The development of tangram-based geometry test to measure the creative thinking ability of junior high school students in solving two-dimensional figure problems

E Cahyanita¹, S Sunardi¹, E Yudianto¹, N R Aini¹, and H T Wijaya¹
¹Postgraduate of Mathematics Education Department, University of Jember, Indonesia

Abstract. Geometry is a branch of mathematics that demands creative thinking. Teachers need a geometry instrument that is fun, simple, and meaningful to measure the creative thinking ability of junior high school students. This developmental research used a 4-D model consisting of defining, designing, developing, and disseminating the tangram-based geometry test. This research was intended to describe the process of developing a tangram-based geometry test. Tangram-based geometry test development included validation by experts. The product has passed the validation stage and obtained a score of 4.47 (scale 1-5), so it was feasible to use. Research try out subjects were 3 out of 30 students who were VIII grader at junior high school that was chosen due to van Hiele levels. Data on students' creative thinking profile acquired through tests and interviews. Fluency, originality, flexibility, and elaboration are the aspects of creative thinking ability. The results showed that in solving tangram-based geometry tests, a student at the creative level (level 3) satisfied all aspects of creative thinking, a quite creative student (level 2) satisfied fluency and flexibility aspects, and almost uncreative student (level 1) satisfied fluency aspect only. According to the results, this developed tangram-based geometry test was valid, feasible, and effective to measure junior high school students' creative thinking ability.

1. Introduction
Education is an essential element for the holistic development of the individual, society, and the nation because education takes the most part in creating the quality of Human Resources (HR) [1]. One of the subjects that must be in the education curriculum in Indonesia is Mathematics. Students are equipped with problem-solving abilities in learning mathematics, including critical, logical, and creative thinking ability. Seeing this fact, mathematics is necessary. Geometry is a branch of mathematics that studies points, lines, planes, and spaces, along with their properties, sizes, and relationships to one another.

Geometry is enjoyable and more comfortable to learn because it studies the visual patterns that can be linked to the real physical world. However, students' result in learning geometry was still unsatisfying. This was clearly shown by the results of students' scores measured by the standard used internationally. The results of TIMSS 2015 and PISA 2015 showed that The mathematics ability of Indonesian students was still at the low benchmark [2]. Students faced difficulties in solving geometry problems, especially with applying and reasoning problems of geometry. Geometry presents various problems that require individuals to think divergent that is closely related to creative thinking [3].
Creative thinking is a thinking ability that allows students to apply their imagination and remain flexible in creating new ideas, alternatives, or possibilities and seeing new relationships between existing definitions that might be needed in solving problems and challenges [4, 5].

The problems in learning geometry in schools lie in the learning method, in which teachers are less varied and ignore visual media. Visual media and physical activities help the teacher facilitate a clear and accurate explanation, attract attention, and describe facts that might be quickly forgotten if not visualized [6]. A simple aid that teachers can choose as media in learning geometry, moreover, supports the development of students' creative thinking is Tangram.

Tangram is a Chinese puzzle consisting of a square card or board cut straight into several pieces of different sizes. The Tangram parts are geometric shapes, one piece of square, five pieces of triangles, and one piece of parallelogram [7]. Tangram may boost students' interest in mathematics, empower the student to distinguish various forms, develop students' understanding of the characteristics of shapes, find the relationship between the seven pieces of Tangram, and able to explore existing tangrams with the new forms that they imagine so it can increase their creativity [8]. The use of Tangram can increase students' creativity by integrating it with the van Hiele learning phase. Van Hiele classified geometric thinking ability into five levels, visualization (level 0), analysis (level 1), informal deduction (level 2), deduction (level 3), and rigor (level 4) [9, 10]. Tangram game links to students' creative thinking ability. Playing tangram puzzles is an effective method to improve children's geometric thinking ability. Tangram provides students with empirical experiences [11]. In junior high schools, tangrams can be used in various tasks, such as finding area, axes of symmetry, and similarity of shapes, as well as proving the Pythagorean Theorem.

Encouraging students' creative thinking ability entails an instrument that embraces the fundamental aspects of creative thinking ability [12]. However, teachers still did not have sufficient test instruments. The test instrument is useful for providing stimulants to students and seeing student's achievements in fulfilling aspects of creative thinking. The test is a tool to assess in written form to record or see students' achievement in line with the assessment targets [13]. Teachers often gave tests that contained routine problems and low-level questions instead of open-ended problems. Hence, teachers did not optimize the measurement of students' creative thinking ability. Besides that, teachers still used conventional tests to see students' abilities. As a result, students were lack of motivation in solving geometric problems. Accordingly, the researcher wanted to develop a geometry test using simple, fun, and meaningful media. Students could be interested and challenged to solve the problems, and teachers could see students' creative thinking abilities. This article aimed to describe the process of developing a tangram-based geometry test package to measure students' creative thinking ability.

2. Research Method

This research design is Research and Development (R & D), which used the Thiagarajan 4-D model, and the try out research was at SMPN 1 Bondowoso for the 2020/2021 academic year. The development cycle of the tangram-based geometry test in this research was divided into four phases, (1) defining, (2) designing, (3) developing, and (4) disseminating [13, 14]. The method was chosen since it is suitable for developing evaluation components in education.

This development aimed to produce a tangram-based geometry test package is based on the aspects of creative thinking ability and was tested for validation, practicality, and effectiveness. The data obtained by conducting questionnaires, tests, and interviews. The first step was to determine the area and research subject. Furthermore, product development is processed with the 4-D stage [15].

2.1 Define

Examined the problems, student characteristics, needs, and materials to be used in development. The chosen material that relevant to this development was the Two-Dimentional figure. Students were grouped based on their geometric thinking degree utilizing test the Van Hiele Geometry Test (VHGT). Van Hiele Geometry Test comprises 25 multiple-choice questions. Every five items represent one van hiele level. Questions number 1 to 5 represents the visualization level, 6 to 10 for analysis level, 11 to
15 for informal deduction level, 16 to 20 represent deduction level, and 21 to 25 represent rigor level. Students are classified as that level if they can answer 3 to 5 questions correctly. Students cannot proceed to the next level if they cannot reach the previous level.

2.2 Design
The researcher designed the test package and produced a sample of the test package (prototype). The selected media was a tangram puzzle. The prototype was designed based on the content and material format.

2.3 Develop
The result of this stage was a draft of a test package that had been validated by the experts. Product try out was conducted to quantify the level of validity, effectiveness, and practicality of the test packages that had been developed.

2.3.1. Validation. Validation was needed to know the product feasibility. The tangram-based geometry test validation was carried out by a mathematics teacher and two lecturers of the mathematics education department.

2.3.2. Field test. Field tests were conducted to obtain direct suggestions from the education practitioner. Test legibility and limited try out were conducted on three students. The limited and field try out was conducted by using questionnaires and tests. Simultaneously, the test legibility obtained from interviews was intended to know the legibility of the product. If teachers and students used the test, the researcher would provide a user response questionnaire to determine the product's practicality.

2.3.3. Revision. The Tangram-Based Geometry Test was revised based on the result of the field try out and validation. We concluded the product feasibility as a consideration for the use of this product.

2.4 Disseminate
The tangram test package would be distributed to schools with the appropriate level that is grade VII of junior high school through Mathematics Teacher Organization for Junior High School (MGMP). This research was a pilot study for a larger-scale study.

The developed product was used to measure students' creative thinking ability through tests and interviews. Students' score becomes the primary consideration upon the effectiveness of this product. It is categorized as effective if 80% of the testing subject passed minimal completeness criteria (KKM). Creative thinking aspects involved are fluency, originality, flexibility, and elaboration [16]. There are five classifications of creative thinking abilities consisting of levels 0, 1, 2, 3, and 4, as shown in table 1. Level 4 is the highest, and level 0 is the lowest level of creative thinking. Each creative thinking level has its own characteristics to be assessed and to refer to the students' creative thinking levels. The criteria of each level can be seen in Table 1 [17].

| Creative Thinking Level | Criteria |
|-------------------------|----------|
| Level 4 (Very Creative) | Student achieves the entire aspects of creative thinking. Student can answer a problem with more than three possible solutions fluently (fluency), reveal new or unique solutions (originality), find many ways in solving a problem (flexibility), answer systematically and detail (elaboration) |
| Level 3 (Creative)      | Student achieves three or all aspects of creative thinking and finds three unique possible answers (originality) in different ways (flexible) fluently (fluency). |
Creative Thinking Level | Criteria |
--- | --- |
Level 2 (Quite Creative) | Student achieves two aspects of creative thinking and carries two possible answers flexibly and fluently. |
Level 1 (Almost Not Creative) | Student achieves one aspect of creative thinking, bring out one answer, and interpret their answer fluently (fluency). |
Level 0 (Not Creative) | Student achieves no aspects of creative thinking. Student gives no possible answers or solutions fluently. |

3. Result and Discussion

The result of this research was a tangram-based geometry test on two-dimensional figure material. This study was designed to measure students' creative thinking ability in solving two-dimensional figure problems. The discussion of the results in this study was written as follows.

3.1. Tangram Based Geometry Test

The test package produced by the geometry test consisted of question instructions, test package grids, test question packages, answer keys, scoring guidelines, assessment guidelines, analysis, and recommendations. The test questions were essay questions with open-ended problem types in Indonesian. The problems raised were related to the sub-topic of triangular and quadrilateral shapes in mathematics for grade VII of Junior High School.

The defining stage began with defining the learning needs by analyzing the objectives and limitations of the material, examining students' characteristics based on the design and development by giving the Van Hiele Geometry Test (VHGT) to determine the students' level of thinking, and identifying the primary ability to be developed.

The next stage was designing the prototype of the product (draft I). At this stage, the material, media, and format were selected. The chosen material was a two-dimensional figure using Tangram media. The test designed referred to the creative thinking aspects with open-ended questions to measure students' thinking abilities. The prototype was validated by experts to determine the validity level of the product. The validators were lecturers at the Faculty of Teacher Training and Education, University of Jember. Validation was used to determine the test package product's feasibility, which determined its suitability for the research objectives. The test package was scored 4.47 points by the validators, which were categorized as good. Thus, the product was declared valid and feasible to use. The details of the validation result are shown in Table 2.

| Table 2. Test Package Validation Results. |
| --- | --- | --- |
| Aspect | Mean | Category |
| Contents | 4.73 | Valid |
| Construct | 4.4 | Valid |
| Language | 4.3 | Valid |
| Instructions | 4.45 | Valid |

The examples of products that have been developed based on the aspects of creative thinking are shown in Figure 2 below.

3.2. Profile of Students' Creative Thinking Ability

The test package was tested on students of class VIII of SMPN 1 Bondowoso, who were selected after being given a van Hiele test package in the previous stage. The data were collected by using written tests and interviews. Then, the data were analyzed qualitatively by observing the test results and then confirming the results to the participants through an interview to confirm the validity of the data. The data obtained were then discussed extensively to conclude. Students' answers were assessed according to the assessment guidelines, then the students' scores were calculated. After getting students' scores, their level was determined with the following formula:

\[ NP = \frac{R}{SM} \times 100 \]

NP is the percentage value of the student's creative thinking ability score obtained from the student's raw score (R) in which it was then divided by the maximum score of the whole questions (SM). The scores are classified based on the interpretation of the student's creative thinking level, which is shown in the following Table 1 [17].

| NP   | Creative thinking level category |
|------|----------------------------------|
| 80 <NP ≤ 100 | Very creative                  |
| 60 <NP ≤ 80  | Creative                        |
| 40 <NP ≤ 60  | Quite Creative                  |
| 20 <NP ≤ 40  | Almost Not Creative             |
| 0<NP ≤ 20    | Not Creative                    |

The written test questions were analyzed to check the correctness of the answers and find out what aspects of the students' creative thinking emerged. The interview results were analyzed to clarify the information provided by the students on the answer sheets. The students' scores were represented in Figure 2. The data were analyzed as follows.
3.2.1. The Student of Visualization Level

The students with level 0 or visualization level were called S1. The results of the S1 field try out on the test packages were revealed as follows.

The students at this level understood the meaning of these questions well. S1 was able to bring up the fluency aspect by providing three possible series of flat shapes with two pieces of the tangram. In creating a triangle tangram, the students provided two possible answers by cutting the big triangle into two small triangles horizontally and vertically and expressing their ideas correctly. However, they have not reached the flexibility aspect yet. S1 could not combine tangrams of different sizes to form a two-dimensional figure and provide other possible cuts. The following interview excerpt showed it. (R = Researcher, V = visualization student)

R: Have you ever worked on a problem like this before?
A: Never, ma'am.
R: Can you assemble a tangram of different sizes to make it a 2D shape?
A: I have no idea if the tangram of different sizes should be combined
R: Can you make a triangular tangram with more than two pieces?
A: No, ma'am

Regarding the originality aspect, S1 did not provide a common answer well by combining six tangrams into three flat shapes even though he could not combine tangrams of different sizes and make a triangular tangram with a larger number of pieces. While in the elaboration aspect, he was not capable of describing the answers systematically. Thus, the student's percentage score at the visualization level was 34 and categorized in level 1 of the creative thinking category (almost uncreative).
3.2.2. The Student of Analysis Level

Students with level 1 or analysis level were called S2. The results of the S2 field try out on the test packages were shown in Figure 4.

![Figure 4. Students' answers with the level of analysis](image)

S2 had a clear understanding of the problem and was able to interpret his ideas. S2 gave various answers; they were four flat shapes covering triangle, trapezoid, parallelogram, and square using several pieces of the tangram. It showed that S2 met the fluency aspect. Students with analysis level established levels in three different ways, combining triangles and levels and the combination of triangles and squares. The various ways to construct a flat shape revealed that S2 achieved the flexibility aspect. Besides, students could also make tangrams by cutting horizontally and vertically on a triangular frame, with the maximum number of pieces produced were 10. The originality aspect was reached by the student about his answer to the interview session. S2 did the first answer due to something he had ever seen. Even though he had never worked on a problem given, the first answer was common from S2. The following interview with S2 showed it. (R = Researcher, A = analysis student)

R: Have you ever worked on a problem like this before?
A: No, ma’am.
R: What do you think about this test package?
A: It’s fun, it makes me easier to understand the material, and quite challenging.
R: How do you find the triangle tangram with 10 pieces?
A: I tried it myself by cutting the triangle and then adjusting the size. The first triangle was made because I have ever seen my sister’s drawing.

Students can put forward their ideas in detail, but S2 did not write down the steps to solve it systematically. However, the elaboration aspect was not successfully fulfilled since S2 did not use any systematic solutions during the test. The students with the analysis level obtained score of 59 as final scores and they were classified as level 2 or quite creative.

3.2.3. The Student of Informal Deduction Level

Students level 2 or informal deduction level referred to S3. The results of the S3 field try out on the tangram-based geometry test revealed as follows.
Figure 5. Students' answers with the level of informal deduction

The students at this level understood the questions well and were able to interpret ideas. S3 found eight tangrams in the tangram assembling problem and provided three possible alternative answers to the problem of creating a triangular tangram. The fluency aspect was achieved well, as it was shown by many types of flat shapes that he assembled, covering trapezoid, rectangle, triangle, and parallelogram. S3 was able to string all parts of the tangram into a rectangle. On the flexibility aspect, the students at the informal deduction level were able to answer problems from various points of view to achieve well. S3 assembled three trapezoids and three rectangles with a varying number of constituent pieces and different shapes. S3 met the originality aspect well; the answer he gave was unique and imaginative even though he had never gotten a similar question. It was shown by the way he cut the triangles horizontally, vertically, and diagonally which was supported by the following interview. (R = Researcher, DI = informal deduction student)

R : Have you ever worked on a problem like this before?
DI : I have never encountered a problem like this, ma'am. The test is quite challenging.
R : How do you find the 10-piece triangle tangram?
DI : I initially imagined having a cake and then cutting it up. Then I first thought about the parts that I could cut and whatever the shape was, then I imagined putting it in the triangle.

S3 was able to describe his ideas well and solve the problem in detail and systematically, but S3 did not explain how he found the sizes of each shape. Therefore, S3 achieved the elaboration aspect incompletely. S3 got the final score of 68 and they were classified as student with level 3 or creative.

Based on these results, it can be seen that the level of students' creative thinking abilities was in line with their geometric abilities. For this reason, the researcher suggests the teachers guide the students to practice solving problems more often with open problem types under the guidance of the subject teacher. Also, the teacher should use simple, fun, and creative media in measuring the students' abilities so that they would not experience a lack of motivation in solving problems. Therefore, they can develop their potentials, ideas, and enthusiasm to come up with new ideas and be more creative.
4. Conclusion
This research produced a tangram-based geometric test that was valid, practical, and effective on flat shape material. The test package was declared valid by the validator. It was feasible to measure the creative thinking ability of junior high school students on two-dimensional figure material. The field try out on junior high school students showed that the student with visualization level reached the fluency aspect so that they were classified into Creative Thinking Level 1 or less creative. The students under the Analysis level tended to bring up fluency and flexibility. They were categorized into the students with Creative Thinking Level 2 or quite creative, even though they had no elaboration and originality aspects. The students at the informal deduction level almost reached all aspects of creative thinking, and it made them classified as the students with level 3 or creative.

Acknowledgement
We give our best gratitude to all parties who supported this research. We also thank the Faculty of Teacher Training and Education at the University of Jember and SMPN 1 Bondowoso.

References
[1] Bhardwaj A 2016 Importance of Education in Human Life: a Holistic Approach Int. J. Sci. Conscious. 2 23–8
[2] Rezky R and Wijaya A 2018 Designing hypothetical learning trajectory based on van hiele theory: A case of geometry J. Phys. Conf. Ser. 1097
[3] Bacanli H, Dombayci M A, Demir M and Tarhan S 2011 Quadruple thinking: Creative thinking Procedia - Soc. Behav. Sci. 12 536–44
[4] Im H, Hokanson B and Johnson K K P 2015 Teaching Creative Thinking Ability: A Longitudinal Study Cloth. Text. Res. J. 33 129–42
[5] Ritter S M and Mostert N 2017 Enhancement of Creative Thinking Ability Using a Cognitive-Based Creativity Training J. Cogn. Enhanc. 1 243–53
[6] Alshatri S H H, Wakil K, Jamal K and Bakhtyar R 2019 Teaching Aids Effectiveness in Learning Mathematics Int. J. Educ. Res. Rev. 448–53
[7] Hu Z, Lam K F and Yuan Z 2019 Effective Connectivity of the Fronto-Parietal Network during the Tangram Task in a Natural Environment Neuroscience 422 202–11
[8] Siew N M and Chong C L 2014 Fostering Students’ Creativity through Van Hiele’s 5 phase-Based Tangram Activities J. Educ. Learn. 3
[9] Yi M, Flores R and Wang J 2020 Examining the influence of van Hiele theory-based instructional activities on elementary preservice teachers’ geometry knowledge for teaching 2-D shapes Teach. Teach. Educ. 91 103038
[10] Nisawa Y 2018 Applying van Hiele’s Levels to Basic Research on the Difficulty Factors behind Understanding Functions Int. Electron. J. Math. Educ. 13 61–5
[11] Nugraheni J, Irawan R, Priyatama A N, Fitriani A, Studi P, Universitas P and Maret S 2020 Permainan Tangram Terhadap Berfikir Kreatif Pada Siswa Sekolah Dasar J. Interv. Psikol.12 37–50
[12] Dwi Wiwik Ernawati M, Damris M, Asrial and Muhaimin 2019 Development of creative thinking ability instruments for chemistry student teachers in Indonesia Int. J. online Biomed. Eng. 15 21–30
[13] Muhajir S N, Utari S and Suwarma I R 2019 How to develop test for measure critical and creative thinking ability of the 21st century ability in POPBL? J. Phys. Conf. Ser. 1157
[14] Hidayat T, Susilaningsih E and Kurniawan C 2018 The effectiveness of enrichment test instruments design to measure students’ creative thinking ability and problem-solving Think. Ski. Creat. 29 161–9
[15] Permana A H, Muliyati D, Bakri F, Dewi B P and Ambarwulan D 2019 The development of an electricity book based on augmented reality technologies J. Phys. Conf. Ser. 1157
[16] Sitorus J and Masrayati 2016 Students’ creative thinking process stages: Implementation of
realistic mathematics education *Think. Ski. Creat.* 22 111–20

[17] Utami S, Usodo B and Pramudya I 2019 Level of Students’ Creative Thinking in Solid Geometry *J. Phys. Conf. Ser.* 1227