Mathematical creativity or general creativity?

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The present study aims to investigate whether creativity is domain general or domain specific, by relating students' performance on two tests: the Creative Thinking Test and the Mathematical Creativity Test. Four hundred and seventy six students (Grades 4–6) participated in the study. Through confirmatory factor analysis we purported to compare the fitness of two a-priori theoretical models, representing creativity either as domain general or domain specific. Correlation and crosstabs analysis were also conducted in order to examine whether the data obtained from the two creativity instruments were related and/or were in agreement, respectively. Data analysis converged that creativity is domain specific.

Keywords: Domain general, domain specific creativity.

INTRODUCTION

The generality-specificity issue of creativity "goes to the heart of the question of what it means to be creative" (Baer & Kaufman, 2005, p. 158). Indeed, theoretical and practical issues are related to the way that creativity is approached. For instance, some of the proposed definitions embrace context, assuming that the creative ability is specialized in one or more cognitive fields, whereas others do not make any reference to specific areas (Baer & Kaufman, 2005). Moreover, the adopted identification procedures are either based on a general creativity test, in order to predict individual's creative potential in every field, or use domain specific instruments. Similarly, the educational practices and material for the enhancement of students' creative ability either focus on the development of general abilities that are applicable across domains or they are differentiated amongst various domains.

Taking into consideration the previous discussion, the necessity for conducting research that will shed light on this controversial issue of generality-specificity seems warranted (Silvia, Kaufman, & Pretz, 2009). Indeed, such research is prerequisite of any other research in the domain due to its fundamental position to direct the appropriate adopted theoretical definition as well as the methodology employed and data analysis conducted. Hence, the present study purports to contribute in this direction by examining whether creativity is domain general or domain specific.

What is following is a review on the existing literature about defining and approaching creativity as domain general or as domain specific. Afterwards the methodology used in the study will be presented. Finally we will present the results obtained from the data analysis and discuss them.

THEORETICAL CONSIDERATIONS

Creativity as domain general

Domain general perspective views creativity as a universal ability which contributes to all creative achievements (Plucker, 1999), assuming that this ability is transferable and applicable in any cognitive area (Plucker & Zabelina, 2009). According to Beghetto and Kaufman (2009), the creative expression is similar in all cognitive areas and therefore, a person who has demonstrated a high level of creativity in a field is anticipated to show correspondingly high level of creativity in various fields.

Domain general view of creativity has been supported by empirical findings which either verified the predictive power of domain general instruments on creative achievements in several fields or concluded with similarities by comparing the creative ability in different fields (Beghetto & Kaufman, 2009). In particular, Charyton and Merill's study (2009) found high consistency between a general creativity instrument and a domain specific instrument, concluding that the creative behavior is independent of the field under investigation. Kaufman and Baer (2005) described the creative process and the creative product in various disciplines (e.g., poetry, psychology, mathematics), concluding that creative individuals exhibit similar characteristics and skills in a wide range of disciplines. Similarly, Root-Bernstein and Root-Bernstein (2004) examined the background of creative scientists and artists and found that many scientists were artistic and vice versa. Thus, they proposed that the distinction between different types of creativity might be artificial.

Creativity as domain specific

Domain-specific creativity emerged as a major theoretical position in the 1980s, assuming that creativity cannot be understood if there is no reference in the domain in which it takes place (Plucker & Zabelina, 2009). In this context, the skills, the traits and knowledge that underlie creative ability are differentiated between cognitive areas (Beghetto & Kaufman, 2009). Several studies presented evidence to support domain specificity of creativity (e.g., Baer & Kaufman, 2005; Plucker, 1999).

In these studies researchers concluded with low correlations between creative results in different fields of knowledge indicating that there is not a general creative ability that contributes to creative performance in different disciplines (e.g., Plucker & Zabelina, 2009). In particular, Hocevar (1976, in Baer, 1998) found that the correlations among various self-report indices of creativity in different domains were low to moderate. In the same line, Baer (1991) found low or non-statistically significant correlations between verbal and mathematical creative tasks. In a systematic work conducted by Baer (1993) with students from childhood to adulthood, he concluded that independently of age groups and content the correlations were consistently low.

Furthermore, using more advanced statistical analysis researchers reached multiple-factors models to describe the structure of creativity, verifying that there are distinct domains that differentiate creative ability (Silvia, Kaufman, & Pretz, 2009). For instance, Kaufman and colleagues (e.g., Kaufman, Cole, & Baer, 2009) suggested a multi-factors model to describe creativity.

PURPOSE OF THE STUDY

By considering the abovementioned discussion, it is obvious that both the domain general and domain specific perspectives of creativity are supported by strong arguments leading to a polarization of the debate (Silvia, Kaufman, & Pretz, 2009). The field is still blurred and the question whether creativity is domain general or specific remains unanswered. Hence, this study aims to examine this issue.

Moreover, Silvia, Kaufman and Pretz (2009) claimed that the methodology and statistical analyses followed by researchers may affect their conclusion regarding generality and specificity. For instance, the majority of research studies which used correlation analyses concluded to creative generality while research studies which used advanced statistical methods found evidences for the domain specificity of creativity. In order to eliminate these limitations, in the present study we will use a combination of statistical analyses, in order to investigate whether different statistical approaches offer affirmative evidences for one direction.

This study has two purposes: (a) to investigate whether creativity is domain general or domain specific; (b) to examine whether the exploitation of different statistical approaches leads to similar conclusions concerning the generality-specificity issue.

METHODOLOGY

Four hundred and seventy six students attending Grades 4 (N=202), 5 (N=165) and 6 (N=109) in public schools in Cyprus participated in the present study. Aiming to investigate whether creativity is domain general or domain specific, two tests were administered: the Mathematical Creativity Test (MCT) and the Creative Thinking Test (CTT). The tests were administered in paper and pencil form and one hour was allocated to students for completing them (MCT: 40 minutes, CTT: 20 minutes).

Mathematical Creativity Test (MCT)

The MCT consisted of four multiple-solutions tasks with problem solving and problem posing situations (see Fig1), taking into consideration relevant research studies on mathematical creativity (e.g., Kattou, Kontoyianni, Pitta-Pantazi, & Christou, 2013). The selection of the four tasks included in the MCT was based on the results of a task analysis that took place at a previous phase of the study. For each task students were asked to provide multiple solutions, solutions that were distinct from each other and solutions that none of their peers could provide. This was done in an effort to capture students' fluency, flexibility and originality. These three abilities constituted the assessment criteria. In particular, the assessment was based on the number of correct mathematical solutions students' proposed (fluency), the number of different mathematical ideas included in students' answers (flexibility) and the scarcity of answers (originality) (Kattou, et al., 2013).

Specifically, we employed the assessment method proposed by Kattou and colleagues (2013): (a) Fluency score: we calculated the ratio between the number of correct mathematical solutions that the student provided, to the maximum number of correct mathematical solutions provided by a student in the population under investigation. (b) Flexibility score: we calculated the ratio between the number of different types of correct solutions that the student provided, to the maximum number of different types of solutions provided by a student in the population under investigation. (c) Originality score: it was calculated according to the frequency of a student's solutions in relation to the solutions provided by all the students (score 1 was given to students whom one or more of their solutions appeared in less than 2% of the sample's solutions, score 0.8 was given to students whom one or more of their solutions appeared between 2% and 5%, score 0.6 was given to students whom one or more of their solutions appeared between 6% and 10%, score 0.4 was given to students whom one or more of their solutions appeared between 11% and 20%, score 0.2 was given to students whom one or more of their solutions appeared in more than 20% of the sample's answers). Therefore, three different scores yielded for each student in each task. The final score of the test was obtained by adding the respective scores of fluency, flexibility and originality in the four tasks and then by converging them to a scale ranging from 0 to 1.

Creative Thinking Test (CTT)

The CTT included two tasks, one verbal and one figural, taken from the respective subtests of the Torrance Tests of Creative Thinking (Torrance, 1974). Concretely, the first task required students to provide unusual uses of a common everyday object, while the second one asked students to complete simple repeated figures to make a picture. Students were asked to provide as many answers as they could in a specific time interval. Their answers were assessed according to their fluency, flexibility and originality as described above.

Data analysis

The data were quantitatively analysed with the modeling program Mplus (Muthén & Muthén, 1998) in combination with the statistical package SPSS. Specifically, correlation analyses took place aiming to examine the correlation between participants' performances in the two tests. Moreover, crosstabs analysis allowed us to examine whether the two tests provided similar or different results regarding the identification of creative individuals. Confirmatory Factor Analysis (CFA) was employed, to test the validity of alternative theoretical models that present creativity as domain specific and domain general. The alternative models that were compared are discussed below.

Model 1 regards creativity as domain general. In this model creativity is defined across fluency, flexibility and originality, independently of the instruments used. Model 2 regards creativity as domain specific, implying that distinct creative abilities exist. Thus domain specific creativity in mathematics is differentiated from the creative ability that was measured with a test not targeted in mathematics. Each of the domain specific creativities is comprised by the abilities of fluency, flexibility and originality.

RESULTS

Correlation analysis

Aiming to investigate the existence of correlations between the creative abilities (fluency, flexibility, originality) of the same test or/and between the same crea-

> Make as many groups of numbers as you can, using the numbers given below. Label each group with its characteristic.
>
> 2, 3, 7, 9, 13, 15, 17, 25, 36, 39, 49, 51, 60, 64, 91, 119, 121, 125, 136, 143, 150
>
> Warnings: You can use each number in more than one group.
> Each group should contain more than two numbers.

Figure 1: Example of tasks from the Mathematical Creativity Test

tive ability between the two tests, correlation analysis was conducted, as presented in Table 1. From the correlation analysis it can be deduced that all variables were significantly correlated with each other ($p<.01$). However, the correlations exist between the abilities of the same test were higher (ranging between $r=.579$ and $r=.812$), as they are compared to the correlations of the same ability across the two tests (ranging between $r=.208$ and $r=.421$).

To examine whether the two tests used in the present study identify the same participants as creative, crosstabs analysis was conducted. It is important to mention that the participants were primarily split in categories according to their performance in each test. Specifically, four groups emerged based on students' performance on the MCT and four other groups emerged based on their performance on the CTT as follow: Group 1 included students whose performance belonged to the lowest 15% of performances on the corresponding test, whereas Groups 2 and 3 included students whose performance belonged between 15%-50% and 50%-85% of performances, respectively. Group 4 included students whose performance belonged to the highest 15% of the performances (max score was 3 – the score was obtained by adding fluency, flexibility and originality scores). The descriptive statistics of each group of students are presented in Table 2.

Crosstabs analysis was also conducted aiming to investigate whether students who were classified as creative using the MCT were also creative according to the CTT and vice versa. The results of the analysis are presented in Table 3.

Data analysis showed that 4.20% of the participants were identified as creative with both instruments. However, among the students who were regarded as high mathematical creative (Group 4) only the 28.99% (20 out of 69) were also regarded as creative according to the CTT. Similarly, only 27.78% (20 out of 72) of the students who were highly creative using the CTT for their assessment (Group 4) were mathematically creative as well. Based on the abovementioned percentages, a student who is creative using as indicator his/her performance in one of the instruments is not necessarily identified as creative by the other instrument.

	CTT			MCT		
	Fluency	Flexibility	Originality	Fluency	Flexibility	Originality
Fluency CTT	1	.615	.579	.421	.237	.166
Flexibility CTT	.615	1	.595	.301	.208	.198
Originality CTT	.579	.595	1	.314	.225	.214
Fluency MCT	.421	.301	.314	1	.719	.621
Flexibility MCT	.237	.208	.225	.719	1	.812
Originality MCT	.166	.198	.214	.621	.812	1

Table 1: Correlations between fluency, flexibility, originality in MCT and CTT

	Groups according to CTT		Groups according to MCT	
	N (%)	Mean (SD)	N (%)	Mean (SD)
Group 1	72 (15.13)	.99 (.23)	71 (14.92)	.56 (.12)
Group 2	164 (34.45)	1.54 (.14)	168 (35.29)	.91 (.10)
Group 3	168 (35.29)	1.93 (.10)	168 (35.29)	1.24 (.11)
Group 4	72 (15.13)	2.26 (.14)	69 (14.50)	1.66 (.16)
Total	476 (100)	1.70 (.41)	476 (100)	1.08 (.35)

Table 2: Descriptive statistics of the groups of students

CTT	MCT				
	Group 1 N (%)	Group 2 N (%)	Group 3 N (%)	Group 4 N (%)	Total N (%)
Group 1	25 (5.25)	27 (5.67)	16 (3.36)	4 (0.84)	72 (15.13)
Group 2	19 (3.99)	69 (14.50)	60 (12.61)	16 (3.36)	164 (34.45)
Group 3	23 (4.83)	57 (11.97)	59 (12.40)	29 (6.09)	168 (35.29)
Group 4	4 (0.84)	15 (3.15)	33 (6.93)	20 (4.20)	72 (15.13)
Total	71 (14.92)	168 (35.29)	168 (35.29)	69 (14.50)	476 (100)

Table 3: Results of the crosstabs analysis

Confirmatory factor analysis

Confirmatory factor analysis allowed us to compare the validity of the structure of two alternative models for creativity. For the evaluation of model fitness, three indices were taken into consideration: The chi-square to its degree of freedom ratio (χ^2/df), the comparative fit index (CFI), and the root mean-square error of approximation (RMSEA) (Marcoulides & Schumacker, 1996). An acceptable model should have the value of CFI higher than .90, the value of χ^2/df lower than 2 and the value of RMSEA lower than .08 (Marcoulides & Schumacker, 1996). During the comparison of alternative models, apart from the appropriate values of indices, we choose the model with the highest CFI index and the lowest AIC and BIC indices (Marcoulides & Schumacker, 1996). What follows is a description of the structure of the two alternative models, however, only the model with the best "fitness" on the data of the present study will be presented diagrammatically, due to space limitation.

In Model 1 creativity is a second order factor which consists of the general abilities of fluency, flexibility and originality. Each of these three abilities constitute first order factors that are constructed by students corresponding performance in the two tests. This model implies that independently of the measure or the domain, fluency, flexibility and originality form a general factor, that of domain general creativity. Data analysis indicated that the Model 1 does not have good indicators of adjustment to the research data (CFI=.961, χ^2=276.614, df=115, χ^2/df=2.405, RMSEA=.063, AIC=-7515.508, BIC=-7282.245), due to the fact that the χ^2/df is higher than 2.

Model 2 (see Figure 2 in Appendix) suggests that different types of creativity exist which form different factors: creativity measured using the MCT and creativity measured with the CTT. Each domain specific type of creativity is comprised of fluency, flexibility and originality. Confirmatory factor analysis showed that Model 2 has very good "fitness" on the data of the present study (CFI=.990, χ^2=152.926, df=111, χ^2/df=1.378, RMSEA=.039, AIC=-7631.196, BIC=-7381.703). In particular, the analysis suggested that two independent second order factors exist. Each of these context-dependent creative abilities is formed by fluency (MCT: r=.96, p<.05, CTT: r=.87, p<.05), flexibility (MCT: r=.99, p<.05, CTT: r=.98, p<.05), and originality (MCT: r=.95, p<.05, CTT: r=.86, p<.05), implying that fluency, flexibility and originality in the two instruments do not constitute a common factor but they are distinguished according to the stimuli. Indeed, each of the three components of content-dependent creativity is comprised by the corresponding performances on the specific measurement. For instance, the second order factor "Fluency" in the MCT is comprised by "Fluency 1"- "Fluency 4", that is the measured fluency ability in the four tasks of the MCT.

Comparing the two models, the second model has a better fit to the data; firstly the CFI index has higher value in Model 2 as compared to Model 1 (CFI_{Model1}=.961, CFI_{Model2}=.990,); secondly Model 2 has the lowest value of AIC and BIC indices (AIC_{Model1}=-7515.508, AIC_{Model2}=-7631.196, BIC_{Model1}=-7282.245, BIC_{Model2}= -7381.703,), thirdly Model 1 has an inappropriate value for one of the indices that are taking into account for the evaluation of model fitness (χ^2/df=2.405>2).

DISCUSSION

Is creativity domain specific or domain general? Although both opposing views have been examined and empirically supported by several researchers, is still one of the enduring controversies of the creativity research. According to Baer and colleagues (Baer, 1998; Baer & Kaufman, 2005) the importance in answering that question goes to the heart of the field and consequently influences the educational practices. Due to the importance of the domain generality-specificity issue both in educational and research domains (Baer, 1998; Kaufman & Baer, 2005), the present study attempted to investigate this controversial issue.

The result obtained through data analyses converged to the domain specificity of creativity. Specifically through the comparison of two alternative theoretical models which define creativity as specific or general, confirmatory factor analysis confirmed the appropriateness of the domain specific model. By employing similar statistical analysis other researchers found multiple-factors models to describe the structure of creativity, verifying that there are distinct domains of creative ability (Kaufman, Cole, & Baer, 2009). Therefore, psychologists and educators should no longer characterise individuals as creative, but instead, as creative in specific domains. Consequently, research work on creativity is anticipated to be specialized in different fields in order to develop an integrated picture of the concept, rather than considering creativity as a general aspect.

This result was also supported by the correlation analyses which aimed at investigating the relationships between creative abilities (fluency, flexibility, originality) on two different dimensions: correlations of the same creative ability between the two instruments and correlations of the three creative abilities within the same instrument. Negligible correlations were found between the same creative ability across the two measurements (e.g. MCT fluency- CTT fluency), whereas high correlations were observed between the three abilities (fluency, flexibility, originality) that were measured within the same instrument. Low correlations between creative results in different domains were identified by numerous researchers (Baer, 1991; Kaufman & Baer, 2005; Plucker & Zabelina, 2009). By interpreting this result, one may assume that there are not identical and systematic creative abilities which may arise to stimuli of different domains; hence the existence of "a universal creativity" which is transferrable from one cognitive field to another is rejected (Kaufman & Baer, 2005).

Finally, the results of the crosstabs analysis illustrated that students' performance on the two creative instruments were not in agreement. In particular, a high percentage of participants who were considered as creative using one of the instruments were not consistently found as creative using the other instrument, whereas only a low percentage of participants were identified as creative by both instruments. Based on these results we can conclude the inadequacy of general creativity instruments to identify creative thinking in specific domains. Hence, the necessity for developing domain specific instruments to measure creative ability is obvious (Hong & Milgram, 2010). Extending the above conclusion, by identifying a student who is creative in mathematics does not necessary imply that she/he is also creative in art or literature, and vice versa. Additionally, a student who has shown high creative ability in one field is not automatically excluded from being creative in the subject of mathematics.

REFERENCES

Baer, J. (1991). Generality of creativity across performance domains. *Creativity Research Journal, 4*, 23–39. doi: 10.1080/10400419109534371

Baer, J. (1993). *Divergent thinking and creativity: A task-specific approach*. Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Baer, J. (1998). The case for domain specificity of creativity. *Creativity Research Journal, 11*, 173–177. doi: 10.1207/s15326934crj1102_7

Baer, J. & Kaufman, J. C. (2005). Bridging generality and specificity: The Amusement park theoretical (APT) model of creativity. *Roeper Review, 27*(3), 158–163. doi: 10.1080/02783190509554310

Beghetto, R. A., & Kaufman, J.C. (2009). Intellectual estuaries: Connecting learning and creativity in programs of advanced academics. *Journal of Advanced Academics, 20*, 296–324. doi: 10.1177/1932202X0902000205

Charyton, C., & Merrill, J. A. (2009). Assessing general creativity and creative engineering design in first year engineering students. *Journal of Engineering Education, 98*, 145–156. doi: 10.1002/j.2168-9830.2009.tb01013.x

Hong, E., & Milgram, R. M. (2010). Creative thinking ability: Domain generality and specificity. *Creativity Research Journal, 22*(3), 272–287. doi: 10.1080/10400419.2010.503535

Kattou, M., Kontoyianni, K., Pitta-Pantazi., D., & Christou, C. (2013). Connecting mathematical creativity to mathematical ability. *ZDM, 45*(2), 167–181. doi: 10.1007/s11858-012-0467-1

Kaufman, J. C., & Baer, J. (Eds.). (2005). *Creativity across domains: faces of the muse*. Mahwah, NJ: Lawrence Erlbaum Associates.

Kaufman, J. C., Cole, J. C., & Baer, J. (2009). The construct of creativity: A structural model for self-reported creativity ratings. *Journal of Creative Behavior, 43*, 119–134. doi: 10.1002/j.2162-6057.2009.tb01310.x

Marcoulides, G. A., & Schumacker, R. E. (1996). *Advanced capacity equation modelling: Issues and techniques.* NJ: Lawrence Erlbaum Associates.

Muthén, L. K., & Muthén, B. O. (1998). *Mplus user's guide*. Los Angeles, CA: Muthén & Muthén.

Plucker, J. (1999). Reanalyses of student responses to creativity checklists: Evidence of content generality. *Journal of Creative Behavior, 33*, 126–137. doi: 10.1002/j.2162-6057.1999.tb01042.x

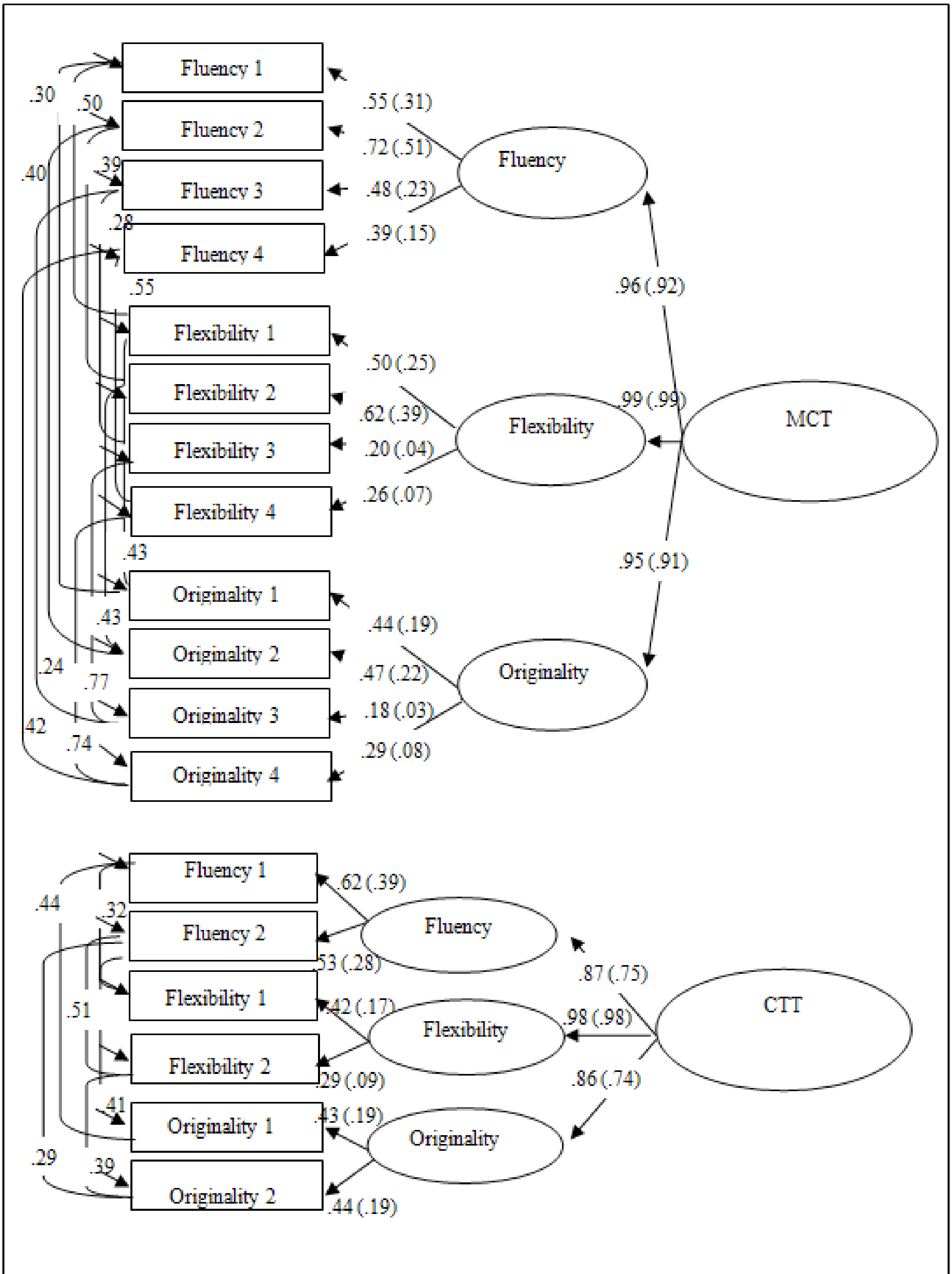
Plucker, J. A., & Zabelina, D. (2009). Creativity and interdisciplinarity: One creativity or many creativities? *ZDM, 41*, 5–11. doi: 10.1007/s11858-008-0155-3

Root-Bernstein, R., & Root-Bernstein, M. (2004). Artistic scientists and scientific artists: The link between polymathy and creativity. In R.J. Sternberg, E.G. Grigorenko, & J.L. Singer (Eds.), *Creativity: From potential to realization* (pp. 127–151). Washington, DC: American Psychological Association.

Silvia, P. J., Kaufman, J. C., & Pretz, J. E. (2009). Is creativity domain-specific? Latent class models of creative accomplishments and creative self-descriptions. *Psychology of Aesthetics, Creativity, and the Arts, 3*(3), 139–148. doi: 10.1037/a0014940

Torrance, E. P. (1974). *The Torrance tests of creative thinking-norms-technical manual research edition-verbal tests, forms A and B- figural tests, forms A and B.* Princeton, NJ: Personnel Press.

APPENDIX



* The first number indicates factor loading and the number in parenthesis indicates the corresponding r^2.

Figure 2: Model of domain specific creativity