mathematics Olympiad team were divided into two groups, namely a group of beginner students and a group of experienced students. The group of beginner students got training, while the group of experienced students did not get training, but had attended training in the previous year. The group of beginner students consisted of students in grades X and XII who were actively learning in the school, while the group of experienced students was grade XI students who were doing internship programs.

Several studies have shown that enrichment programs have a positive effect on the achievement of gifted students, including research by Al-Zoubi (2014) and Kim (2016). Al-Zoubi in his research took a sample of 30 gifted students (15 girls, 15 boys) who were randomly selected through a lottery from 120 students. The results of this study indicate that enrichment program influences an increase in the academic achievement of gifted students. Meanwhile, Kim (2016) compiled 26 studies on the effects of enrichment programs between 1985 and 2014, reviewing research on programs for gifted students. The findings of Kim's research

demonstrate that enrichment programs improve academic performance among gifted students. Nonetheless, Nieder's (2019) research shows that the effect of enrichment programs on student achievement cannot be predicted. This could be due to several reasons, including irregular student attendance or frequently incomplete homework, very few students enrolled in enrichment programs, or in studies that got poor school grades.

Many studies have been conducted regarding the effect of enrichment programs on student achievement, but have not examined their impact on their performance in mathematics competitions. Researchers suspect that the enrichment program has a positive influence on student achievement in mathematics competitions. This is consistent with the findings in San Jose (2022) which states that lots of programs are carried out over a long period, guaranteeing better student performance in math competitions. Apart from these factors, San Jose also mentioned several other factors that influence student achievement in mathematics competitions, including school and community priorities, the dominance of multiple intelligences, and study habits. In this study, we investigate how many enrichment program meetings are needed for beginner students to catch up with experienced students.

RESEARCH METHOD

This study involved two groups of gifted students with different initial conditions, those are the experienced students group and the beginner students group. The group of experienced students (Group A) is a group of gifted students who have attended an enrichment program, while the group of beginner students (Group B) is a group of gifted students who have never gotten into an enrichment program. Both groups were given test 1 to determine the initial abilities of students from each group. Furthermore, Group B was given 7 enrichment program meetings, while Group A was not. After conducting an enrichment program for Group B, both groups took part in the preliminary round of the national mathematics competition, which we call test 2. Next, the enrichment program was again given to Group B for 10 meetings and ended with the final round of the national mathematics competition, which we refer to as test 3, which was followed by both groups. The illustration of this research design is depicted in Figure 1.

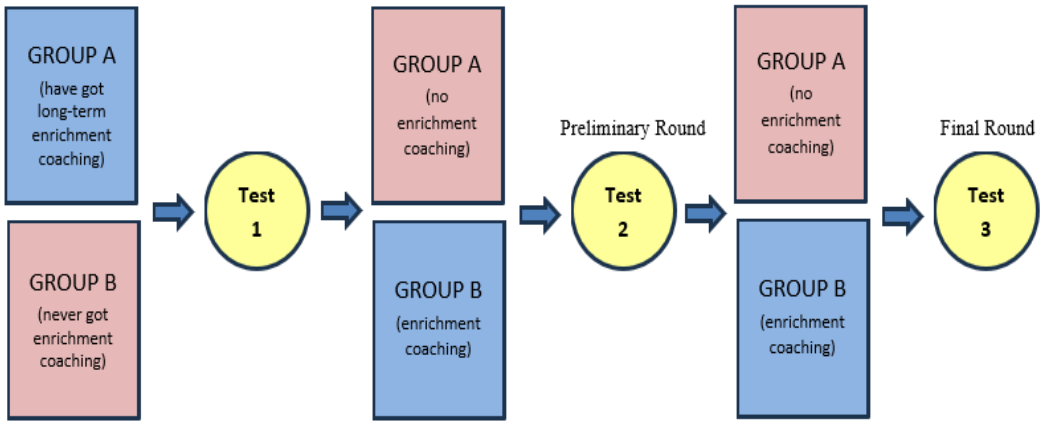

Figure 1. Illustration of Research Design

Participants

The participants consisted of 10 students of SMK Negeri 1 Turen which consisted of two groups. Group A consisted of 4 students who had attended an enrichment program and Group B consisted of 6 students who had never attended an enrichment program. The sample selection used a purposive sampling technique because the researchers only involved gifted students who were members of the Mathematics Olympiad team.

Instruments

In this study, there were two instruments, namely Test 1, Test 2, and Test 3. Instrument Test 1 consisted of 10 HOTS questions with a score of 10 for each question. Meanwhile, Test 2 was a preliminary round of the National Vocational High School Mathematics Competition with 30 multiple-choice questions. Meanwhile, Test 3 is a matter of the final round of the National Vocational High School Mathematics Competition with 5 essay questions.

Data Analysis

The Mann-Whitney U Test is the non-parametric test alternative to the independent *t*-test. The Mann-Whitney tests whether the populace medians of the two groups vary. This test uses the rank of the sample data instead of their specific value. This test assumes that the samples are taken from two independent populations, and are not normally distributed. The hypothesis for The Mann-Whitney U test is

$$H_0: \eta_A = \eta_B \text{ vs } H_1: \eta_A \neq \eta_B \text{ (two tailed)}$$
or
$$H_0: \eta_A \geq \eta_B \text{ vs } H_1: \eta_A < \eta_B \text{ (left tailed)}$$
or
$$H_0: \eta_A \leq \eta_B \text{ vs } H_1: \eta_A > \eta_B \text{ (right tailed)}$$

where η_A is the median of population A and η_B is the median of population B. The first step of the Mann-Whitney test is to arrange all the observations in order of magnitude. Then, rank all scores, neglecting which group they belong to. The lowest score is assigned a rank of "1", the next lowest is assigned a rank of "2", and so on. Then compute the values of U, using the formula in Equation (1).

$$U_A = R_A - \frac{n_A(n_A + 1)}{2} \tag{1}$$

where U_A is the Mann-Whitney test statistics of Group A, R_A is the sum of the ranks for Group A, and n_A is the sample size of Group A. The Mann-Whitney test utilizes a normal approximation to calculate the p-value of the test.

$$Z = \frac{U_A - \mu_{U_A}}{\sigma_{U_A}} \tag{2}$$

where

$$\mu_{U_A} = \frac{n_A n_B}{2} \tag{3}$$

$$\sigma_{U_A} = \sqrt{\frac{n_A n_B (n_A + n_B + 1)}{12}} \quad (4)$$

The Z is approximately distributed as a normal distribution with a mean of 0 and a standard deviation of 1. The normal approximation p-value for the three alternative hypotheses utilizes a continuity correction of 0.5.

$$H_1: \eta_A \neq \eta_B \qquad P\ value = 2 \times P\left(Z \leq \frac{(k + 0.5) - \mu_{U_A}}{\sigma_{U_A}}\right) \quad (5)$$

$$H_1: \eta_A < \eta_B \qquad P\ value = P\left(Z \leq \frac{(U_A + 0.5) - \mu_{U_A}}{\sigma_{U_A}}\right) \quad (6)$$

$$H_1: \eta_A > \eta_B \qquad P\ value = P\left(Z \geq \frac{(U_A - 0.5) - \mu_{U_A}}{\sigma_{U_A}}\right) \quad (7)$$

where $k = \min(\mu_{U_A}, n_A(n_A + n_B + 1) - \mu_{U_A})$. If the data contains ties (identical values), then the σ_{U_A} is replaced by Equation (8) (Hollander et al., 2014).

$$\sigma_{U,ties} = \sqrt{\frac{n_A n_B}{12}\left(n_A + n_B + 1 - \frac{\sum_{i=1}^{I}(t_i^3 - t_i)}{(n_A + n_B)(n_A + n_B - 1)}\right)} \quad (8)$$

where n_A is the sample size of Group A, n_B is the sample size of Group B, it is the number of ties for the i-th rank, and I is the number of sets of ties.

RESULTS AND DISCUSSION

Results of Test 1

The pretest consists of 10 short questions in the HOTS category. The maximum score for each question is 10. Thus, the maximum pretest score is 100. The pretest scores are presented in Table 2, the pretest results statistics are presented in Table 3, and the boxplot diagram is presented in Figure 2.

Table 2. The Score of Test 1

Student's Name	Group	Test 1
RN	A	88
SA	A	80
HA	A	73
NF	B	73
TP	A	70
AP	B	46
AK	B	37
VK	B	32
DC	B	30
AM	B	20

Table 3. Descriptive Statistics of Test 1

Statistic	Group A	Group B
Sample size	4	6
Sample average	77.75	39.67
Sample standard deviation	8.02	18.42
Median	76.5	34.5
Outliers	-	73

Figure 2 shows that the scores obtained by students in Group A are higher than Group B. The median value is marked with a thick horizontal line on the inside of the box. Even though the boxplot diagram shows that the median k values for the two groups are different, to be sure we did hypothesis testing to compare both groups. We used the Mann-Whitney test instead of the independent t-test since the data contains an outlier (extreme value) in group B. The Mann-Whitney test used in Test 1 is a one-tailed test that tests whether the median of Group A was greater than the median of Group B. The Mann-Whitney right-tailed hypothesis test used is $H_0: \eta_1 \leq \eta_2$ vs $H_1: \eta_1 > \eta_2$ with a significance level of α=0.05. Since the data contains ties, therefore the normal approximation uses the ties correction.

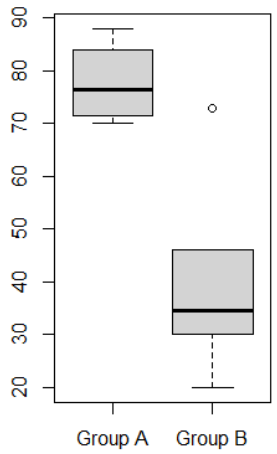

Figure 2. The Boxplot Diagram of Test 1

The Mann-Whitney statistic is calculated using Equation (1) and we obtained $U_A = 22.5$. To compute the p-value, the normal approximation is used. Using Equation (3) we obtained $\mu_{U_A} = 12$. Since the data contains ties the standard deviation (σ) is calculated using Equation (8) and yield $\sigma_{U,ties} = 4.6762$. Since we use the $H_1: \eta_1 > \eta_2$, thus, we use Equation (7) to compute the p-value. The p-value of the test is 0.0162. This means that the probability of type I error (error of rejecting the correct H_0) is small at 1.62%. Because the p-value < α, then the null hypothesis (H_0) is rejected. Hence, the population median of Group A is considered to be larger than the population median of Group B.

The results of this analysis indicate that the group of gifted students who have gotten a long-term enrichment program obtained better scores than gifted students who have never attended an enrichment program. This is in line with the results of the previous study conducted by Al-Zoubi (2014) and Kim (2016) which show that

gifted students who get enrichment programs can perform better than gifted students who do not get enrichment programs. Although the number of research samples involved in this study was small, by using the Mann-Whitney test, we show that the theory was correct and also applied to small samples.

Results of Test 2 and Test 3

After Test 1 was carried out, students in group B were given an enrichment program in 7 meetings. Then both groups took part in the preliminary round of the mathematics competition which we considered as Test 2. The questions in the preliminary round were in the form of 30 multiple-choice questions. Correct answers are given a score of +4, no answer is given a score of -1, and wrong answers are given a score of 0. So the maximum score for the preliminary round is 120 and the minimum score is -30. The preliminary round scores are presented in Table 4 and the boxplot diagram can be seen in Figure 3.

Table 4. The Score of Test 2

Student's Name	Group	Test 2
HA	A	26
RN	A	24
SA	A	21
AM	B	21
TP	A	20
DC	B	16
AP	B	9
NF	B	7
VK	B	7
AK	B	4

The Test 2 score boxplot diagram shows that students in group A got high scores on the test again even though they did not take the enrichment program. While the students in group B, most of them got low scores on Test 2, even though they got an enrichment program. The Mann-Withney's test for Test 2 scores with the hypothesis: $H_0: \eta_1 \leq \eta_2$ vs $H_1: \eta_1 > \eta_2$, results in a p-value of 0.01597 so that the null hypothesis is rejected, which means that the median of Group A is greater than the median of Group B. This indicates that the enrichment program does not affect student achievement in mathematics competitions. This reveals that other factors influence student achievement in mathematics competitions.

In general, many factors affect student achievement. Bertolini et al. (2012) mention several levels of factors that influence student achievement, including personal factors, interactions with other people, and the larger system that surrounds students. Mohd, Mahmood, and Ismail (2011) stated that the level of patience, self-confidence, and willingness to solve math problems has a positive influence on students' mathematics achievement. Al-Agili et al. (2012) state that teacher attribution shows a positive relationship with student achievement. Meanwhile, San Jose (2022) states that mentoring efforts, school and community priorities, learning styles, the dominance of multiple intelligences, and study habits influence student achievement in math competitions.

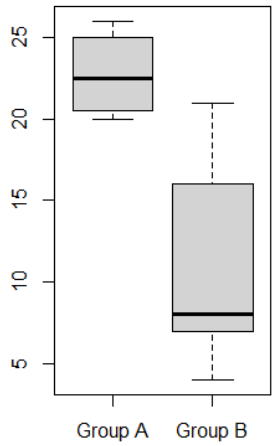

Figure 3. The Boxplot Diagram of Test 2

In this study, we suspect that students' prior knowledge is a factor that has a significant influence on student achievement on Test 2. Previous researchers have examined the effect of early abilities on student achievement at both the elementary, secondary, and tertiary education levels, as well as in several disciplines. In the first years of school, cognitive abilities such as memory and early numerical abilities are often associated with predictors of arithmetic performance and general mathematics performance (Nogues & Dorneles, 2021). At the secondary school level, students' prior knowledge also has a significant influence on learning outcomes in various subjects, such as mathematics (Hevriansyah & Megawanti, 2017; Lestari, 2017; Zulkarnain, 2019), biology (Shidik, 2019), and physics (Astuti, 2015). In Higher Education, prior knowledge also has a significant influence on student achievement in physics (Halloun & Hestenes, 1985), chemistry (T. Hailikari et al., 2008; T. K. Hailikari & Nevgi, 2010), and psychology (Thompson & Zamboanga, 2003).

After students from Group A and Group B took part in the elimination round and all students from both groups were declared entitled to enter the next round, we again provided an enrichment program to Group B. The Enrichment program was carried out in 10 meetings. Next, students from both groups took part in the final round which we considered Test 3. In Test 3, students worked on 5 descriptive questions. Student scores on Test 3 are presented in Table 5 and a boxplot diagram of Test 3 scores is presented in Figure 4.

Table 5. The Score of Test 3

Student's Name	Group	Test 3
NF	B	81
VK	B	62
RN	A	59.65
AM	B	51.5
HA	A	47.05
SA	A	45
AP	B	37.5
DC	B	32.5
TP	A	31.5
AK	B	24

The boxplot diagram in Figure 4 shows that the median values for the two groups are almost the same. To test whether the medians of the two groups are the same, we use the two-tailed Mann-Whitney test. This test hypothesis is $H_0: \eta_A = \eta_B$ vs $H_1: \eta_A \neq \eta_B$ and the significance parameter of 0.05. The p-value of the test is computed using Equation (5) and yields a p-value of 0.9151. The p-value is greater than the significance parameter, thus the null hypothesis cannot be rejected, which means that the score of the Group A population is assumed to be equal to the score of the Group B population. In other words, the difference between the value of Group A and the Group B populations is not big enough to be statistically significant.

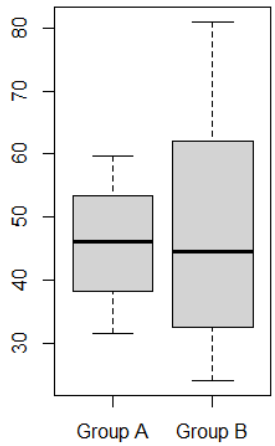

Figure 4. The Boxplot Diagram of Test 3

The results of the analysis of test scores 3 showed that there was no significant difference between the scores of Group A and Group B. This indicated that the long-term enrichment program given to Group B had an impact on Group B's achievement in the mathematics competition. This is in line with the findings in San Jose's (2022) research which states that lots of programs are carried out over a long period, guaranteeing better student performance in math competitions.

CONCLUSION

We can conclude from the data analysis and the discussion that a long-term enrichment program (17 meetings) has a significant effect on students' mathematics achievement. This can be seen from the results of the analysis in Test 1 and Test 3, where both Group A and Group B showed good performance after being given a long-term enrichment program. By guiding beginner students for 17 meetings, the abilities of beginner students can match the abilities of students who have taken part in enrichment guidance and mathematics competitions.

The drawback of this study is that this study only examines the distinction in scores of the two groups given different treatments. We did not test whether students in Group B has an increase in achievement after being given enrichment. This is because the ranges and scales of the scores on each test are different, so a special method must be applied to equate the ranges and scales of the scores. Z-

score normalization or min-max normalization may be possible but does not guarantee accurate results because the difficulty level of the test increases.

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