Development of a problem-based learning test to measure grade xii students' mathematical creativity and adversity quotient

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Abstract
This study aims to overcome the low ability of mathematical creative thinking and adversity quotient of students in solving number problems and series. One of the alternative efforts to overcome this problem was that a comprehensive and integrated and integrated handling was needed, including RPP, LKPD and Evaluation Tools. This research was part of this integrated effort to produce a valid and practical test instrument to measure students' mathematical creative thinking skills. The development of a test instrument using the design-based research (DBR) method refers to the Plomp model, which consists of three stages of preliminary research, a developing or prototyping phase, and an assessment phase. The research approach was quantitative and qualitative with one group pretest-posttest design. The research subjects were 36 students of class XI MIPA one of the public schools in Bandung District in 2019/2020. The results showed the mathematical creative thinking test instrument was valid and practical; the learning design using the PBL model which was modified by the ZPD theory as a whole can significantly improve students 'mathematical creative thinking skills, so that the developed test instrument effectively measures students' mathematical creative thinking skills; and adversity quotient criteria including Camper's criteria, namely those who camp.
Keywords: Design Based Research; Test Instruments; Creative Thinking Ability; PBL Model; Adversity Quotient

Abstrak
Penelitian ini bertujuan untuk mengatasi rendahnya kemampuan berpikir kreatif matematis dan adversity quotient peserta didik dalam menyelesaikan soal barisan dan deret. Salah satu upaya alternatif untuk mengatasi masalah tersebut adalah diperlukan penanganan yang komprehensif dan terpadu serta terintegrasi, meliputi RPP, LKPD dan Alat Evaluasi. Penelitian ini merupakan bagian dari upaya terpadu tersebut untuk menghasilkan instrumen tes yang valid dan praktis untuk mengukur kemampuan berpikir kreatif matematis siswa. Pengembangan instrumen tes menggunakan metode design-based research (DBR) yang mengacu pada model Plomp, yang terdiri

dari tiga tahap yaitu tahap penelitian pendahuluan, tahap pengembangan atau pembuatan prototipe, dan tahap penilaian. Pendekatan penelitian yang digunakan adalah kuantitatif dan kualitatif dengan desain penelitian one group pretest-posttest design. Subjek penelitian adalah 36 siswa kelas XI MIPA salah satu SMA Negeri di Kabupaten Bandung tahun ajaran 2019/2020. Hasil penelitian menunjukkan instrumen tes kemampuan berpikir kreatif matematis valid dan praktis; desain pembelajaran dengan menggunakan model PBL yang dimodifikasi dengan teori ZPD secara keseluruhan dapat meningkatkan kemampuan berpikir kreatif matematis siswa secara signifikan, sehingga instrumen tes yang dikembangkan efektif mengukur kemampuan berpikir kreatif matematis siswa; dan kriteria adversity quotient termasuk dalam kriteria Campers, yaitu yang berkemah.

Kata Kunci: Penelitian Berbasis Desain; Instrumen Tes; Kemampuan Berpikir Kreatif; Model PBL; Adversity Quotient

Introduction

Globalisation is marked by the accelerated development of science and technology, which requires the education system to produce high-quality human resources (Schleicher, 2012). Human resources with the ability to think creatively, innovatively, critically, and have good character are needed by Indonesia today (Trilling & Fadel, 2009; Atiyah & Nuraeni, 2022). Therefore, to meet the demands of the times, in 2013 the government launched a new curriculum that is oriented towards three aspects: knowledge, attitudes, and skills (Kemendikbud, 2013). This curriculum, known as the 2013 Curriculum or *Kurikulum 2013*, emphasizes competence-based learning and the development of 21st-century skills such as problem-solving, critical thinking, and collaboration (Center for Curriculum and Bookkeeping, 2014; Ghassani et al., 2023).

These skills are needed by learners to adapt to the rapidly changing world in recent years (OECD, 2018). In an effort to produce the expected next generation, it is necessary to conduct training in every subject in school, including mathematics. Mathematics plays a crucial role in developing logical, analytical, and creative thinking, which are essential for problem-solving in real-life contexts (NCTM, 2000; Kilpatrick, Swafford, & Findell, 2001). Therefore, mathematics education must not only focus on procedural knowledge but also on higher-order thinking skills such as reasoning, problem-solving, and creativity (Anderson & Krathwohl, 2001; Handayani, 2023).

Maths is a subject that can train students in improving logical and systematic thinking. This is in accordance with the objectives of learning mathematics according to the 2013 curriculum (Anwar, et al., 2015). One of them is to understand mathematical concepts, explain the relationship between concepts and apply concepts or logarithms flexibly, accurately, efficiently, and precisely in solving problems.

One of the abilities used to solve mathematical problems is the ability to think creatively. With creative thinking skills, a person can analyse the problem at hand in an organised manner, formulate innovative questions, and design original solutions (Amalia, et al., 2015; Arnisya & Afriansyah, 2024). According to Siswono (Anwar, et al., 2015) creative thinking is defined as a combination of logical thinking and divergent thinking based on intuition but still in consciousness. Divergent thinking generates many ideas in solving problems, making it useful in finding creative and effective solutions.

In addition to creative thinking skills, there are also other factors needed in solving complex problems, namely factors within students or internal factors (Efwan et al., 2024). Intelligence or intelligence is one of the internal factors classified into psychological factors that affect learners in finding effective solutions to problems (Isviana, et al., 2015; Kosasih, Gita, & Nurjanah, 2024). Based on this, there are several types of intelligence that can affect the ability of students to solve problems, one of which is Adversity Quotient (AQ). According to Stoltz (2000) AQ is a form of intelligence other than Intelligence Quotient (IQ), Spiritual Quotient (SQ), and Emotional Quotient (EQ) that has the aim of overcoming difficulties. AQ can be used to measure the extent of a person's effort when facing complex problems. In other words, AQ can be said to be a fighting spirit.

In reality, the low quality of creative thinking and AQ in solving mathematics problems is still widely found. In addition, the reasoning of students who are still convergent, namely thinking that is towards one point or centred on examples of problems given by educators, is also still a problem (Isvian, et al., 2015). Based on the results of interviews with educators in one of the public schools in Bandung Regency, it shows that students have difficulty in answering problems that require using other methods or formulating new concepts to solve mathematical problems. For example, especially in compulsory mathematics learning with arithmetic and geometric sequence patterns, most students tend to use standardised formulas and have difficulty using methods other than procedural.

This is in accordance with research conducted by Nurdin (Fauzia, et al., 2017) which shows that the subject matter of rows and series is one of the concepts that uses many formulas or procedures. Learners tend to face difficulties to use the concepts that exist in rows and series when learners only memorise formulas or rules without understanding them. This shows that most learners only memorise procedures and formulas in learning the concept of rows. Thus, many learners are unable to answer questions in the form of applications and require a deeper understanding of the concept.

In addition, one of the significant differences between learners when solving mathematics problems is the quality of their fighting power or Adversity Quotient (AQ). Stoltz (1997) introduced AQ as a measure of how well someone can withstand and overcome challenges, which plays a crucial role in academic persistence. Based on the results of observations made by researchers at one of the tutoring institutions in Bandung, it shows that students tend to have the character of giving up easily when given mathematics problems with High Order Thinking Skills (HOTS) characteristics. This aligns with research showing that students with low AQ often perceive challenging tasks as threats rather than opportunities for growth (Syukri et al., 2020). Furthermore, when students are given practice problems with these characteristics, they tend to assume that these problems are difficult and impossible to solve, which may stem from a fixed mindset and lack of resilience in facing cognitive challenges (Dweck, 2006).

To solve these problems, an integrated approach is needed that includes the development of learning designs, learning media, and evaluation tools. This research is one of these integrated efforts, especially in developing test instruments to measure students' diverse mathematical creative thinking abilities. To measure these abilities, an assessment instrument in the form of a written test is needed. The form of test used is a description test. Descriptive tests are used because they are able to assess students' mathematical creative thinking skills and reduce the possibility of students guessing answers, as stated by Ruseffendi (1991).

In addition, another strategy that can be used to measure mathematical creative thinking skills is by using open-ended problems. Open-ended problems are problems that have more than one answer or strategy to solve them. That is, open problems have answers and ways that are not single to solve them. So that it allows students to develop novelty of ideas, fluency and flexibility of thinking, and the ability to elaborate (Masitoh & Hartono, 2017).

The problems used to measure creative thinking skills are problems that are applied in the context of real life. Real-world contexts provide meaningful situations that allow students to connect mathematics to their daily lives, making learning more relevant and engaging (Boaler, 1998). This is because the problems presented can be a challenging, motivating, and fun learning tool for students. In particular, open-ended and contextual problems can stimulate students' curiosity and foster divergent thinking, which is a core component of creative thinking (Silver, 1997). Based on this, this study aims to produce a valid and practical test instrument to measure mathematical creative thinking ability. The development of valid and practical instruments is essential to ensure that the assessment accurately reflects students' creative potential and can be effectively implemented in the classroom (Mardapi, 2017).

Method

This study uses a design-based research (DBR) method that refers to the Plomp model (Putrawangsa, 2018), consisting of three stages: preliminary research, developing or prototyping phase, and assessment phase. The subjects of this study were 6 students for the limited trial and 30 students of class XI MIPA in one of the public schools in Bandung Regency in the 2019/2020 academic year for the field trial. The following figure shows the stages of design-based research according to Plomp's model.

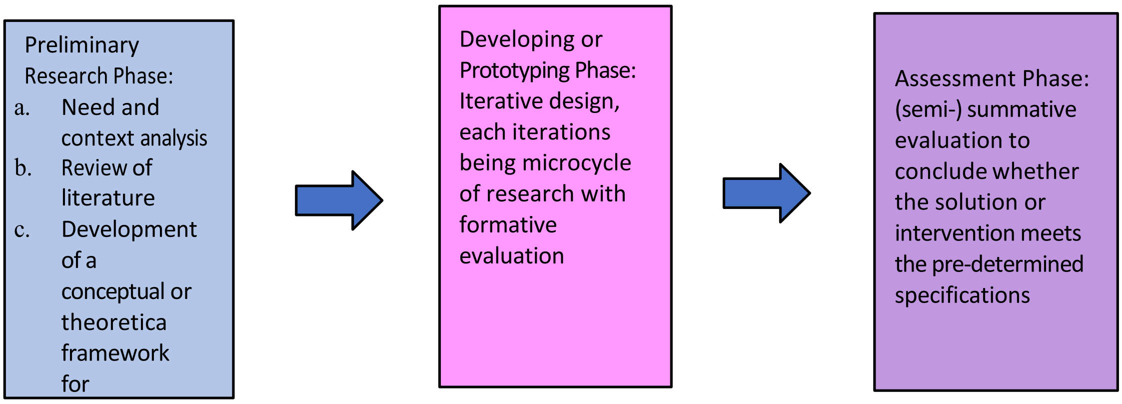

Figure 1. Stages (Phases) of Design Based Research as a Development Study (Ihsan & Kosasih, 2018)

This study uses a design-based research (DBR) method that refers to the Plomp model (Putrawangsa, 2018) see Figure number 1, consisting of three stages: preliminary research, developing or prototyping phase, and assessment phase. The subjects of this study were 6 students for the limited trial and 30 students of class XI MIPA in one of the public schools in Bandung Regency in the 2019/2020 academic year for the field trial. The following figure shows the stages of design-based research according to Plomp's model.

The DBR stage consists of several phases which can be explained as follows: The Preliminary Phase consists of a number of activities consisting of context analysis and needs (problem) analysis including reviewing the syllabus, competency standards, basic competencies so as to produce indicators of competency achievement and literature review. The Development or Prototyping Phase includes design development activities that are still in the form of prototypes through trial activities that are carried out repeatedly (iterative) (Putrawangsa, 2018). The iterative prototyping process is carried out as a basis for improving the quality of test instruments. The initial design at the prototyping stage is referred to as prototype I. Prototype I will be evaluated and trialled in 2 groups, namely expert review and limited trial. Prototyping is carried out until it produces a prototype that is ready for field testing. The assessment phase is a semi-summative assessment to determine the effectiveness of the test instrument in measuring students' mathematical creative thinking skills after being given treatment using the overall learning design.

The data analysis technique used in this research is quantitative and qualitative data analysis. Qualitative data analysis was conducted to determine the content validity of the test instrument based on the review of the test instrument judgement sheet, including aspects of material, construction, language, and the suitability of the questions in the test with creative thinking indicators (Arikunto, 2012). Content validity ensures that the test items represent the intended domain and are relevant to the constructs being measured (Creswell & Creswell, 2018). Meanwhile, quantitative data analysis was used to determine the quality of the test instrument based on the validity, reliability, differentiating power, difficulty level, and practicality of the instrument (Mardapi, 2017). Quantitative data was analysed using Microsoft Excel 2019 to calculate the quality of the instrument, while the effectiveness of the test instrument was measured using the paired sample t-test, which is commonly used to compare pre- and post-test results in educational research (Fraenkel, Wallen, & Hyun, 2012).

Result

The test instrument was used to measure the mathematical creative thinking ability of students by using a modified Problem-Based Learning (PBL) model based on the Zone of Proximal Development (ZPD) theory. According to Vygotsky's ZPD theory, students learn best when working on tasks slightly above their current level of competence with the guidance of teachers or peers (Vygotsky, 1978). PBL encourages students to explore, inquire, and construct knowledge actively, which aligns well with the development of creative thinking skills (Hmelo-Silver, 2004). The material measured in this test instrument is the number line and series—topics that require conceptual understanding and flexible thinking. This research follows the research and development method based on the Plomp model, which includes three main stages: 1) Preliminary investigation, 2) Design and prototyping, and 3) Assessment or evaluation phase (Plomp & Nieveen, 2013). The Plomp model is widely used in educational design research to ensure that the developed product is theoretically grounded, validated, and practical for use in real educational settings.

Table 1. Limited Trial Test Instrument Quality Results

No	Result	1st Formative	2nd Formative	Final Evaluation
1	Expert Validity	1,00	1,00	1,00
2	Empirical Validity	0,730	0,670	0,830
3	Reliability	0,562	0,406	0,749
4	Average Distinguishing Power	0,600	0,630	0,920
5	Average Level of Difficulty	0,350	0,310	0,300
6	Practicality		3,88	

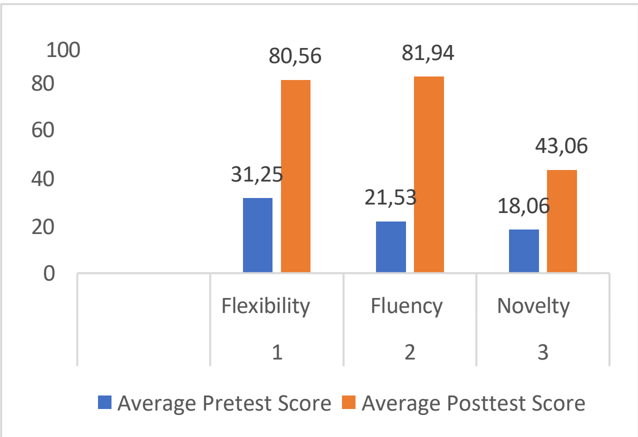

Figure 2. Pretest and Posttest Score Results

Table 2. Pretest and Posttest Normality Test Results

Result	Kolmogorov-Smirnov Test		
	Statistic	Df	Sig.
Pretest	0,131	36	0,119
Posttest	0,122	36	0,191

Table 3. Homogeneity Test Results

		Levene Statistic	df1	df2	Sig.
Learners' Grades	Based on Mean	3,100	1	70	0,083
	Based on Median	2,723	1	70	0,103
	Based on Median and with adjusted df	2,723	1	65,060	0,104
	Based on trimmed mean	2,951	1	70	0,090

Table 4. Results of Paired Samples t-test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	T	Df	Sig. (2-tailed)
Pair 1	pretest – postest	-44,972	20,451	3,409	-51,892	-38,052	-13,194	35	0,000

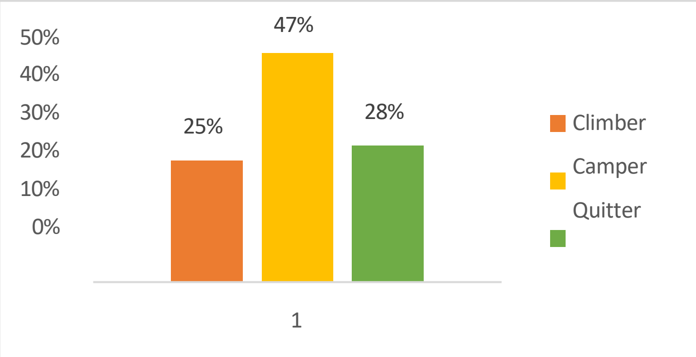

Figure 3. Criteria for Adversity Quotient in Experimental Classes

Discussion

1. Preliminary Phase

The preliminary phase resulted in the design of an evaluation tool in the form of a test instrument for the subject matter of number rows and series. This phase also produced a number of indicators which included 12 Knowledge Competency Achievement Indicators (GPA) and 8 Skill GPA. The GPAs were formulated using operational verbs that can be measured, covering knowledge and skills, and adjusted to the indicators of mathematical creative thinking ability, namely fluency, flexibility, and novelty.

After designing the GPA, a lattice of test instrument questions was made that was adjusted to the GPA, as well as making questions and answer keys for the test instrument. The question grids were developed based on three aspects, namely content, construct, and language. The design of the question content focuses on the suitability of the material taught at the high school level. In addition, the questions are designed based on problems that are easily found in real life. The goal is to help students to more easily understand the material of number ranks and series. The question construct is designed in accordance with the indicators of creative thinking, namely flexibility (question 1), fluency (question 2), and novelty (question 3). Meanwhile, the language used in the questions is in accordance with the KBBI rules, does not use local languages that can cause double meanings, and the question sentences are made communicative and simple so that they are easily understood by students.

The design will be further refined by the researcher. The preliminary design consists of 3 sets of evaluation tests, namely formative evaluation tests 1, 2, and end-of-chapter evaluation tests. The final result at the preliminary research stage is the initial design of the mathematical creative thinking test which will be further developed at the prototyping phase.

2. Prototyping phase

At this stage, the initial design that has been designed is referred to as Prototype 1. Prototype 1 was developed based on input from experts and the results of limited trials to evaluate its quality. The following are the results of the evaluation of Prototype 1.

a. Expert Review

Prototype 1 validation was conducted by three lecturers from the Mathematics Study Programme, Faculty of Teacher Training and Education, Universitas Islam Nusantara in two stages. In the first stage, the average assessment of the three validators showed that there were items that were not in accordance with the content validity aspects. The validators assessed that Prototype 1 was feasible to use for limited trials after improvements were made. Improvements were made to formative tests 1 and 2, focusing on the flexibility and fluency indicators. As well as on the final evaluation test for the fluency and novelty indicators. The validator suggested that Prototype 1 be improved and then revalidated by the same expert.

Based on the results of stage II validation, the average assessment of the three validators stated that the test items were in accordance with the content validity aspects. The three validators also assessed that Prototype 2 is feasible to use for limited trials, therefore Prototype 2 is valid based on expert views. Furthermore, the validated Prototype 2 was tested in a limited trial.

b. Limited Trial

Prototype 2 was trialed in one class for a limited trial which was not a research subject. With the aim of knowing the feasibility of the prototype before the field trial. In this trial, the validity, reliability, distinguishing power, difficulty level, and practicality of the prototype will be tested. Implementation of formative test 1 on the second meeting after the material of arithmetic series and sequence is delivered. Formative test 2 at the fourth meeting, and the final evaluation at the fifth meeting after the material on rows and series has been delivered. Furthermore, at the sixth meeting, students filled out a response questionnaire to determine the practicality of the test instrument. The following are the results of data analysis from Prototype 2.

According to Ruseffendi (1991), a good instrument must have validity and reliability. A test is said to be reliable if it gives consistent results. Based on Table 1, it is known that the test is classified as valid and reliable. Based on the validity and reliability criteria, it is medium for the formative test and high for the final evaluation. This shows that the tests that have been developed can be trusted and provide the same results when the creative thinking test is carried out on different subjects, places or conditions. As Arikunto (2013) states, tests with at least moderate reliability and validity can be considered good and reliable.

The test instrument also showed good discriminating power for the formative test and very good for the final evaluation. This indicates that the mathematical creative thinking test can differentiate the abilities of students with high and low abilities. According to Arikunto (2018), the differentiating power of the question is the ability of the question to distinguish between high and low ability students. A good question is a question that can only be answered correctly by clever students, because questions that can be answered correctly by clever and less clever students do not have good differentiating power.

When viewed from the level of difficulty of the test instrument, the average mathematical creative thinking test items have a medium level of difficulty, with some questions classified as difficult. According to Arikunto (2013), the ideal question is a question that is not too easy or too difficult. Although there are some difficult items, the mathematical creative thinking test has a good level of difficulty. As Arikunto (2013) stated, questions that are too easy or too difficult can be used depending on the purpose.

According to Arikunto (2013), the test instrument is said to be practical if the results of filling out the learner response questionnaire are at least good criteria. The practicality questionnaire used contains the components of helpfulness and ease. The results of the learner response questionnaire obtained an average of 3.8 with a positive interpretation. Based on these results, Prototype 2 which has been valid, reliable, has good differentiating power, and moderate difficulty level, and is practical, can be referred to as Prototype 3. Prototype 3 is the final product of the prototyping research stage that is suitable for use. Prototype 3 will be tested further in the field trial.

c. Assessment phase.

Prototype 3 produced in the previous stage was tested in a field trial to semi-summatively assess the developed tools as a whole. The prototype 3 trial was conducted together with other learning designs, such as lesson plans and LKPD. The trial was conducted in one experimental class. The pretest and posttest activities were carried out to determine the effectiveness of the developed test. The following are the results of pretest and posttest data.

Based on Graph 1, students' mathematical creative thinking skills are still low and not optimal. This low ability can also be seen from the results of students' answers who have not been able to solve each problem correctly and precisely. This may be due to the fact that the material tested is still relatively new, although the basic concepts of rows and series have been learned in grade 8. Thus, the low average score of students on the pretest shows that they rely more on their ability to remember material from junior high school.

After the treatment, the average posttest score showed an increase compared to the pretest, with more learners achieving the ideal score. This increase can be seen in each indicator of mathematical creative thinking, as shown in Figure 1. This indicates that the learners' mathematical creative thinking skills improved after the implementation of the overall learning design. To determine whether this improvement was significant, a paired t-test was conducted. Previously, a prerequisite test was conducted which included normality test using Kolmogorov-Smirnov and homogeneity test using Levene. The following are the results of the prerequisite testing:

The normality test for the distribution of students' pretest and posttest scores was carried out with a significance level of 5%. Based on Sugiyono (2010: 159), the null hypothesis (H_O) and alternative hypothesis (H_1) are formulated as follows:

H_0: the data is normally distributed,

H_1: data is not normally distributed.

The test criteria are if the significance value ≥ 0.05, then H_0 cannot be rejected; if the significance value < 0.05, then H_O is rejected. The Kolmogorov-Smirnov test results show that the pretest and posttest significance values are more than 0.05, so H_0 cannot be rejected and it can be concluded that the data is normally distributed.

Furthermore, a homogeneity test was conducted to determine the similarity of variance between pretest and posttest data. Based on Sugiyono (2010: 175), H_0 and H_1 for the homogeneity test are:

H_0 : The variances of the two groups of data are homogeneous

H_1 : The variances of the two data groups are not homogeneous

To test the homogeneity hypothesis, the Levene test was used with the test criteria: if the significance value ≥ 0.05, then the null hypothesis cannot be rejected, while if the significance value <0.05, the null hypothesis is rejected. The results of the homogeneity test of students' pretest and posttest scores are presented in Table 3 as follows:

Levene's test shows that the significance probability of 0.083 is greater than 0.05, so H_O cannot be rejected. Based on these results, it can be concluded that the variance of the two groups of data is homogeneous. After ensuring that the data is normally distributed and homogeneous, a paired sample t-test is conducted using SPSS version 25. The hypothesis used is a one-tailed test on the right side, as stated by Sugiyono (2010):

$H_0 : \mu_1 \geq \mu_2$
$H_1 : \mu_1 < \mu_2$

When μ_1 : The mean pretest score of the experimental class.
μ_2 :Mean posttest score of the experimental class.
H_0 : Mean pretest score ≥ mean posttest score.
H_1 : Mean pretest score < mean posttest score.

According to Sugiyono (2010) "to conduct a one-party hypothesis test, the sig. (2-tailed) value must be divided by 2".

With the following test criteria:

a) If $\frac{significant\ value}{2} \geq 0{,}05$ then H_0 cannot be rejected and H_1 rejected.

b) If $\frac{significant\ value}{2} \geq 0{,}05$ then H_0 rejected and H_1 cannot be rejected.

Based on table 4, it is obtained that the significance value (2-tailed) is 0.000. Because the test used is a one-party test, the significance value of $0.000 = 0.000$ is smaller than 0.05 so that $H_0$is rejected and H_1 is accepted.

These results indicate that there is a significant difference between the mean scores of the pretest and posttest in the experimental class. Which indicates an increase in students' mathematical creative thinking skills after treatment. Based on these results, it can be concluded that the test instrument is effective in measuring students' mathematical creative thinking ability.

The criteria for adversity quotient of students after experiencing learning with the PBL model modified by ZPD theory in accordance with Stoltz's theory (Isviana, et al., 2015) in the experimental class are categorised as in graph 2.

Based on Figure 2, it is known that 47% of learners have Adversity Quotient in the medium category (Campers) after learning with PBL model. This category shows that learners are able to struggle effectively enough to face problems and complete the given responsibilities. Although they sometimes experience setbacks or give up easily when faced with problems that exceed their abilities, they are not able to overcome them.

Conclusion

Based on the results of the research and discussion, it can be concluded that: 1) The development of creative thinking test instruments with the Design-Based Research method that refers to the Plomp model produces valid and practical test instruments with positive interpretations; 2) The learning design with the PBL model modified by ZPD theory as a whole can significantly improve students' mathematical creative thinking skills, so that the test instruments developed are effective in measuring students' mathematical creative thinking skills; and 3) The Adversity Quotient criteria of students fall into the Campers category, namely those who are able to struggle quite effectively in facing challenges.

Based on this study, several recommendations can be made. First, researchers who are interested in the concept of mathematical creative thinking can relate it to one or more mathematical skills. Second, various methodologies can be used to assess mathematical creative thinking ability. Third, further research that is more in-depth about the test instruments that have been developed can be carried out in different places or a wider population. Finally, the discussion of mathematical creative thinking in geometry can be an interesting research topic.

Conflict of

The authors declare that no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely by the authors.

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