4.2 The Geometric Creativity Test

Since the purpose of the study is to develop the geometric creativity of the mathematically gifted students using the suggested enrichment program, the present researcher has to design a tool, a geometric creativity test, to assess the geometric creativity of the mathematically gifted students before and after administering the suggested enrichment program. In designing the geometric creativity test, the present researcher passes through the following steps:

4.2.1 Specifying the Aim of the Test

The aim of the geometric creativity test is to assess the geometric creativity of the mathematically gifted students in terms of creativity components before and after administering the suggested enrichment program.

4.2.2 Specifying the Creativity Components that the Test Measures

By reviewing literature and prior studies[17] related to the subject of creativity and geometric creativity, the present researcher was able to determine the geometric creativity components[18] that the test measures as follows:

1. Fluency: the student's ability to pose or come up with many geometric ideas or configurations related to a geometric problem or situation in a short time.
2. Flexibility: the student's ability to vary the approach or suggest a variety of different methods toward a geometric problem or situation.
3. Originality/Novelty: the student's ability to try novel or unusual approaches toward a geometric problem or situation.
4. Elaboration: the student's ability to redefine a single geometric problem or situation to create others, which are not the geometric problem, situation itself, or even its solutions but rather the careful thinking upon the particular aspects that govern the geometric problem or situation changing, one or more of these aspects by substituting, combining, adapting, altering, expanding, eliminating, rearranging, or reversing and then speculating on how this single change would have a ripple effect on other aspects of the problem or the situation at hand.

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[17] See El-Rayashy & Ibrahim Al-Baz Mohamed 2000; Haylock 1997; Ibrahim Al-Baz Mohamed 1999; Mann 2005; Mohamed 2003, Park 2004 …….you can add in shaa Allah some references for literature, too. Not only studies

[18] For more details about creativity components see chapter 2: Review of literature, part 3.

4.2.3 Preliminary Form of the Test

This step includes identifying test specifications, items type, writing items, and writing directions of the test.

For the test specification, table 2 shows the geometric creativity components of the test, the items that measure each component, the number of items corresponding to each component, and the percentage of each component.

Table 2
Specifications table of the geometric creativity test

Components of the geometric creativity	Items	Number of items	Percentage
Fluency	1, 2, 3, 4	(4 items)	33%
Flexibility	5,6,9	(3 items)	25%
Originality/Novelty	7,8,12	(3 items)	25%
Elaboration	10,11	(2 items)	17%
Overall Geometric creativity test		(12 items)	100%

Concerning the items type in the test, The GCT includes open-ended, and non-routine geometric situations and problems that require producing many various and different responses. In designing these situations and problems the researcher took into consideration some criteria for a task to be effective in revealing geometric creativity and in distinguishing between students in a particular population in terms of the creativity of their responses: (1) The students' responses should show a wide range of geometric and mathematical ideas. (2) A large number of appropriate responses are possible for these students. (3) The students' responses should show a consistent interpretation of the instruction in the task. (4) There should be several clear responses that can be obtained by most students. (5) There should be a number of appropriate responses that are obtained by relatively few students. (6) These original responses should have a degree of face validity for indicating creative ability in geometry and they should not be geometrically trivial (Haylock, 1997, p. 72).

Regarding the writing items of the test, they are written in verbal and nonverbal ways and a vision of the expected responses for each item of the test is put into account.

The GCT, in its preliminary form, consists of 12 items that are distributed among the four components of geometric creativity: fluency, flexibility, originality, and elaboration. Items 1, 2, 3, and 4 are designed to assess students' geometric fluency. Items 5, 6, and 9 are designed to allow students to come up with not only many ideas but also many categories of ideas in order to assess their geometric flexibility. Items 7, 8, and 12 are designed to allow students to show unusual and unique ways of solutions to find out how original/novel

geometric ideas they have. Items 10 and 11 are designed to assess students' geometric creativity in elaborating a geometric problem or situation.

Even though each item is intentionally designed to assess only one component of geometric creativity, it will be used to assess other components as well. To explain how each item can be used to assess different components of geometric creativity, for example, suppose that a student responds to item 1 – that requires writing down as many geometric concepts and terminology as possible that start with letter p – by the responses: parallel, parallelogram, perpendicular, polyeder, pyramid, point, and point of symmetry. In this example, as the student comes up with 7 relevant responses, his/her fluency score on this item will be 7 points and as the responses can be classified into three different categories according to different domains of geometry: Euclidean geometry, space geometry, and transformational geometry, which reflects the students' ability to vary his/her approach and break from mental sets to come up with not only different responses but also varied ones, therefore his flexibility score on this item will be 3 points. Similarly, the student's originality score can be assessed on this item, as is the statistical infrequency of responses in relation to peer group responses. Table 3 shows the test items, the four components of geometric creativity and which components can be assessed with each item. Noting that:

× Indicates that the item is intentionally designed to assess this component.

* Indicates that the item will be used to assess this component and it is not intentionally designed to assess it.

Table 3
Test items and geometric creativity components

	Fluency	Flexibility	Originality	Elaboration
Item 1	×	*	*	
Item 2	×	*	*	
Item 3	×	*	*	
Item 4	×	*	*	
Item 5	*	×	*	*
Item 6	*	×	*	*
Item 7	*	*	×	
Item 8	*	*	×	
Item 9	*	×	*	
Item 10	*	*	*	×
Item 11	*	*	*	×
Item 12	*	*	×	

As for the writing directions of the test, simple directions are written for the students, including some instructions that stimulate students' creative thinking. Instructions to inform students of the time allowed for the test and how to answer the test items are also included. The directions also indicate that the answer to each item is not restricted.

4.2.4 Grading Method of the Test

Reviewing literature and prior studies[19] related to the subject of creativity in general, and mathematical and geometric creativity in particular, the researcher identified a grading method for the test. Through this method, each student should have 4 scores for fluency, flexibility, originality, and elaboration for each item of the test as well as the overall score of geometric creativity, as follow:

Fluency: The number of relevant responses. Each relevant response is given one point.

Flexibility: The number of different categories of relevant responses: answers, methods, or questions. Each flexibility category is given one point.

Originality/Novelty: It is the statistical infrequency of responses in relation to peer group. The more statistical infrequency the response has, the more originality it manifests. Each response is given zero, one, two, three or four points according to the following table:

Table 4
Grading originality points for the geometric creativity test

The number of students who registered the response	1 Student	2 Student	3 Student	4 Student	5 Student
Originality mark	4	3	2	1	0

Elaboration: It is graded by the number of follow-up questions or problems that are posed by redefining – substituting, combining, adapting, altering, expanding, eliminating, rearranging, or reversing – one or more aspects of the given geometric problem or situation. Each correct response is given one point.

Overall Geometric Creativity:

It is the sum of fluency, flexibility, originality, and elaboration scores that represents the creativity thinking ability in geometry.

[19] El-Rayashy & Ibrahim Al-Baz Mohamed 2000; Haylock 1997; Ibrahim Al-Baz Mohamed 1999; Mann 2005; Mohamed 2003, Park 2004

4.2.5 Content Validity of the Test

For validating the GCT, the researcher presented it, in its preliminary form, to a group of judges[20] specialized in teaching and learning mathematics in China, Egypt, and Germany. These judges reviewed the items, in their initial form, for clarity, readability, and appropriateness to measure what it is designed to measure and the level of mathematically gifted students in the high schools[21]. Most changes suggested by the judges had to do with rhetorical and sequencing considerations. For one thing, upon the judges' request for the readability of the test items, the researcher used different fonts and font styles within the test items so that students could easily distinguish between the items statement and the items directions as well as quickly recognize the items tasks. The judges also found that the question example given in item 3 is too complicated and it should be split into two questions. The question example was "Is it a plane figure such as rectangle or a solid figure such as a sphere?" Thus, it was changed to: "Is it a plane figure such as rectangle? Is it a solid figure such as a sphere?" For the same item, the judges recommended adding one more question, which is not Yes/No question. So, the researcher added one more question, which is "Does it have vertices?", "How many?" For item 9, the judges suggested changing the given example, which was "$\triangle$AEF and $\triangle$BDC is a pair of equivalent triangles" as it would restrict the students' thinking, causing them to only think about equivalent figures in terms of triangles. Accordingly, the researcher changed it to: "Triangle BCE and parallelogram ABDE is a pair of equivalent figures". Finally, and more importantly, in items 5, 6, 7, 8, 9, 10, and 11 the judges were afraid that the mathematical symbols used in these items might not be recognized by the students in German schools as they use another system of symbols. For example: German students would not recognize $\overrightarrow{AM}$ as a ray, rather it would be recognized as a vector. So the researcher was directed to use the same symbols used in German schools as shown in the German version[22]. The test, in its final form, is presented in Appendix G.

4.2.6 The Piloting of the Test

The researcher attempted a test piloting aiming at calculating: (1) the reliability coefficient for the test, (2) item-internal consistency reliability for the test items, (3) experimental validity for the test, and (4) the suitable time-range for the test. In this respect, the GCT was translated into German and administered to a sample of (30) students, 15 male and 15 female, in the university of education in Schwaebisch Gmuend at the end of the summer semester of the academic

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[20] A list of judges who validated the geometric creativity test is presented in Appendix F.

[21] A letter to judges used for validating the items of the geometric creativity test is presented in Appendix E.

[22] The German version of the geometric creativity test is presented in Appendix I.

year 2008. Students' responses on the test were analyzed to calculate the scores of the geometric creativity components for each student.

(1) The reliability coefficient

The reliability coefficient (Cronbach's α (alpha)) for all test items as they measure geometric creativity was calculated using SPSS16. It was 0.83, a high reliability coefficient. Consequently, the GCT prepared by the researcher was proven reliable to measure the geometric creativity ability as a whole.

(2) Item-internal consistency reliability

As for the item-internal consistency reliability, (Cronbach's α (alpha)) is calculated for each of the geometric creativity component scores (i.e. fluency, flexibility, originality, and elaboration) as subscales of the test, as follows:

For the fluency as a component of geometric creativity and a subscale of the geometric creativity test, the reliability coefficient (Cronbach's α (alpha)) was calculated for the fluency scores of the 12 items of the test and it was 0.62. To improve the reliability coefficient of the fluency component as a subscale of the test, SPSS suggests that if items 9 and 11 are deleted it might result in a better reliability coefficient for the fluency. Deleting items 9 and 11 from the statistical analysis of the test items gives a reliability coefficient that equals 0.72, which is a good reliability coefficient. Consequently, measuring the fluency component of geometric creativity using items 1, 2, 3, 4, 5, 6, 7, 8, 10, and 12 of the prepared test is reliable.

Regarding the flexibility as a component of geometric creativity and a subscale of the test, the reliability coefficient (Cronbach's α (alpha)) was calculated for the flexibility scores of the 12 items of the test and it was 0.55. To improve the reliability coefficient of the flexibility component as a subscale of the test, SPSS also suggests that if item 9 and 11 are deleted it might result in a better reliability coefficient for the flexibility. Deleting items 9 and 11 from the statistical analysis of the test items gives a reliability coefficient that equals 0.64, which is an accepted reliability coefficient for flexibility as a subscale of the test. Consequently, measuring the flexibility component of geometric creativity using items 1, 2, 3, 4, 5, 6, 7, 8, 10, and 12 of the prepared test is reliable.

As for the originality as a component of geometric creativity and a subscale of the test, the reliability coefficient (Cronbach's α (alpha)) was calculated for the originality scores of the 12 items of the test and it was 0.59. To improve the reliability coefficient of the originality component as a subscale of the test, SPSS also suggests that if item 11 is deleted it might result in a better reliability coefficient for the originality. Deleting item 11 from the statistical analysis of the test items gives a reliability coefficient that equals 0.60, which is an accepted reliability coefficient for originality as a subscale of the test.

Consequently measuring the originality component of geometric creativity using items 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, and 12 of the prepared test is reliable.

Regarding the elaboration component of the test, the reliability coefficient (Cronbach's α (alpha)) was calculated for the elaboration scores of items 5, 6, 10, and 11 that include the elaboration component and it was 0.41. To improve the reliability coefficient of the elaboration component as a subscale of the test, SPSS also suggests that if item 11 is deleted it might result in a better reliability coefficient for the elaboration. Deleting item 11 from the statistical analysis of the test items gives a reliability coefficient (Cronbach's α (alpha)) for elaboration component that equals 0.51, which is a low reliability coefficient for the elaboration as a subscale of the test. Consequently measuring elaboration component of geometric creativity using items 5, 6, and 10 of the prepared test is not reliable.

After deleting items[23] 9 and 11 from the statistical analysis of the test, the statistical attributes (mean, standard deviation, and Cronbach's α (alpha)) of the overall geometric creativity test and its subscales (fluency, flexibility, originality, and elaboration) were calculated as shown in table 5. The table shows that the subjects of the pilot test had a mean of 120.50 (SD = 42.08) and the reliability coefficient (Cronbach's α (alpha)) for the geometric creativity test as a whole scale is 0.85 (high reliability coefficient) which means that the prepared geometric creativity test after deleting the two items is still reliable to measure the geometric creativity as a whole ability.

Table 5
Statistics attributes of the pilot study of the geometric creativity test

Components of the geometric creativity	M	SD	Cronbach's α (alpha)
Fluency	39.67	11.76	0.72
Flexibility	23.77	5.94	0.64
Originality	44.53	21.83	0.60
Elaboration	12.53	4.92	0.51
Overall Geometric creativity test	120.50	42.08	0.85

Regarding the geometric creativity component, fluency, the subjects had a mean of 39.67 (SD = 11.76) and the reliability coefficient (Cronbach's α (alpha)) was 0.72 (good reliability coefficient) that means that after deleting the two items, the prepared test is suitable for measuring the fluency component of geometric creativity.

[23] An explanation for why item 9 and 11 do not go with the other test items is that item 9 contains concepts about the area of triangle and parallelogram, which are heavily stressed during different levels of students' learning in primary school, high school, and even in their preparation in the university. As for item 11 it was difficult for the subjects since 13 out of 30 gave wrong or no response to this item.

As for the second geometric creativity component, flexibility, the subjects had a mean of 23.77 (SD = 5.94) and the reliability coefficient (Cronbach's α (alpha)) was 0.64 (accepted reliability coefficient), which means that after deleting the two items, the prepared test is suitable for measuring the flexibility component of geometric creativity.

Regarding the originality component, the subjects had a mean of 44.53 (SD = 21.83) and the reliability coefficient (Cronbach's α (alpha)) was 0.60 (accepted reliability coefficient), which means that after deleting the two items, the prepared test is suitable for measuring the originality component of geometric creativity.

Concerning the elaboration component, the subjects had a mean of 12.53 (SD = 4.92) and the reliability coefficient (Cronbach's α (alpha)) was 0.51 (low reliability coefficient). One interpretation for low consistency of elaboration component would be because the elaboration component of geometric creativity has many subscales (aspects) to measure, which have a negative effect on the consistency of the component items. Even though the reliability coefficient for the elaboration component was low, the researcher believes that the elaboration construction is an important component of geometric creativity and during the intervention; the researcher will measure it using the prepared test. This finding evokes the need for further studies with bigger sample size of students to get better a reliability coefficient for the prepared test and its subscales as well.

(3) The experimental validity

The experimental validity of the test was calculated as the square root of the test reliability coefficient. It was calculated before deleting items 9 and 11 as 0.913 and after deleting items 9 and 11 it was 0.922 and that shows that the geometric creativity test has a high experimental validity.

(4) The suitable time-range

The time each student took to finish the test was calculated. Table 6 shows the statistical attributes of the time taken by the students in the pilot test. The subjects had a mean 94 (SD = 17.16), median = 90, mode = 85.

Table 6
Statistical attributes of the test time in the pilot testing

Mean	Median	Mode	SD	Minimum	Maximum
94	90	85	17.16	60	145

To determine the suitable time-range for the test, the researcher calculated the time each student tested took then calculated the mean of the time the first

student took (60 minutes) and the last one took (143 minutes), so the suitable time of the test was calculated as 100 minutes.

The suitable time of the test = $\frac{60+145}{2}$ = 102.5 minutes.