

## A COMPREHENSIVE TOOL FOR ASSESSING CREATIVE THINKING IN MATHEMATICS EDUCATION

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### Abstract

In education, creativity is viewed as a fundamental behaviour especially when it comes to mathematics where students are motivated to tackle problems in unique ways. The present study sought to design, construct and validate an instrument that would assess creativity in geometry by employing three aspects of creativity as proposed by the aforementioned model-fluency, flexibility and originality. The instrument was administered to 30 junior high school students in Malang Indonesia. In this study, the assessment of internal and external consistent validity and dimensional structure of the instrument using a combination of Cronbach's Alpha, Exploratory Factor Analysis (EFA), and inter-rater reliability was done. The reliability estimates showed that across the 7-item test, a validation score of Cronbach's Alpha at 0.857 was achieved. Item-Total Statistics indicated that most items possessed high item-total correlations except item Q3 which possessed low item-total corrected correlation. EFA resulted in the segregation of 2 components, which accounted for 81.280% of the variance of the construct and were labeled as fluency/flexibility and originality. This finding is consistent with already existing theories in creativity areas which argue that creative thinking is a multi-faceted phenomenon. This needs elucidation in order to improve the validity of the affected test items especially those aimed at measuring the different dimensions of creativity. The research enriches the existing literature based on creativity in mathematics education, considering the primary aim to develop a sound and valid tool for assessing students' creative problem-solving abilities in geometry.

**Keywords:** Creative thinking; geometry education, fluency; flexibility; originality; exploratory factor analysis.

### Abstrak

Dalam pendidikan, kreativitas dianggap sebagai perilaku fundamental, terutama dalam matematika di mana siswa didorong untuk menghadapi masalah dengan cara yang unik. Penelitian ini bertujuan untuk merancang, membangun, dan memvalidasi instrumen yang akan mengukur kreativitas dalam geometri dengan menggunakan tiga aspek kreativitas yang diusulkan oleh model sebelumnya, yaitu kelancaran (fluency), fleksibilitas, dan orisinalitas. Instrumen ini diujikan kepada 30 siswa sekolah menengah pertama di Malang, Indonesia. Dalam penelitian ini, penilaian validitas konsisten internal dan eksternal serta struktur dimensi instrumen dilakukan dengan menggunakan kombinasi Cronbach's Alpha, Analisis Faktor Eksploratori (EFA), dan uji reliabilitas antar-penilai (inter-rater reliability). Estimasi reliabilitas menunjukkan bahwa pada tes 7-item, skor validasi Cronbach's Alpha sebesar 0,857 tercapai. Statistik Item-Total menunjukkan bahwa sebagian besar item memiliki korelasi item-total yang tinggi kecuali item Q3 yang menunjukkan korelasi terkoreksi item-total yang rendah. EFA menghasilkan segregasi dua komponen yang menjelaskan 81,280% varians dari konstruk dan diberi label sebagai kelancaran/fleksibilitas dan orisinalitas. Temuan ini konsisten dengan teori yang sudah ada di bidang kreativitas yang berpendapat bahwa berpikir kreatif adalah fenomena multi-aspek. Klarifikasi lebih lanjut diperlukan untuk meningkatkan validitas item tes yang terpengaruh, terutama yang bertujuan untuk mengukur dimensi kreativitas yang berbeda. Penelitian ini memperkaya literatur yang ada tentang kreativitas dalam pendidikan matematika dengan tujuan utama untuk mengembangkan alat yang valid dan dapat diandalkan untuk menilai kemampuan pemecahan masalah kreatif siswa dalam geometri.

**Kata kunci:** Berpikir kreatif; pendidikan geometri; kelancaran; fleksibilitas; orisinalitas; analisis faktor eksplorasi.



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## INTRODUCTION

Education emphasizes on whole brain development, a fact which has made it necessary to pay attention on the skills development of creativity, especially in learning problem solving skills and in promoting innovation of learners (Aytekin & Topcu, 2024; Handayani, Sa'Dijah, Sisworo, Sa'Diyah, & Anwar, 2020; Khalil, Tairab, Qablan, Alarabi, & Mansour, 2023; Purnomo, et al., 2023). It is important to note that creative thinking, more than ever before, is being regarded as a necessary skill in the 21<sup>st</sup> century because society is always looking for new solutions to problems that are unique, complex and challenging. As defined in the Guilford (1967) seminal work, creative thinking incorporates a series of components such as fluidity, adaptability and novel idea generation, which in most cases operate in aspects of problem-solving prowess and hence determining the need for such in any object or situation. With this as an initial point of consideration, many changes have occurred in the research into education practices at this time, especially regarding improving the measurement of the psychology of creativity in relation to certain academic processes, for example, mathematically (Gao, Li, Shen, & Sun, 2020; Joklitschke, Rott, & Schindler, 2022).

Mathematics in particular, and geometry in detail, provides an interesting object to study the concept of creativity. When solving geometric problems, students are expected to go beyond using the appropriate theorems and procedures and find different ways of approaching the problems, seeking a variety of solutions from constructing different viewpoints.

It has been shown that the inclusion of creative elements in the process of mathematics education improves the students' interest and understanding of mathematics concepts (Leikin & Lev, 2013). On the contrary, such orientation is very important; creativity in mathematics education has not been greatly stressed up until now with most emphasis being placed on facts or procedures rather than on creativity (Kandemir, Tezci, Shelley, & Demirli, 2019; Levav-Waynberg & Leikin, 2012).

Therefore, one of the purports of the present research was the creation and validation of an instrument which measures creativity in geometry education. Such content was developed within the frameworks of Guilford (1967) and Torrance (1974). on how all creative thinking may be divided into three components: fluency, flexibility, and originality. Fluency is the ability to produce a large number of ideas and alternative solutions, flexibility is the ability to change perspective or approach and originality is the ability to think outside the box. In doing so, they understand the concepts much more fully, and are stimulated to find different ways to solve the given task.

It is also important to note that the conceptual framework of this dissertation has adopted the notion that creative thinking is not a unitary construct rather a number of dimensions. Guilford (1967) structure of intellect model on the other hand, explains that creativity is multi- faceted and its dimensions that interrelate with each other, whereas. In these frameworks about creative cognition such as Torrance (1974)) emphasized more the importance of fluency, flexibility and originality as essentials of creativity. In such cases, these

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attributes are often referred to when examining the range of student divergent, rather than convergent thinking, often called standard problem solving. The ability to solve open-ended problems also highlights the creative processes in solving mathematical tasks whereby students are able to think broadly and come up with numerous solutions to a given problem (Razumnikova, 2012; Runco, 2022).

Creativity in this case can also be evaluated by proposing several methods of solving the same geometrical problem, changing the positions of shapes and figures without rules and finding pictures that do not follow common pictures. Leikin (2009) conducted studies which show that not only does creativity in mathematics promote better students' problem solving but also better conceptual realization of mathematics. Suggested studies underscore the critical need for the development of assessment capabilities in mathematics teaching and learning, especially with respect to assessing creativity which is known to be multi-dimensional.

Nonetheless, the main reason that drives this present investigation is the quest of creating an effective and comprehensive measureable assessment of the three aspects of creativity in the domain of geometry education, that is, fluency, flexibility, and originality.

Previous work points to the absence of appropriate instruments for assessing mathematical creativity notwithstanding increased efforts to promote it as an avenue of uplifting the depth of learning (Runco, 2014). The previous studies have concentrated on creative education assessment in its wider scope usually resorting into measuring activities which do not provide the full picture for the context

of mathematical problem solving. For example, Cropley (2006) pointed out that it is necessary to mention that the measurements of creativity should have the context; otherwise they are of little use as creativity varies in the contexts. Plucker, Beghetto, and Dow (2004) detail that in mathematics, creativity is exercised through problem solving in which students are supposed to search for several ways to arrive at conclusions, look across the various ways, and create new processes which are different from conventional ones. Considering these gaps in the literature and the all-important need to create better creativity assessment instruments in mathematics, this work sought to bridge this gap by constructing an instrument which focuses on the creative ideation process in two dimensional geometrical shapes.

The tool was designed to enable measuring total fluency, flexibility, and originality of communication in students in the course of their geometry problem-solving and its modification through students' techniques in handling geometric issues. The reliability and validity of the instrument were evaluated via sophisticated statistics – Kronbach's Alpha internal consistency, exploratory factor analysis (EFA) for structural dimensionality, inter-rater reliability (Field, 2017).

The following research questions led this study: (1) What is the reliability of the creative thinking instrument aimed at measuring the three dimensions of fluency, flexibility, and originality in a geometry problem-solving situation? (2) What is the factor structure of the instrument and how does it address the multi-dimensional nature of creative thinking? And (3) How do the test items fit the theoretical models of the constructs of fluency,

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flexibility, and originality, and what modifications should be made to the instrument to enhance its validity and reliability?

The growth of this creative thinking instrument greatly impacts on instructional and pedagogical concern in the field of mathematics education research. In relation to geometry, this document adds to the literature seeking to provide tools that measure students' imaginative abilities by focusing on practical issues of STEM education.

In terms of development, this instrument can be employed by teachers to help and measure creativity in their students, which is very vital in the current economy in as far as critical thinking is concerned.

Furthermore, this research raises a few issues regarding the question of what is expected criteria for assessing the creative potential within the practice of teaching mathematics. This study shows that once defined it is possible to structure and assess components of creative thought, which can impact the process of learning among students.

Thus, the purpose of this study was to design and evaluate the suitable measure of creativity in geometry (supervisor gauge) necessarily applicable to fluency, flexibility and originality. Considering development of new creative products, and work in mostly directive documents in design education cum science, this research makes the first step in emphasizing the importance of creativity within the teaching of mathematics. The result of this study and discussion will enhance the development and refinement of creative thinking assessment instruments once deployed as tools for educators and scholars.

## **METHODS**

The research followed a quantitative descriptive design aimed at assessing the creative thinking skills of students in geometry. The primary objective was to evaluate how effectively the creative thinking instrument measured the three core dimensions of creative thinking: fluency, flexibility, and originality. The study also tested the instrument's reliability, validity, and factor structure using statistical analyses such as inter-rater reliability testing, Cronbach's Alpha, and Exploratory Factor Analysis (EFA).

This research was carried out among 30 7th and 8th-grade students of one of the Malang State Schools. The selection of the participants was done using purposive sampling by ensuring that the students were a bit more comfortable to geometry basics, since it was important that ensures students' success in carrying out the creative thinking tasks. Such requirements demanded that students had taken for at least one semester geometry subject so that the students would be able to provide with relevant suggestion on the hearing test items. There was no coercion in the participation of each student to ensure compliance with the ethical norm of obtaining voluntary consent. Informed consent from the students' guardians and permission from the school administration were obtained before the onset of the study.

The creativity assessment within this Study above includes the use of a tool analysing geometric creativity among students through test items which are seven in number and are all open ended. The process of constructing the test items was guided by an analysis of available literature relevant to geometric education and creative

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thinking. The creation of the items was guided more by important theoretical models such as Guilford's (1967) model of creativity and Torrance's (1974) model of creative thinking in education, and other more current models in the scope.

The items came after the review of relevant literature that summarized strategies for promoting creative thinking, well children's creation of ideas, changing views in solving the problems provided, and what uniqueness they show in their answer. Studies such as those by Plucker et al (2004) and Runco (2014) informed the development of the instrument's measured categories because it has been well documented that creativity in education comprises of the several content areas documented in these studies.

The content was built around three core areas of the instrument which encompassed the abilities of the learners to generate many ideas fluency, flexibility of concepts and originality. Building on that framework, Guilford (1967) and Torrance (1974) have placed certain dimensions in creative thought at school. Such dimensions have been consistently acknowledged as an essential component of creative thinking in educational research.

The definition of fluency refers to the ability to produce a large number of ideas or solutions, flexibility concerns the ability to change points of view, and originality evaluates the novelty or creativity of ideas generated in problem solving.

Every single test item made sure that it would measure one or more factors associated with measuring fluency, flexibility, and originality in creative thinking. Fluency-focused tasks typically placed students in situations

requiring them to solve a geometry problem in multiple ways (for instance, find all possible methods of calculating, given many different methods of calculating the area of a quadrilateral). Flexibility-focused tasks were the ones in which students had to use various strategies for the same problem (for example, students would move shapes around to make a figure that was different than the one given to them). Originality-focused tasks were those, which required students to solve the problems in ways, which were non-obvious or out of the box (e.g., students would bend, twist, and combine triangles, rectangles, and other shapes to form new designs).

In tandem with this performance task, a comprehensive rubric was developed to evaluate student responses quantitatively and qualitatively based on the three dimensions of fluency, flexibility, and originality. The rationale for each dimension of the rubric was drawn largely from instruments available in the literature, particularly Cropley (2006) on creativity scoring in educational tasks.

Four levels were proposed also in the rubric meaning in strategy invention: (1) Fluency: Number of effective solutions provided, (2) Flexibility: Range of different approaches employed, (3) Originality: How original is each of the solutions when compared with what educators usually encounter in their practice.

In order to achieve the content validity of tests and rubrics, the test items and rubrics were also reviewed by people with specialist knowledge in mathematics education and creativity research. Also, refinement of the items was necessary in order to incorporate expert opinions on the meaning of the items and also to ensure that each item

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effectively assessed the specific aspect of creative thinking that it was designed for. According to this step, those guidelines are derived from the work of Creswell (2018) on development and validation of educational assessment tools.

The start of this research start is the creative thinking test was given to students in a one BY one ‘in the class sitting- hour’ classroom condition. Here, students were asked to be creative, extending their creativity beyond the most conventional solutions appliances carving geometry problems. Each student received individually a printed test with 7 open-ended items and use the appropriate materials required to finish the assignment.

Two rounds of scoring were undertaken after the presence of students recording the written responses during the above experiment in order to examine the reliability of the practice. In the first, a research team member who had been familiarized with the rubric assigned creative thinking scores... In the first round, the first rater did not fail in following through on the instructions given in the rubric. They were scored in the second round by an independent external rater in order to enhance the inter-rater reliability of the test. The external rater was trained in rubric use through several practice and review sessions with the research team for the full understanding of the criteria for all dimensions. This second round was necessary to perform reliability tests on the first rater's scores which had been termed inter-rater reliability and this was calculated using Cohen's Kappa to verify the consensus.

A variety of statistical tools were employed in order to examine the data on scoring processes. Initially, reliability analysis was performed by

means of determining internal consistency of the instrument using Cronbach's Alpha – 0.857: High reliability was in evidence. Inter-rater reliability was also examined and assessed by Cohen's Kappa to attain a higher agreement among the independent raters. After that, Exploratory Factor Analysis (EFA) was carried out to identify the dimensions of creative thinking that were measured with the test in particular investigating whether the instrument assessed fluency, flexibility, originality and so on. Data was deemed adequate for factor analysis based on the Kaiser-Meyer-Olkin (KMO) which was higher than 0.7 and Bartlett's test of Sphericity which was significant ( $p < 0.001$ ). Then factors were extracted and item loadings assessed using Principal Component Analysis (PCA) with Varimax rotation. Also, the extent of each item's variance accounted for by the factors was measured using communalities, with items having communalities greater than 0.5 identified as well fitting. In the end, the parameters of unfitted factors were calculated aiming to account for 60% of the variance of the extracted factors as this general normative rule is usually achieved in social studies.

Ethical framework and research ethics: The above mentioned methodological procedures were carried out in accordance with ethical norms proposed by Creswell and Creswell (2018). Child assent was taken from each student's parent before the study commenced, and it was made clear to students that they could choose whether or not to participate in the study.

Authors guaranteed that all student responses were kept anonymous during the grading and analysis processes to protect confidentiality.

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The design of the present study was done in a way that focuses on measuring the creative ability of junior high school students in geometry. The preparation of the test items was based on the pertinent literature that encompasses creativity and education in geometry, so it was guaranteed that the items related to important aspects of creativity such as fluency, flexibility, and originality. Scoring of the data obtained was systematic where inter rater reliability was used in explaining the issues raised thereby increasing the objectivity and reliability of the results. The statistical tests conducted which included factor analysis and reliability testing ascertained the validity and internal consistency of the instrument used to be high.

## RESULTS AND DISCUSSION

The assessment done using the creative thinking instrument also provided a clearer picture of the reliability validity and the factor analysis done on the creativity instrument. This conclusion is drawn from data that includes among other parameters, Cronbach's Alpha, Item-Total statistics, Communalities, Total Variance Explained, and Component Score Coefficient Matrix. These types of analyses assist in confirming the reliability, validity, and dimensionality of the scale measure in regression analysis within the scope of this investigation.

The reliability of the instrument was evaluated using the Cronbach's alpha coefficient, which was 0.857 for the 7 items classified in Table 1. As noted by George and Mallery (2016), any alpha value greater than 0.7 is considered acceptable for most cases and in this case, the use of the instrument is justifiable as it indicates

good ability to consistently measure the concepts. The alpha value of 0.857 indicates that the items were very reliable in the assessment of creativity thinking abilities.

Table 1. Reliability Statistics

Cronbach's Alpha	N of Items
.857	7

A careful twenty-four evaluation of the item-total statistics, see Table 2. A transfer statement and an articulation of translation can be helpful. A thorough understanding of these psycho – educational response items may bring insights in explaining why several items were retained to perform to an aggregate. For instance, Q1 is associated with a correctly computed item total correlation of 0.876 meaning quite a lot towards the measurement device reliability. On the contrary, neglecting this item would bring down Cronbach's alpha to 0.820, a point which also justifies the reason for including this item. In the same vein, with item-total correlations of 0.838 and 0.832, respectively, Q2 and Q5 form part of the instruments and demonstrate how reliable the instruments are. It could be said with a degree of certainty that these items are within the tool and solidify its internal consistence.

While other items yield higher corrected item-total-correlations than Q3, Q3 yields the lowest value (0.300). If Q3 was deleted, alpha would go to .871 being some justification that this item then seems not to contribute positively towards the construct involved thus it is advocated for a modification or even deleting it in order to make the measuring instrument more reliable. These results are comparable with the findings made by those of Hair et al.(2014) where low item-total

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correlation items are said to be removed for better concentration of the scale and enhance the internal consistency of the measurement tools.

The validity of the instrument was further evaluated through factor analysis, specifically using the Communalities table (see Table 3). This table demonstrates the proportion of variance in each item that is explained by the extracted components. For instance, item Q1 exhibits a high

communality of 0.875, suggesting that the majority of its variance is accounted for by the underlying factors identified in the factor analysis. Similarly, items Q3 and Q6 show strong communalities of 0.886 and 0.904, respectively, further reinforcing that these items are well-represented by the factors extracted during the analysis. This indicates that these items align well with the underlying constructs the instrument is intended to measure.

Table 2. Item-total statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Q1	25.0667	49.375	.876	.820
Q2	25.6333	51.413	.838	.829
Q3	26.0333	58.792	.300	.871
Q4	22.6000	40.938	.733	.821
Q5	22.9333	43.995	.832	.807
Q6	23.8333	45.178	.693	.827
Q7	21.9000	41.472	.518	.880

The lower communality of Q7 (0.672) suggests that this item might not be as strongly related to the underlying factor structure as other items, but it still meets the acceptable threshold according to (Field, 2017), who suggests that communalities above 0.5 are sufficient in social science research.

Table 3. Communalities

	Extraction
Q1	.875
Q2	.819
Q3	.886
Q4	.740
Q5	.794
Q6	.904
Q7	.672

The factor analysis extracted two primary components that together account for 81.280% of the total variance, which is considered a high percentage. Typically, a cumulative

variance above 60% is deemed satisfactory for factor analysis of psychological constructs (Field, 2018). Component 1 explains 54.237% of the variance, and likely represents dimensions of fluency and flexibility in creative thinking, indicated by high loadings of items such as Q1 (0.911), Q2 (0.865), and Q5 (0.785). Component 2, which explains 27.043% of the variance, seems to capture originality, as reflected by high loadings from Q3 (0.941) and Q6 (0.794). This two-component structure aligns with theories on the multidimensionality of creativity, emphasizing the distinct roles of fluency, flexibility, and originality in cognitive processes.

The Rotated Component Matrix, see Table 4, clarifies the factor structure, showing which items load onto each component. Q1, Q2, Q4, Q5, and Q7 load heavily onto Component 1, suggesting that they are primarily

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associated with fluency and flexibility. On the other hand, Q3 and Q6 load more onto Component 2, indicating that these items are more reflective of originality. This separation aligns with theoretical perspectives on creative thinking, which distinguish between these dimensions (Guilford, 1967; E. P. Torrance, 1974).

The presence of two distinct components aligns with findings from other research, suggesting that creative thinking is multi-dimensional and typically involves components like fluency, flexibility, and originality (Plucker et al., 2004).

Table 4. Rotated component matrix<sup>a</sup>

	Component	
	1	2
Q1	.911	
Q2	.865	
Q3		.941
Q4	.826	
Q5	.785	.421
Q6	.522	.794
Q7	.804	

The Component Score Coefficient Matrix presented in Table 5 specifies the individual contribution made by each item towards the identified components. Items Q1 and Q2 have been highlighted to have greater contributions to Component 1, as they correlate more with fluency and flexibility dimensions of creative thinking. Conversely, items Q3 and Q6 are better buddies with Component 2, meaning they are more on the originality side of creativity. This distinction enhances clarity on how each item relates to the various sub-categories of the overall concept of creative thinking as assessed through the instrument provided.

Surprisingly, Q5 shows some degree of cross-loading between the two components, meaning it is likely to address both fluency/flexibility and originality. Although cross-loadings can indicate problems in what a specific item is assessing, in this situation it may indicate the interaction between fluency and originality since some behaviours/responses may display both (Runco, 2014).

Table 5. Component score coefficient matrix

	Component	
	1	2
Q1	.258	-.056
Q2	.230	-.008
Q3	-.208	.631
Q4	.223	-.018
Q5	.171	.112
Q6	.003	.418
Q7	.302	-.279

Extraction Method: Principal Component Analysis.  
Rotation Method: Varimax with Kaiser Normalization.

The findings of this study have far-reaching importance that should be taken into account when fine-tuning the instrument and adopting it in the future. To begin with, the reliability of the item is high, as indicated by a positive Cronbach's Alpha value. However, it may even be suggested that a modification or even deletion of item Q3 will improve the overall coherence of the instrument in relation to creative constructs. This modification could make students' evaluation of their ownership of creative potential more valid.

The decomposition of this particular factor into two components points to the effectiveness of the instrument in capturing dimensions of creative thinking in this case fluency/flexibility and originality. This observation also follows models of

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creativity that have gained acceptance in research with respect to the *s\_e\_o\_r\_m* – – . Contrary to this, caution should be exercised when using some of the items, especially Q5, which had some cross-loading on both factors. Understanding how such items fit within each of the factors would enhance the understanding of how the items operate with each factor of creativity. These implications underscored the need for further instrument enhancement especially in terms of education, where the different dimensions of creative thinking have to be measured appropriately.

Going forward, this tool could be a consistent and legitimate way to measure creativity in education especially in terms of investigating how students produce ideas (fluency), shift from one idea to another (flexibility), and develop new creative ideas (originality). In some of the future studies, further refinements of certain items may allow clearer differentiation of some of the dimensions, without sacrificing the usefulness of the instrument in different settings.

All the inferences drawn from this reliability and factor analysis in the previous chapter attest to the strength of the creative thinking instrument. The instrument is deemed reliable with a Cronbach's Alpha of 0.857 and accurately measures two of the three components of creative thinking, fluency/flexibility and originality. Some issues like Q3 which are slightly less focused as well as consistent with the constructs of the instrument such that additional work would be necessary possibly useable. All these issues reinforced the importance of being able to stretch individuals creatively as well as the existing multi creation of the

instrument scope and use within the educational research arena.

Such findings make a valuable contribution to understanding the issues of reliability and validity of the professional creative activity evaluation tool that measures fluency, flexibility and originality amongst others. The findings of the reliability analysis, suggesting tools were both reliable and valid albeit some limitations could be addressed. Such literary findings are consistent with the previous literature focusing on the multidimensionality of creativity and thus highlight the importance of item construction and analysis in educational research.

Internal Consistency test returned the Cronbach's Alpha 0.857 indicating that out of seven items of the creative thinking instrument there was on high consistency amongst the seven items of the instrument. This result corroborates the fact that the construct being evaluated by the instrument was able to be accurately assessed up holding the reliability standards proposed by George and Mallery (2016). Cronbach's alpha is one of the methods that has been accepted in determining the internal consistency of the measurement instruments Cronbach's Alpha above 0.7 implies that the contents of the items under the construct invoke the same trend.

However, the item Q3 shows the lowest item-total correlation at .300 which indicates that this item equally contributes to the construct being measured as do the others. If Q3 were to be eliminated, the reliability would more likely be improved, or at least not lessened which explains the anticipated increase in Cronbach's Alpha to 0.871. This also demonstrates that Q3 is not as well fitted to other items in the scale as some of the other items which is ,an

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issue that is also noted by Hair et al., 2013, encouraging such items that are found to have very low item-total correlations be either enhanced or eliminated so that reliability of the instrument is not compromised. Q1 and Q2 on the other hand show a high level of item total correlation of 0.876 and 0.838 respectively indicating that these item revisions are appropriate in respect to the target construct.

In conclusion, while the overall instrument's reliability in measuring the creative process is quite compelling, it can be improved by, among other things, adjusting or deleting some items like Q3. Thus Torrance (1974) underfoot measures that are intended to assess creativity in individuals contain no such extreme views, yet they should be internally consistent with fluency, flexibility, and originality among the constructs.

The Exploratory Factor Analysis (EFA) led to the identification of two significant factors, which account for 81.280% of the variance. The first explains 54.237%, which seems to represent fluidity and flexibility in the concept of creative thinking as it includes items such as Q1 (0.911) and Q2 (0.865) due to high loadings. The second accounted for 27.043% of the variance more likely focuses on originality, since such items as Q3 (0.941) and Q6 (0.794) are high in loadings.

The factor comprising fluency, flexibility and originality is consistent with the common view regarding creativity which defines it as multi-faceted comprising interrelated independent components (Guilford, 1967; E. P. Torrance, 1974). Fluency refers to the ability to produce many ideas. Flexibility refers to the ability to switch from one idea or method to

another. Originality means the production of new ideas and new combinations of ideas.

The Rotated Component Matrix supports this distinction. It was found that Q1, Q2, Q4, Q5 and Q7 cluster the most on Component 1 (fluency/flexibility) Q3 and Q6 more cluster on Component 2 (originality). Studies to date have seen fluency-flexibility and originality divide in self assessments of creativity that originality being one of the factors that emerge after performing the factor analysis of creativity assessments (Plucker et al., 2004; Runco, 2014).

Interestingly, Q5 cross-loads onto both components, so overall, it seems this item might be measuring the constructs of logical fluency and originality. Cross-loadings, though at times deemed unnecessary, tend to capture the nature of the creative process where, by some behaviors or responses, are more than one dimensional. This seems to be the case particularly in situations where the patenting of several ideas with respect to a given theme (fluency) and an ultimatum of only a few but highly unique ideas (originality) is needed as in this case (Cropley, 2006).

The Communalities results provide further support for the validity of the instrument. For instance, high communalities for Q1 (0.875), Q3 (0.886) and Q6 (0.904) imply that these items have been accounted for very well in the extracted factors. This implies that the instrument explains most of the variance observed in these items, which is consistent with the theory underlying creativity. On the contrary, Q7 has a lower ranking in communalities of 0.672, meaning the item may not tap into the same concise underlying factor structure as most other items, however,

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still remains within the cutoff limit for communalities in social science studies (Field, 2017).

The importance of ensuring that alignment exists between all measurement items and the theoretical constructs that they are supposed to measure properly is clear from the following findings. From the communalities results, it is evident that most of the items have been effective in measuring fluency, flexibility and originality, but seems as if Q7 has potential for improvement.

The conclusions drawn by this study suggest that such creative thinking assessment tool despite been reliable and valid needs more improvements to steps up its usability further. It appears that deleting or modifying Q3 should enhance the instrument's reliability and validity in measuring creativity. Other items such as Q5 which are loading on fluency/flexibility and originality can also be improved in order to clearly separate these dimensions.

Even with these admissible flaws, the fact that the instrument is able to measure fluency/flexibility and originality concurrently enhances the understanding of creativity in a multi-facet manner. Meanwhile, Guilford (1967) Torrance (1974) defined the problem of creativity more broadly, development of these studies is also confirmed by the findings of this study. Two fundamental aspects of creative thought are measured by the tool and these aspects can be assessed using the tool even in educational settings among learners' creative abilities.

Moving forward, it is important to examine the instrument in more detail to understand the relationship between fluency, flexibility, and originality as well as how these three interact with

one another when looking at other studies. In a study cited by Runco (2014), numerous factors internal and external to the person who engages in creative thinking influence the outcome of creativity, underscoring the need for more effective and advanced measurement tools in the comprehension of complex phenomena such as creativity.

To summarize, the creative thinking instrument as used in this study appears to be both reliable and valid, while having a two-factor structure that includes the fluency/flexibility as well as originality components. The results provide tentative directions for further development of the instruments, in particular in relation to the domains which have more complex pictures than expected such as Q3 and Q5. As a whole, this measure is highly appropriate for evaluating creative thinking and has significant value to those engaged in exploring and developing methods of targeting educational promotion of creativity.

## **CONCLUSIONS AND SUGGESTIONS**

The purpose of this study was to create and validate a creative thinking instrument which was meant for use in the assessment of fluency, flexibility, and originality of geometry problem-solving. The findings demonstrate that the instrument is confirmed to be reliable and valid with a Cronbach's Alpha value of 0.857, showing a very strong internal consistency in the seven items. This further validates that the instrument measures creative thinking effectively in a geometry teaching context. From the factor analysis, two components were distinguished, representing fluency/flexibility and originality, accounting for 81.280% of the total variance. These findings

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support and give credence to the established theories of creativity such as the one generated by Guilford (1967) and Torrance (1974) which suggest that creativity can not be defined in unidimensional in nature. The distinctiveness between fluency/flexibility and originality adds support to the theoretical boundary of those constructs, providing evidence that thinking in geometry is not one dimensional but a combination of related skewed concepts filled with creativity.

As for the certain research questions stated above, the instrument has an acceptable level of reliability which exceeded the threshold for widely accepted minimum level of Cronbach's Alpha coefficient of 0.7 which testifies about the appropriateness of the tools to measure creative thinking in education context. Nevertheless, one item: Q3 was associated with a low corrected item-total correlation which meant that this item represented problems and as such may require revisions or deletion to enhance the reliability of the instrument.

The factor structure of the instrument validates creativity theoretical models; that is, the instrument measures the various aspects of creative thinking, as fluency/flexibility is represented basically by the items Q1, Q2 and Q5, and originality by the items Q3 and Q6. Such two-component structure is consistent with the theories and models of creative thought processes that have existed, especially the works of Guilford and Torrance who stresses fluency, flexibility and originality as core elements of creativity. Understandably, the instrument is also useful for theoretical predictions, although a number of items of the overall structure (Q3 and Q5) would probably require revision.

Categorical data provided all success level in the study; that is, the aim of the study to come up with a reliable and valid instrument for assessing creative thinking in geometry was achieved. Such an instrument is very useful for the teachers in gauging students' creative prowess by their ability to produce a large number of ideas (fluency), to shift from one perspective to another (flexibility), and to create something that has not been done before (originality). The world today places a higher premium on creativity than in the past, and this instrument opens a unique avenue and assessments for students' creative abilities within the geometry perspective.

Nonetheless, this study is successful as it pinpoints areas of further development. Changes to or deletion of one of the items in Q3 would contribute positively to the internal consistency of the instrument while further work on item Q5, which loaded on both fluency/flexibility and originality factors, would assist in defining its purpose in the evaluation of such dimensions. Further studies should be done in the future to evaluate the application or conditions of using the tool in other educational domains in order to reinforce its generalization or validity in different teaching and learning scenarios. Also, more research could be done as to how these aspects of creative thinking, namely, fluency, flexibility and originality, should relate with each other in the context of various fields within mathematics and other subjects making the tool more comprehensive.

The study establishes a clear contribution to mathematics education through the development and validation of an assessment tool for creative

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thinking in geometry with selected facets such as fluency, flexibility, and originality. The novelty of this research is that it is able to establish a clear two-component factor structure that distinguishes fluency/flexibility from originality which conforms with the models of creativity developed by Guilford and Torrance. This innovative approach enables a more nuanced understanding of creative problem-solving in geometry, demonstrating that it is not a singular process but a multifaceted one. Furthermore, the tool provides a different approach for educators to assess and develop creative components in students so that they are able to produce a multiplicity of ideas, change their thoughts and come up with new solutions with respect to the field of geometry. Given that the need for creativity is now on the increase in education, this tool places geometry within a more creative context in students in terms of assessment and development. Future work however needs to investigate the use of the tool in other educational contexts and how it fits within the more extended mathematics education more enhancing its universality and usefulness.

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