MONOGRAPH

From computational thinking to creative thinking: an analysis of their relationship in high school students

Del pensamiento computacional al pensamiento creativo: un análisis de su relación en estudiantes de educación secundaria

Do pensamento computacional ao pensamento criativo: uma análise de sua relação em alunos do ensino médio

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Abstract

The objective of the article is to determine which dimensions of computational thinking are related to the dimensions of creative thinking. The methodology is quantitative with a descriptive non-experimental cross-sectional design. Two instruments are used: one that measures computational thinking through the Directions, Loops, Conditionals, and Functions dimensions, and another that measures creative thinking through the Originality, Fluency, Elaboration, and Flexibility dimensions. The sample was made up of N = 275 students from 7 educational institutions in the Diguillin province, Ñuble Region, Chile. The results show that computational and creative thinking are related to each other. The loops and conditional dimensions are significantly related to all the creative thinking dimensions. The creative thinking dimension elaboration is the most influenced by loops and conditionals, followed by fluidity, originality and flexibility. In conclusion, loops and conditionals are the essential dimensions for stimulating the creative thinking dimensions.

Keywords: *Correlation; Thinking; Creativity; Skills*

Resumen

El objetivo del artículo es determinar que dimensiones del pensamiento computacional se relacionan con las dimensiones del pensamiento creativo. La metodología es cuantitativa con un diseño descriptivo no experimental transversal. Se utilizaron dos instrumentos, uno mide el pensamiento computacional a través de las dimensiones Direcciones, Bucles, Condicionales y Funciones y el otro, mide el pensamiento creativo a través de las dimensiones Originalidad, Fluidez, Elaboración y Flexibilidad. La muestra estuvo compuesta por N=275 estudiantes de 7 establecimientos educativos de la Provincia del Diguillin, Región de Ñuble, Chile. Los resultados demuestran que el pensamiento computacional y creativo están relacionados entre sí. Las dimensiones bucles y condicionales se relacionan significativamente con todas las dimensiones del pensamiento creativo. De estas dimensiones, las que reciben mayor influencia de los bucles y condicionales son la elaboración, seguida de la fluidez, la originalidad y la flexibilidad. En conclusión, los bucles y condicionales son las dimensiones esenciales para estimular las dimensiones del pensamiento creativo.

Palabras clave: *Correlación; Pensamiento; Creatividad; Habilidades*

Resumo

O objetivo do artigo é determinar quais dimensões do pensamento computacional estão relacionadas às dimensões do pensamento criativo. A metodologia é quantitativa com um delineamento transversal não experimental descritivo. Foram utilizados dois instrumentos, um mede o pensamento computacional por meio das dimensões Direções, Loops, Condicionais e Funções, e o outro mede o pensamento criativo por meio das dimensões Originalidade, Fluidez, Elaboração e Flexibilidade. A amostra foi composta por N = 275 alunos de 7 estabelecimentos de ensino da província de Diguillin, região de Ñuble, Chile. Os resultados mostram que o pensamento computacional e o criativo estão inter-relacionados. Os loops e as dimensões condicionais estão significativamente relacionados a todas as dimensões do pensamento criativo. Dessas dimensões, as mais influenciadas por loops e condicionais são mão de obra, seguidas de fluidez, originalidade e flexibilidade. Em conclusão, loops e condicionais são as dimensões essenciais para estimular as dimensões do pensamento criativo.

Palavras chave: *Correlação; Pensamento; Criatividade; Habilidades*

Translation by **Mary Kathleen Hayes**

1. Introduction

The contemporary world is characterized by enormous technological advances, globalization and an accelerated accumulation of knowledge (Van de Oudeweetering and Voogt, 2018). In this context, there is a consensus among different international organizations associated with educational change and innovation, including the Organization for Economic Co-operation and Development (OECD, 2018), United Nations Educational, Scientific and Cultural Organization (UNESCO, 2017), Partnership for 21st Century Skills (P21, 2008) and Assessment and Teaching of 21st Century Skills (ATC21S) (Griffin, McGaw, and Care, 2012), that today's students need a group of new skills in order to face tomorrow's challenges. These skills are known as 21st Century skills. Salamanca and Badilla (2020) define them as "a group of cognitive, social, emotional and digital skills that will help today's students face the challenges and problems that will arise when they are citizens of society in the 21st Century" (p.35).

Meanwhile, Van Laar, Van Deursen, Van Dijk and De Haan (2019) summarized and conceptualized six 21st Century skills directed at knowledge workers: information skills, communication, collaboration, critical thinking, creativity and problem solving. Along the same lines, the European Commission (2018) identified the new skills necessary to progress in the 21st Century, they call them key competences, and include: "Literacy competence; Multilingual competence; Mathematical competence and competence in science, technology and engineering (STEM); Digital competence; Personal, social, and learning to learn competence; Civic competence; Entrepreneurship competence; and Cultural awareness and expression competence" (p.38).

Continuing with Salamanca and Badilla (2020) and their referential framework of 21st Century skills, two essential skills for society's present and future converge in the cognitive dimension: *computational thinking and creative thinking*. Both skills are essentially characterized by their great capacity at promoting systems thinking and problem-solving skills in students (Resnick, et al., 2009a). When these skills work together, they become a powerful cognitive tool that helps creatively face several problems that may arise in society.

Examples of creative problem solving through computational thinking frequently appeared throughout 2020 due to the Covid-19 crisis. The most relevant include face shields that facilitate medical staffs' vision, mask supports that help users avoid hurting ears due to prolonged mask wearing, and low-cost mechanical ventilators. All these initiatives mix computational thinking, creativity and technology use.

According to the World Bank Forum (2018) computational and creative thought are among the highest ranked necessary skills for the future world of work.

Over the last years, studies have been done on how computational thought influences creative thought (Villadiego, López and Sierra, 2015; Bustillo and Garaizar, 2016; Silva, 2016; and Santoyo, 2016; Salamanca and Badilla, 2018). In general, they conclude that *the stimulation of computational thinking influences creative thinking*. However, they do not go into depth as to how this interaction is produced, nor do they describe in detail the relationships that are generated between the different dimensions that make up these skills.

As a result of these questions, this study has been done to determine which dimensions of computational thinking are related to which dimensions of creative thinking. This inquiry aims to contribute new perspectives on these skills and help to understand how they are related in greater depth.

2. Computational thinking: definition and dimensions

Computational thinking has surfaced as a fundamental cognitive skill to be developed in students. This is due to its problem-solving potential by using the principles of computer logic programming and its applicability to different aspects of everyday life. The stimulation of computational thinking is related to the use of digital tools, mainly the logic mechanism used for problem solving when programming software in computers.

Computational thinking is mainly characterized as a problem-solving process. This perspective is shared by several authors, including Wing (2006, 2011), who defines it as "implied thought processes in the formulation of problems and their solutions, so they are represented in a manner that can be effectively addressed by an information-processing agent" (p. 3718). The International Society for Technology in Education (ISTE) and Computer Science Teachers Association (CSTA) (2011) coincide, defining it as "a problem-solving process that includes formulating problems with a computer; logical organization; data analysis and representation; automating solutions with algorithmic thinking; identifying, analyzing, implementing, generalizing and transferring solutions" (p.1).

According to Román-González (2016), computational thinking is "the ability to formulate and solve problems based on the fundamental concepts of computer studies, using the inherent logic of computer programming languages: basic sequences or directions, loops, conditionals, functions and variables" (p.163).

Currently there are different characterizations of computational thinking (Wing, 2011; ISTE-CSTA, 2011; Zapata-Ros, 2015; Román-González, Pérez-González and Jiménez-Fernández, 2015), and each author assigns different dimensions and characteristics.

For this study, the authors have selected the standards proposed by CSTA (2011) for secondary students in the American education curriculum (K-12). These are understood as: "implementing solutions for problems by using the concepts of programming language: *loops*, conditional sentences, logical expressions, variables and functions" (p. 17).

With these standards, Román-González, Pérez-González and Jiménez-Fernández, (2015), created the Computational Thinking Test (CTT), which evaluates the dimensions addressed in this study. There are 4 computational thinking dimensions, defined as: a) Directionality, understood as the ability to execute a sequence of instructions, b) Loops, understood as the ability to execute the same sequence of instructions several times, converting the programs into more concise expressions, c) Conditionals, understood as the ability to make decisions based on certain states or situations and d) Functions, understood as how to relate values between two variables.

3. Creative thinking; definition and dimensions

Creative thinking is a cognitive component of human creativity, and its stimulation is fundamental for solving different types of problems. According to Resnick (2009b) "Success is not only based on what some one knows, but also their ability to think and act creatively. In other words, we are now living in the society of creativity" (p. 1).

This study considers Guilford's definition (1950) as the most appropriate for understanding creative thinking, as he defines it as "a problem-solving method…, referring to the abilities that are characteristic of creative individuals, such as fluidity, flexibility, originality and divergent thinking." (p.454).

According to Guilford, human intelligence is multifactorial, where two predominant types of thinking coexist. On one hand, there is convergent thinking, characterized by logic and reason. On the other hand, there is divergent thinking, characterized as a way of understanding reality and solving problems that arise with a different type of logic that is no less important. Along the same line, Torrance (1962), who was one of Guilford's collaborators, defined creative thinking as "a process of discovering problems or information gaps, formulating ideas or hypotheses, testing them, modifying them and communicating the results" (p.16). In other words, he assigns a global character to human cognition.

According to these authors, creative thinking is made up of 4 main dimensions: a) Fluidity, understood as the creative characteristic for generating an elevated number of ideas, through either verbal or figurative stimulation, b) Flexibility, understood as creativity's ability to change a process, the ability to transform, reinterpret or reconsider a problem, c) Originality, understood as the ability to produce novel, unconventional answers, far from the norm and d) Elaboration, understood as the level of detail, development or complexity of creative ideas, the capacity to develop, complete or embellish a determined answer (Jiménez, Artiles, Rodríguez and García, 2007, p. 15).

4. Computational thinking's influence on creative thinking

There is evidence that confirms that computational thinking and creative thinking can be stimulated by different educational strategies. However, strategies aimed at learning programming and the use of ICT tools are the most used and have the most proven impact.

Nonetheless, demonstrating the relationship existing between these two types of cognitive skills has yet to be described in depth. Some studies show the impact that learning how to program has on computational thinking and its influence on creative thinking. Yet, they do not describe the existing relationships between the different dimensions that make up these skills.

For example, the most representative study on this topic was done by Villadiego, López, and Sierra (2015). Their objective was to determine the influence that learning how to program computers has on the creative thinking dimensions of 11th grade students from two educational institutions in Córdoba, Colombia. They used a quantitative methodology with a quasi-experimental design on an experimental and a control group, taking pre- and post-test measurements. The sample was N=170 secondary students between the ages of 14 and 18. The authors used the Test of Creative Imagination for Young People, or PIC-J for its name in Spanish (Artola, 2008). 12 intra-group, inter-group and inter-institutional comparisons were made by nonparametric tests. The main results show that participants from the group that was intervened with Scratch software obtained significant scores after the intervention. The creative thinking dimensions that showed greater influence were *fluidity*, *flexibility* and *elaboration* ($p < .005$).

The study concludes that creative thinking can be developed through learning programming with Scratch. However, it does not present the relationships between the dimensions that make up computational thinking and their influence on the previously described dimensions that make up creative thinking.

Another study done by Silva (2016), aimed to evaluate the impact of learning programming on improving levels of development of creative thinking in secondary students taking the course Computer Studies and Informatics in Peru. The author used a mixed methodology, predominately quantitative designed pre- and post-test for related samples. The sample was made up of N=30 students. The figural Torrance Test of Creative Thinking was used (Jiménez et al., 2007) and the main results show that learning programming has a positive impact on the dimensions *originality*, *fluidity*, *flexibility* and *elaboration*.

Along this same line of research, Santoyo's 2016 study aimed to evaluate the influence on creative thinking skills when 9th grade students learning Technology and Information create video games. The methodology was mixed, with a pre-experimental design. The sample was made up of N=13 students. The figural Torrance Test of Creative Thinking was used (Jiménez et al., 2007). The results showed that *originality* and *elaboration* were the most impacted creative thinking dimensions.

Other studies with similar characteristics have addressed this topic, but they do not specify the impact on the creative thinking relationships. For example, Bustillo and Garaizar (2016) carried out a study on a group of people deprived of liberty in a detention center in Alava, Spain. The objective was to determine what changes occurred in creative thinking when learning to program. The methodology was mixed, with a quantitative focus and with a pre- and post-test design. The sample was made up of

N=28 subjects ranging in age from 24 to 48. The CREA Test (Corbalán and Limiñana, 2010) was used to measure creative thinking. The statistical analyses showed higher averages for creative thinking after the post-test intervention, M =12.89 points. An average increase of 5.21 points was reported after the intervention. At an inferential level, the differences after the intervention are statistically significant, reaching a t value (11) =-5.18, p <.001. It was concluded that learning programming and stimulating computational thinking influence the development of creative thinking. One of the study's weaknesses is that it does not report the dimensions of creative thinking that were affected by learning programming, and therefore by computational thinking.

In Chile, Salamanca and Badilla (2018) study aimed to stimulate creative thinking in primary students by teaching them to program. A quantitative methodology was used, with a quasi-experimental pre- and post-test design. The sample was made up of N=16 7th grade students in a Technology class at a public establishment in the city of Chillan Viejo, Ñuble Region. The figural Torrance Test of Creative Thinking was used (Jiménez et al., 2007). The results showed that the students scored a total of 28.15 points higher on the post-test. However, at an inferential level, the results were not satisfactory, as the difference was not significant t (11) = -3.002, p >.05. Nonetheless, the authors state that the results are inconclusive, as: a) it is possible that the students had difficulty learning to use the software commands and basics and b) the number of sessions scheduled may not have been sufficient to have a greater impact on creative thinking. Finally, this study does not refer to the development of the different dimensions that make up creative thinking, and the sample was quite limited for generalizing the results.

In summary, as can be seen in the scientific literature, when computational thinking is stimulated by learning to program, it is possible to stimulate the 4 dimensions of creative thinking, and where *elaboration* is the dimension with greatest impact, followed by *fluidity*, *originality* and *flexibility*.

5. Method

A quantitative method is used, with a transversal non-experimental correlational design. According to Ato, López and Benavente (2013), transversal studies are "a determined temporal moment, and follow an eminently associative tradition" (p.1048).

5.1 .Objetive

To determine which dimensions of computational thinking are related to creative thinking dimensions in secondary students.

5.2. Population and Sample

The population consists of secondary education students in seventh and eighth year, from seven educational communities in the Diguillin Province, Ñuble Region, Chile. A random sample of a total of N=275 was selected, distributed as n=144 men, or 52.4%, and n=131 women, equivalent to 47.6%.

5.3. Description of the instruments

Two instruments were used to collect data: a) the Computational Thinking Test (CTT) (Román-González, Pérez-González and Jiménez-Fernández, 2015), and b) The figural Torrance Test of Creative Thinking, adapted and assessed for primary and secondary students in the Spanish language (Jiménez et al., 2007).

The objective of the first instrument is to measure the level of aptitude-development of computational thinking in a subject by using multiple choice questions. The test lasts 45 minutes. The target audience are students between the ages of 12 and 13, corresponding to the 1st and 2nd levels of Obligatory Secondary Education (ESO) in Spain. This level is equivalent to 7th and 8th year in Chile, considered part of the primary level. The instrument measures the 4 previously mentioned dimensions of computational thinking: *Directions*, *Loops*, *Conditionals* and *Functions*.

The instrument was validated through the Delphi Method by 20 computer science experts. Reliability was measured by Cronbach's Alpha, which registered an $\alpha = .74$, which is considered an acceptable value (George and Mallery, 2003, p. 231). Factorial validity was estimated through KMO, reporting a value of .874. Additionally, Bartlett's test of sphericity was applied, giving a value of ($\chi^2 = 3796.915$, $p < .01$).

The objective of the second instrument is to evaluate creative thinking in subjects by having them draw. This test lasts 30 minutes. The target audience is students who are in 1st year of primary school to 4th year of ESO. The instrument measures the 4 previously mentioned dimensions of creative thinking: *originality*, *fluidity*, *flexibility* and *elaboration*.

The Torrance test was subjected to a factorial analysis of main components. The components matrix showed that the *originality* dimension obtained an α =.948, *fluidity* α =.967, *flexibility* α =.899, while elaboration obtained a lower result, with an α = .386. In conclusion, the results showed a factorial structure that together explains 70% of the total variance.

5.4. Data collection, preparation and analysis procedure

The instruments were administered in-person. Participants' identities were kept confidential and anonymous; the establishments' directors oversaw that this occurred. Additionally, informed consent and approval were provided, according to the norms at the sponsoring university.

After collecting the data, it was submitted for exploratory analysis to determine normality, eliminating atypical cases, and applying transformations to the data through the Tukey ladder (1977, p.89). However, after this process, it was not possible to reach normality in the sample, so it was decided to work with nonparametric statistics.

The data was analyzed with descriptive statistics, Spearman's correlation and trend line through linear regression. In other words, the data points were adjusted on a line that as a rule does not cross through all of the points; this represents the data's trend. Statistical Package for the Social Sciences (SPSS) Version 23 software was used, (George and Mallery, 200; Visauta and Martori, 2003).

6. Results

Next, the results obtained from the statistical analysis are presented, starting with the descriptive statistics of the scores obtained by the students for the computational thinking dimensions *Directions, Loops, Conditionals and Functions* and the creative thinking dimensions *Originality, Fluidity, Elaboration* and *Flexibility*.

The average score obtained by the students for the four computational thinking dimensions was 11.87 out of a total of 28, representing 42.4%. The average score for the four dimensions of creative thinking, was 115.4 out of 249, which represents 46.3%. In general, the results show that for both instruments, the students were not able to achieve more than 44.35% of the total score.

Table 1 Displays the detail of the average scores obtained by the students for each dimension of computational and creative thinking.

Skills	Dimensions	Mean	SD	Max	Min	Ske	Kur
Computational Thinking	Directions	2.61	1.01	4	0	-.735	.396
	Loops	3.99	1.89	8	0	-.141	-.576
	Conditionals	3.95	2.26	10	0	.409	-.411
	Functions	1.32	.995	4	0	.427	-.296
Creative Thinking	Originality	74.91	33.9	156	2	.163	-.697
	Fluidity	11.63	6.76	31	0	.535	-.364
	Elaboration	15.34	8.32	41	1	.592	-.200
	Flexibility	13.53	6.67	34	0	.424	-.512

Table 1: *Descriptive statistics computational and creative thinking dimensions scores. (Authors' elaboration).*

Note: (1) N=275, (2) Directions Scale= 0 a 4 pts., (3) Loops Scale= 0 a 8 pts., (4) Conditionals Scale= 0 a 12 pts., (5) Functions Scale= 0 a 4 pts., (6) Originality Sacle= 14 a 166 pts. (7) Fluidity Scale= 5 a 40 pts., (8) Elaboration Scale= 0 a 46 pts., (9) Flexibility Scale= 4 a 28 pts. (10) SD= Standard Deviation, (11) Max= Maximum, (12) Min= Minimum, (13) Ske= Skewness, (14) Kur= Kurtosis.

The computational thinking dimensions *conditionals* and *functions* proved to be most difficult for the students, followed by *loops* and *directions*.

As for creative thinking, the dimensions that posed the greatest difficulty for the students were *fluidity* and *elaboration*, followed by *originality* and *flexibility*.

In order to determine which dimensions of computational thinking were significantly related to the dimensions of creative thinking, Spearman's correlation statistic was applied. The results show some significant correlations between the dimensions of the studied skills.

Table 2 shows greater detail pf the results and the magnitudes of the correlations obtained between the dimensions.

Dimension	Originalidad	Fluidez	Elaboración	Flexibilidad
Direcciones	.075	.102	.087	.113
Bucles	.161**	.162**	.203**	.164**
Condicionales	.119*	.138*	.145*	.147*
Funciones	.011	-.002	-.006	.018

Table 2: *Correlations between computational thinking and creative thinking dimensions. (Authors' elaboration).*

*Nota: (1) N=275, (2) ** = P <.001, (3) * = P <.005*

The computational thinking dimensions *loops* and *conditionals* significantly influenced the four dimensions of creative thinking (*originality*, *fluidity*, *elaboration* and *flexibility*) at a level of $p<.001$ and $p<.005$, respectively. According to Hinkle, Wiersma, and Jurs (2003), these correlations are minor, as they may influence other variables more than creative thinking. However, this study did not consider other relevant variables. It specifically sets out to determine how the dimensions of these two 21st Century skills are related.

Once the significant relationships between the computational thinking dimensions *loops* and *conditionals* and the creative thinking dimensions *originality*, *fluidity*, *elaboration* and *flexibility* were identified, their influence was evaluated through a statistic that seeks a lineal adjustment based on nonparametric regression. This procedure allows for verifying the data trends between *loops* and *conditionals* over *originality*, *fluidity*, *elaboration* and *flexibility*. The following figures show a clear, minor linear trend between the computational thinking dimensions and the creative thinking dimensions.

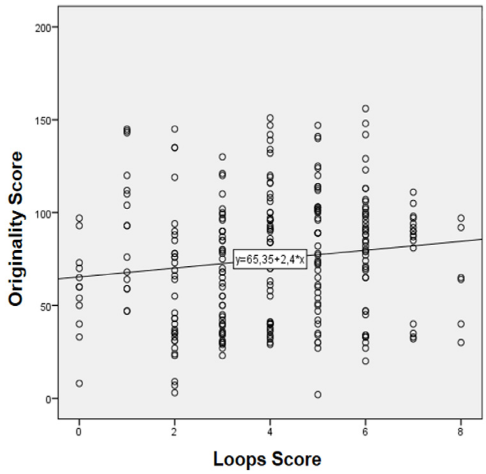

Figure 1: *Linear trend loops over originality*

Note: (1) N=275, (2) R^2 lineal = 0,018, (3) Loops Scale = 0 to 8 pts., (4) Scale Originality= 14 to 166 pts.

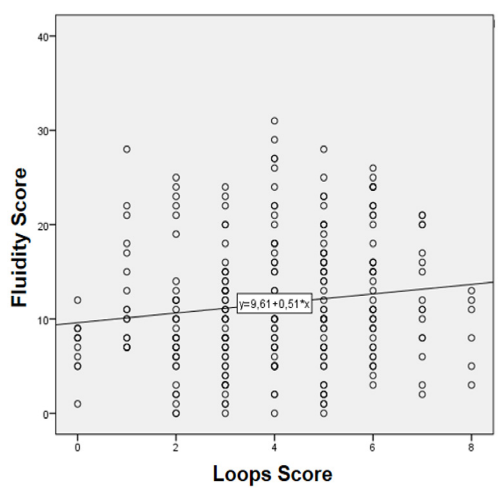

Figure 2: *Linear trend loops over fluidity*

Note: (1) N=275, (2) R^2 lineal = 0.020, (3) Loops Scale = 0 to 8 pts., (4) Fluidity Scale = 5 to 40 pts.

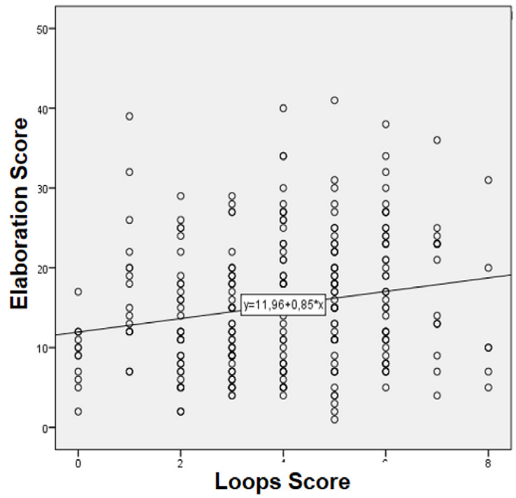

Figure 3: *Linear trend loops over elaboration*

Note: (1) N=275, (2) R^2 lineal = 0,037, (3) Loops Scale = 0 to 8 pts., (4) Scale Elaboration= 0 to 46 pts.

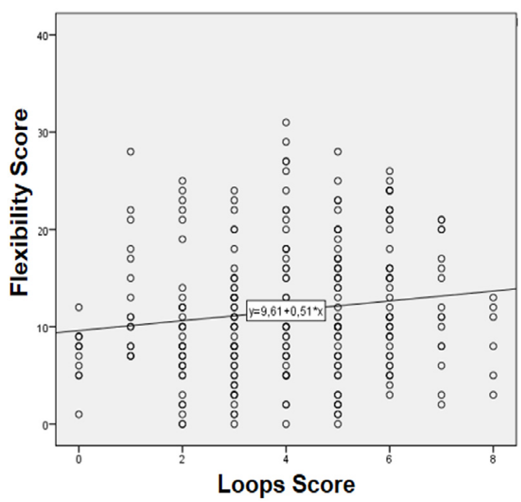

Figure 4: *Linear trend loops over flexibility*

Note: (1) N=275, (2) R^2 lineal = 0,013, (3) Loops Scale = 0 to 8 pts., (4) Scale Flexibility= 4 to 28 pts.

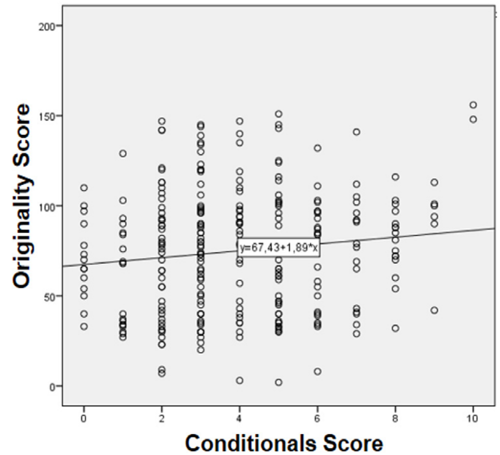

Figure 5: *Linear trend conditionals over originality*

Note: (1) N=275, (2) R^2 lineal = 0,016, (3) Conditionals Scale = 0 to 12 pts., (4) Scale Originality= 14 to 166 pts.

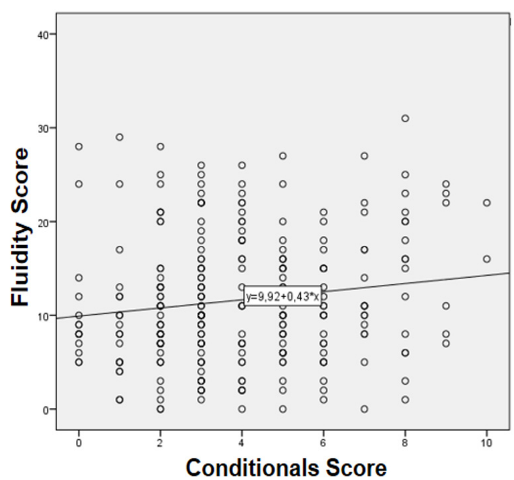

Figure 6: *Linear trend conditionals over fluidity*

Note: (1) N=275, (2) R^2 lineal = 0,021, (3) Conditionals Scale = 0 to 12 pts., (4) Scale Fluidity= 5 to 40 pts.

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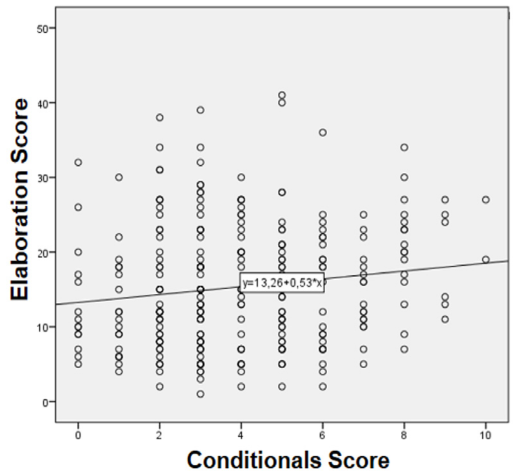

Figure 7: *Linear trend conditionals over elaboration*

Note: (1) N=275, (2) R^2 lineal = 0,020, (3) Conditionals Scale = 0 to 12 pts., (4) Scale Elaboration= 0 to 46 pts.

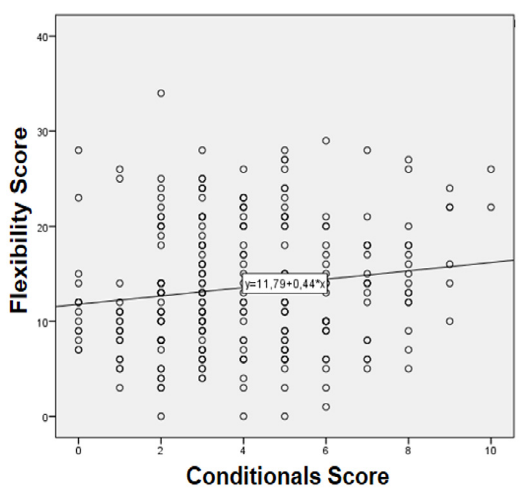

Figure 8: *Linear trend conditional over flexibility*

Note: (1) N=275, (2) R^2 lineal = 0,020, (3) Conditionals Scale = 0 to 12 pts., (4) Scale Flexibility= 4 to 28 pts.

As can be seen in the eight figures, *loops* and *conditionals* have an influence on the four dimensions of creative thinking: *originality, fluidity, elaboration* and *flexibility*. This is displayed by the slope in each graph. While the slope's inclination is minor, it still corroborates that the dimensions *loops* and *conditionals* influence the dimensions of creative thinking.

At a statistical level, each relationships' percentage explanatory is corroborated by observing the results obtained by the R^2, which is understood as the percentage of variation in the answer that the model explains, as well as interpreting the equation of the straight line used in this analysis, represented in its classic form of y= a +b*x.

6.1. Analysis of the loops dimension

Loops showed greater explicative power over *elaboration*, obtaining an R^2 = 4%; in other words, for each correct answer in the *loops* dimension, the *elaboration* dimension score increased an average of 0.85 points.

The *fluidity* dimension obtained an R^2 = 2%, which means that for each correct answer in the *loops* dimension, the *fluidity* dimension score increased an average of 0.51 points.

The *originality* dimension obtained an R^2 = 2%; for every correct answer in the *loops* dimension, the *originality* dimension score increased an average of 2.4 points.

Finally, the *flexibility* dimension obtained an R^2 = 1%, which means that for each correct answer in the *loops* dimension, the *flexibility* dimension score increased an average of 0.4 points.

6.2. Analysis of the conditionals dimension

Conditionals presented a similar explicative power, though not as strong as *loops*. The *elaboration* dimension obtained an R^2 = 2%; for each correct answer in the *conditionals* dimension, the elaboration dimension score increased an average of 0.53 points.

The *fluidity* dimension obtained an R^2 = 2%; for each correct answer in the *conditionals* dimension, the fluidity dimension score increased an average of 0.43 points.

The *originality* dimension obtained an R^2 = 1%; for each correct answer in the *conditionals* dimension, the *originality* dimension score increased an average of 1.89 points.

Finally, the *flexibility* dimension obtained an R^2 = 1%; for every correct answer in the *conditionals* dimension, the *flexibility* dimension score increased an average of 0.44 points.

The low explicative percentages in the studied relationships were expected, as the relationship between the different studied dimensions is nonlinear. However, low R^2 percentages are not a sign of a lack of relationship between the variables. To obtain greater R^2 percentages, more demographic variables must be added to the model, such as students' gender, age or type of educational establishment. Nevertheless, these types of variables were not included as they are not relevant for addressing the specific relationship between the computational thinking and creative thinking dimensions examined in this study.

In summary, *loops have a greater impact on the creative thinking dimension. than conditionals*

Loops have the greatest effect on elaboration, followed by fluidity, originality and flexibility.

Conditionals affect elaboration, fluidity and originality to the same degree, and flexibility to a lesser degree.

7. Discussion

In order to address the results obtained in this study, three topics will be considered: a) the general impact of computational thinking on creative thinking, b) the relationship between the computational thinking dimensions and those of creative thinking and c) the degree of influence that the computational thinking dimensions have on the creative thinking dimensions.

a. As can be observed in the different results obtained by this study, *computational thinking impacts creative thinking*. These results agree with those obtained by Villadiego, López and Sierra, (2015); Bustillo and Garaizar (2016); Silva (2016); Santoyo (2016) and Salamanca y Badilla, (2018), who similarly addressed this issue and obtained the same results, especially when using the block-based educational programming software Scratch.

b. When analyzing in detail the different relationships generated between computational thinking and creative thinking, there were two dimensions of computational thinking that stood out against the others: *loops and conditionals. These dimensions have a significant relationship with the four creative thinking dimensions: originality, fluidity, elaboration and flexibility*.

   These results also agree with Villadiego, López and Sierra, (2015); Bustillo and Garaizar (2016); Silva (2016); Santoyo (2016) and Salamanca and Badilla, (2018), who all addressed this issue. The authors concluded that when computational thought is stimulated, creative thought is also stimulated through the dimensions *originality, fluidity, elaboration and flexibility*. However, they did not specify which computational thinking dimensions were related to creative thinking.

c. As for the degree of influence that the computational thinking dimensions have on the creative thinking dimensions, *loops and conditionals have greater influence on the creative thinking dimensions. Elaboration receives the most influence, followed by fluidity, originality and finally, flexibility*.

These results partially agree with those obtained by Villadiego, López and Sierra (2015), who concluded that after stimulating computational thinking, the creative thinking dimension that was most influenced was *fluidity*, followed by *flexibility* and then *elaboration*.

Similarly, Santoyo (2016) reported the same situation; the most impacted creative thinking dimensions were *fluidity, la originality and elaboration*.

Furthermore, Silva (2016) studied the same topic, and concluded that stimulation of computational thinking influenced the four dimensions of creative thinking (*originality, fluidity, flexibility and elaboration*), but did not determine a hierarchy as was detailed in the present study.

As can be seen, most of the results obtained by this study agree with other similar experiences, which leads us to confirm that computational thinking and its stimulation are related to the development of creative thinking.

However, to effectively guide educational processes that stimulate creative thinking through computational thinking, it is important to pay special attention to the strategies that are developed in the dimensions identified as *loops* and *conditionals*. The results reveal that they appear to be the basis for promoting the stimulation of creative thinking.

8. Conclusions

The objective of this study was to determine which computational thinking dimensions are related to creative thinking dimensions in secondary education students.

In conclusion, the computational thinking dimensions addressed in this study, *loops* and *conditionals*, are significantly related to the four dimensions of creative thinking called *originality, fluidity, elaboration and flexibility*.

Following this, it was concluded that the other computational thinking dimensions addressed in this study, *directions* and *functions*, are not significantly related to the creative thinking dimensions of *originality, fluidity, elaboration* and *flexibility*. However, this does not make them less important when generating an educational strategy whose objective is to stimulate creative thinking through computational thinking.

As for the computational thinking dimensions' degrees of influence, *loops* were shown to have more of an influence on the four creative thinking dimensions (*originality, fluidity, elaboration* and *flexibility*) than *conditionals*.

Of the four creative thinking dimensions addressed in this study, *elaboration* was most influenced by *loops* and *conditionals*, followed by *fluidity*, then *originality* and finally *flexibility*.

As stated throughout this study, reflection on and analysis of computational and creative thinking are imperative for facing the society's future problems from new perspectives (Resnick, 2009b; Papert and Harel, 1991).

Computational and creative thinking are some of the most relevant skills for the 21st Century, as they, permit facing the challenges brought forth by the future society and world of work (World Economic Forum, 2018).

Both skills will be a fundamental pilar for facing tomorrow's world. Therefore, it is necessary to address them from different perspectives, especially those associated with education, and how to effectively stimulate them. Because of this, the present study sought to go into depth on this topic and have a greater understanding of how these skills are related, as well as provide a starting point for the generation of educational strategies that wish to address them.

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