

Development of creative skills of students as a result of the use of ICT tools

Desarrollo de habilidades creativas de los estudiantes como consecuencia del uso de herramientas TIC

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Resumen

La siguiente investigación cuasi experimental de orden cuantitativo, descriptivo y comparativo tiene como objetivo establecer la existencia relacional (estado, factores y diferencias significativas) entre el uso de una herramienta TIC de modelado CAD 3D y las habilidades creativas desarrolladas por los estudiantes del programa de formación Tecnólogo en Mantenimiento Mecatrónico de Automotores del SENA. Se estableció una muestra compuesta por dos grupos (Experimental y Control) con una prueba previa (Pretest ECG), seguido del estímulo o tratamiento al grupo experimental (Intervención modelado CAD 3D) y el grupo control sin estímulo. Finalmente se realizó una prueba posterior (Posttest ECG). De acuerdo con los indicadores evaluados por el instrumento ECG, los sujetos que trabajaron con el modelado CAD 3D desarrollaron las habilidades creativas asociadas a los indicadores evaluados: elaboración (El), conectividad temática (Ct), conectividad expansiva (Ce), fantasía (Fa), habilidad gráfica (Hg), sentido del humor (Sh) y fluidez gráfica (Fg). El puntaje total (Pt), no es considerado como un indicador de habilidad gráfica del ECG, pero brinda una perspectiva holística de los resultados obtenidos de las pruebas, donde se pudo apreciar un aumento en la media, indicando que el uso del modelado CAD 3D desarrolla habilidades creativas en los individuos.

Palabras clave: creatividad, diseño; modelado sólido; CAD 3D; ambientes creativos; innovación; relación.

Abstract

The following quasi-experimental research of quantitative, descriptive, and comparative order aims to establish the relational existence (state, factors, and significant differences) between the use of an ICT tool of 3D CAD modeling and the creative skills developed by students of the training program Technologist in Automotive Mechatronics Maintenance of SENA. A sample composed of two groups (Experimental and Control) was established with a pre-test (Pretest ECG), followed by the stimulus or treatment to the experimental group (3D CAD modeling intervention) and the control group without stimulus. Finally, a posttest (Posttest ECG) was performed. According to the indicators evaluated by the ECG instrument, the subjects who worked with the 3D CAD modeling developed the creative abilities associated with the evaluated indicators: elaboration (El),

thematic connectivity (Tc), expansive connectivity (Ec), fantasy (Fa), graphic ability (Ga), sense of humor (Sh) and graphic fluency (Gf). The total score (Ts) is not considered as an indicator of the graphic ability of the ECG, but it provides a holistic perspective of the results obtained from the tests, where an increase in the mean could be appreciated, indicating that the use of 3D CAD modeling develops creative skills in individuals.

Keywords: creativity; design; solid modeling; 3D CAD; creative environments; innovation; relationship.

1. Introduction

The identification of aspects that develop creativity in students is necessary to understand the complex tasks that emerge in the creative ingenuity of the individual, in the current educational scenarios that call for a renewed teaching, with dyes of “creativity” and transdisciplinary nuances (De la Torre, 2009). This is how the ICT tool of 3D CAD modeling can be a creative strategy tool, which establishes how to communicate what is going to be said through a message represented by means of digital three-dimensional drawing, leading the student to build knowledge and develop skills oriented by the teacher. This reason justifies the need to investigate the relational existence between 3D CAD modeling and the creative skills developed in students of technological level of the Servicio Nacional de Aprendizaje SENA in the Center for Design and Industrial Technological Innovation (Colombia). Consequently, the research question has been generated: Do SENA technologist-level students develop creative skills because of their work with the 3D CAD modeling ICT tool?

Scrivener, Stones, and Cassidy (cited in Bonnardel; Zenasni, 2010), state that CAD modeling generally forces designers to generate early external representations of the represented object, using highly structured elements, which do not correspond to a spontaneous creation process. Whitefield (1986) suggests that CAD systems exert a negative influence on creative design, in fact, he states that students in CAD modeling require more knowledge-focused more on the use of computer technology than on the creative design task, casting doubt on the claim that CAD gives the designer the freedom to be more creative compared to manual design methods. On the other hand, authors such as Mustáamal, Norman, Jabor, and Buntat (2012), Lieu and Sorby (2011), Sönmez (2013), Cho (2016), Lee and Yan (2016) among others, establish that in different university disciplines (there are no studies on these aspects in technical careers) the use of CAD tools can enhance the creative skills of students or designers. It is clear that, without taking into account too much background, the two positions or hypotheses of the research are presented. The first one is the one whose authors affirm that the Computer-Aided Design (CAD), does not force the individuals to the use of complex structures of the thought, and there is therefore no development of the creativity. The second position is the one whose authors affirm that Computer-Aided Design (CAD) forces individuals to use complex structures of thought, and that therefore there is a development of creativity.

2. Theoretical framework

Based on the project proposal, the background, and other information consulted, it is convenient to establish the main theoretical strands that make up the research, based on the proposed model of Figure 1, will correspond to each of the main themes of the theoretical framework, which are: creativity, thinking and human development, and education. Each of these are converging to focus on the development of students’ creative skills because of their work with 3D CAD modeling (Garcia, 2019).

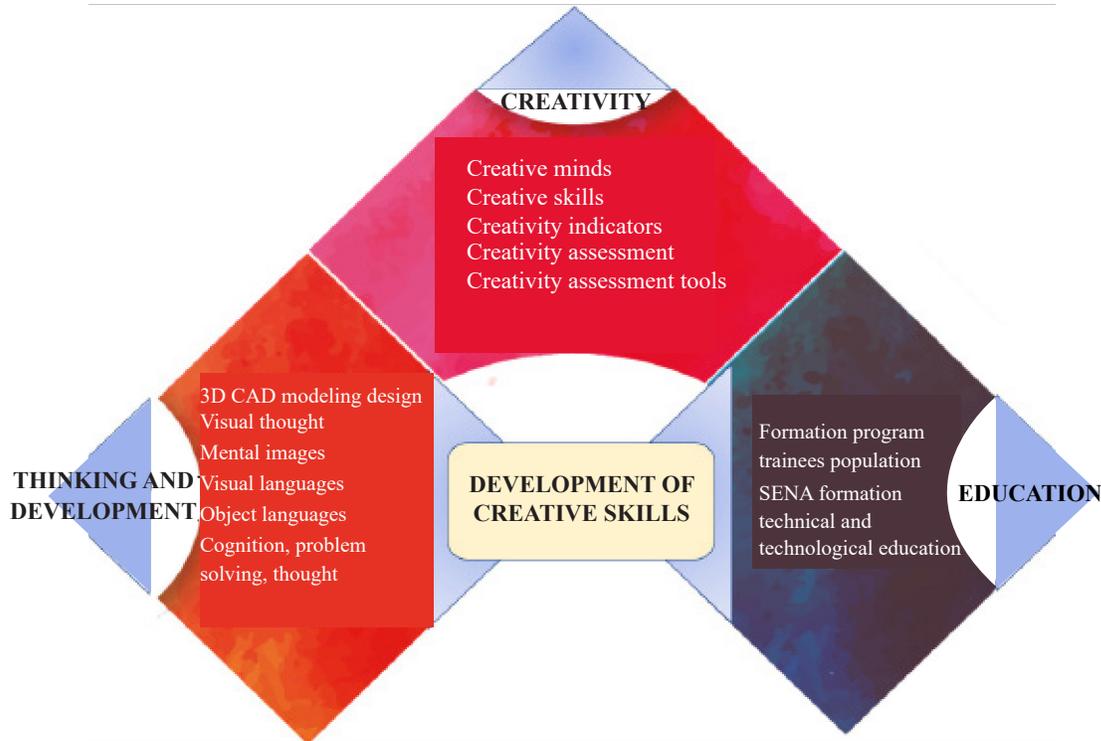


Figure 1. Model for the development of the theoretical framework

Source: Garcia (2019).

2.1. Thought and human development

The cognitive processes associated with human development are the capacities that the individual acquires to know and control the environment in which he or she is going to live. Cognitive development involves the enhancement of intelligence, which is closely related to other mental functions such as attention, memory, thinking, and perception (Ovejero, 2013). Piaget (cited in Ovejero, 2013) explains it through mental processes, focusing on the fact that development has the functions of organization (psychological processes organized in coherent systems) and adaptation (assimilation, accommodation, adjustment, or modification of new experiences to existing schemes).

Perception starts with the reception of the sensory stimulus of objects and their characteristics, and then gives them meaning. The purpose of visual perception is to locate and elucidate the nature of objects in a three-dimensional space, so that the individual can guide their behavior by the environment (Villafañe; Mínguez, 2014). Ovejero (2013) states that thinking is a cognitive process where the person can analyze, understand, coordinate ideas, images, concepts, symbols, among others, to solve problems, reason, and create. Visual thinking was coined by Armheim (1986) who states that its most important operations come directly from the individual's perception of the world (mental images), in which vision serves as the sensory system par excellence that targets and constitutes the cognitive processes. For Lieu and Sorby (2011), visual thinking is the process of expanding creative ideas using visual cues and feedback. Visual cues can take the form of sketches or computer models. In turn, this type of thinking makes use mainly of visual and object language, and according to the type of materiality can be carried out by images of images, non-iconic images, iconic images, or by objects, which are perceived by imaginary reconstruction (Valdés de León, 2011).

2.2. Creativity

Creativity is having ideas and communicating them (De la Torre, 1991) and attends to biocultural periods of the individual. With a cognitive approach to creativity, we speak of the term “domain-specific creativity” which refers to the individual’s ability to manifest creative skills in different areas or curricular domains (Bermejo; Ferrando; Sainz; Soto; Ruiz, 2014).

Authors such as Baer (1994), Gardner (2010), Bermejo, Ferrando, Sainz, Soto, and Ruiz (2014) argue that cognitive development comes on the one hand from different domains of knowledge and on the other hand from the skills and knowledge that underlie performance in each domain or area of knowledge and are not related to others in other domains. There are areas of application that offer diversity and pluralism in creative manifestations, among which are the plastic and visual arts (De la Torre; Ibañez, 2000). Morea and Soraire (2005), propose creativity from two perspectives. The first one is creativity and visual arts and the second one corresponds to creativity and industrial design. In the second, creativity is considered as a broad and alternative associative thinking that has the possibility of representation and symbolization in a divergent way, taking advantage of knowledge through the structuring of various mental routes. Creativity in design is expressed in the production of something, with novelty and coherence, which depending on the context can vary the perception of innovation, value, originality, novelty, among others (Sánchez, 2006).

To identify an individual as creative, researchers such as Boden, Perkins, and Sternberg (cited in Gardner, 2010) suggest creative skills such as: identifying problems and solution spaces, clues to bring results, evaluating alternative solutions, use of time and energy resources, decision making and reflection processes on creative processes. Miller (2009), Bermejo, Ferrando, Sainz, Soto, and Ruiz (2014) establish skills such as idea generation, metaphorical and analogical thinking, perspective-taking or manipulation of ideas, imagination, incubation, and flow of ideas. Research by Guilford, Löwenfeld, and Torrance (cited in Ibañez, 1998) coincide in some fundamental traits, which allow on the one hand to diagnose creative skills. This diagnosis is carried out by means of creativity indicators and factors, which are evaluated with the use of instruments. De la Torre & Ibañez (2000) and Ibañez (1998) address each of the factors, which are: sensitivity to problems, fluency or productivity, mental flexibility, originality, hypothesis formulation, redefining, product improvement, establishing remote or forced relationships, elaboration, synthesis, abstraction, analysis, organization, and communication, among others. Authors such as Guilford, Torrance, Gowan, Yamamoto, among others (cited in Ibañez, 1998) have developed different tests that allow the diagnosis and evaluation of the indicators associated with the creative abilities of individuals.

Given the thematic nature that has laid the foundations of this research, the use of computers as support tools for creative conceptual design has focused on 3D CAD modelers. For Chi-Fu and Jerz (cited in Aguilar; López; De las Heras; Gámez, 2014) they are working tools in graphic expression and development of visual-spatial thinking with representation systems as a language. There is then a taxonomy of the different approaches to the development of tools to support conceptual design presented by O’Sullivan (1991), and Chaur (2004), who classify into six categories, from which the approach based on geometric models is selected. This approach seeks to make geometric representations of the critical details of the product, allowing speed in the presentation of ideas and the possibility of representing functions.

2.3. Education

From the perspective of education, De la Torre and Violant (2006) refer to the creative capacity of students as an aspect of social and educational demand, also mentioning that the wealth of a country is beginning to be valued in terms of innovative potential and creativity has gone from being an individual attribute to social good. The curricular designs of the training programs should consist of an integrated conception, based on the contributions of the systemic and cognitive sciences, whose interdisciplinary fields provide principles,

foundations, and characteristics to rethink pedagogical knowledge regarding learning, design, and organization of teaching. According to the constructivist school, learning is a self-regulated process of resolution of cognitive conflicts, which appear in the student when facing the exercise of problem-solving (De la Torre; Violant, 2006).

For the Ministry of National Education (2008), the professional technician, due to their training, is qualified to work in occupations of an operational and instrumental nature; develops competencies related to the application of knowledge in a set of work activities, carried out in different contexts with a high degree of specificity; almost always deals with normalized or standardized operations, approaching theory more as a basis for the technical object than as an object of study. A technologist develops competencies related to the application and practice of knowledge in a set of more complex and non-routine work activities, and in most cases performed in different contexts. Theory takes on more preponderance and meaning to conceptualize the technological object that allows them to visualize and intervene in design and improvement processes. All their training corresponds to practices in the management of collection, processing, evaluation, and qualification of information to plan, program, and control processes that find in theory reasons and foundations for creativity and innovation.

3. Materials and methods

3.1. Design

Quasi-experimental study of correlational scope, whose positive approach allowed the treatment of quantitative information. According to the research design shown in Figure 2, the study sample consisted of an experimental group and a control group. A Pretest (ECG test) was carried out on both groups. The Experimental Group was given a stimulus or treatment that corresponds to the teaching of 3D CAD modeling (independent variable) and the Control Group was not intervened. Finally, both groups were given a Posttest (ECG test) to evaluate the creative skills (dependent variable), allowing inferences to be made regarding the changes presented as a result of the stimulus.

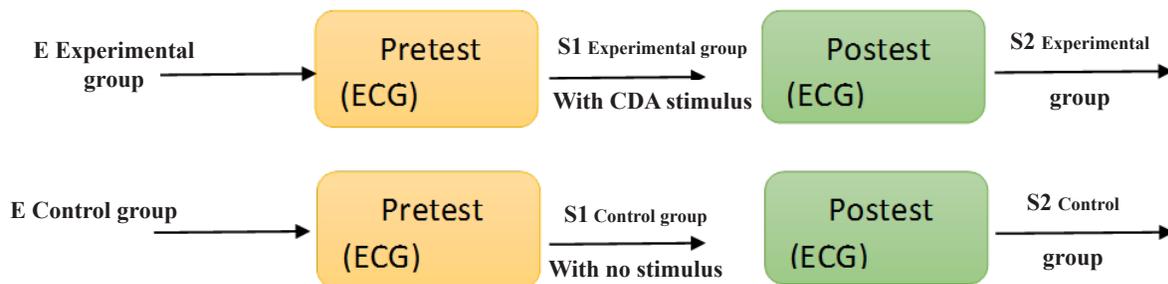


Figure 2. Outline of Research Design
Source: Garcia (2019).

3.2. Population and sample

This research was conducted with the apprentices of the technologist level training program in Automotive Mechatronic Maintenance (Servicio Nacional de Aprendizaje SENA, 2016), of the Centro de Diseño e Innovación Tecnológica Industrial de Dosquebradas (Colombia). As a finite portion of technological level students, the population size was $N = 209$ apprentices (Servicio Nacional de Aprendizaje SENA, 2017), working with a maximum permissible error adopted of 14 % and statistical significance of 10 %. By simple random sampling, a sample represented by 29 individuals (Control Group) and 29 individuals (Experimental Group) was determined (Garcia, 2019).

3.3. Environment

To adjust the homogeneity of the sample, students had to meet the following selection criteria:

- People aged between 17 and 30 years old.
- Those who are studying technology at SENA.
- That the training program to which the students belong does not consider in the curricular structure of the same, the subject of CAD modeling (in this case the training program in Automotive Mechatronic Maintenance of the SENA Centro de Diseño e Innovacion Tecnologica Industrial of the city of Dosquebradas (Servicio Nacional de Aprendizaje SENA, 2016).
- That the program to which the selected population belongs is correlated to knowledge and instrumental management (a characteristic that ensures a population with interests in the management of ICT in the graphic specificity).
- That students must be enrolled in the academic stage of the program.

3.4. Interventions

To evaluate the creative abilities in the pretest and posttest on the subjects that make up the experimental and control groups, the Evaluation of Graphic Creativity (ECG) instrument was used, which corresponds to a psychopedagogical test developed by De la Torre and Violant (2006), based on the same theoretical assumptions of the Abreaction Test to Evaluate Creativity TAEC, which has reliability for the indicators above 0.89 and external validity (De la Torre, 1991). The ECG allows the evaluation of 11 indicators associated with the creative abilities of individuals: resistance to closure (Rc), figurative completeness (Fc), originality (Or), elaboration (El), linear connectivity (Lc), thematic connectivity (Tc), expansive connectivity (Ec), fantasy (Fa), graphic ability (Ga), sense of humor (Sh), graphic fluency (Gf) and total score (Ts). The latter is not an indicator of creativity, but it allows us to have a holistic perspective of the results obtained by the individual and by the group.

For the development of the stimulus in the experimental group (manipulated independent variable) corresponding to 3D CAD Modeling, SENA has important inputs for the legal delimitation of the project, allowing the use of different CAD modelers (SENA, 2017), among which the 3D CAD modeling software Solidworks® has been selected. The intervention has consisted of training or complementary training, whose duration was approximately 2 months (40 hours), with an hourly intensity of 2 sessions per week and each session lasted 2 hours. Modules or topics were selected with the objective that the student interacts directly with three-dimensional geometric modeling techniques in Solidworks®, so that it is consistent with everything raised in the research project in relation solely and exclusively to 3D CAD modeling. The sessions that were carried out were: modeling of geometric parts from sketches, modeling of solids with the use of operations extrude protrusion, extrude cut, rounding, chamfer, hollowing, protrusion and cut by revolution, covering, sweeping, symmetry, assembly of parts, and modeling by surfaces. Each one of the modules was developed in an interrelated way, with the use of challenges or concrete objectives for the students to model parts or solids that can be based on images or photos of the object (challenge), three-dimensional images of the finished object in Solidworks® or physical objects for the students to interact with.

3.5. Statistical analysis

It was carried out with the SPSS® computational tool and was divided into three stages:

- Exploration of variables allows validating that the results obtained do not present missing cases (Garcia, 2019), and a test of independence of variables was performed with the statistical index “chi-square”, where it is concluded that the test was not statistically significant (asymptotic significance values above 0.05), therefore, the variables are independent (Aguayo, 2004). Finally, the comparison of data obtained in the tests is shown (Table 3).
- State of the creative skills: by means of the parametric analysis of the t-test it is determined whether the differences between the means of the experimental and control groups are statistically significant, which will allow us to identify the state of the creative skills of the individuals working with 3D CAD modeling.
- To establish the significant differences: a descriptive frequency distribution analysis has been carried out for both groups, with each of the indicators evaluated in the ECG instrument, for the control group the pretest has been taken into account, and for the experimental group the posttest has been taken into account, in this way the significant differences between the creative abilities of the individuals who appropriate the 3D CAD modeling (experimental group), with the control group can be established.

4. Results

Pretest and posttest evaluation results for the experimental and control groups.

Table 1 and Table 2 show the results obtained for the indicators evaluated by the ECG instrument for each of the 29 subjects in the Experimental and Control groups.

4.1. Data comparison

The following comparisons were carried out and are shown in Table 3:

- Pretest and posttest comparison for the experimental group.
- Pretest and posttest comparison for the control group.
- Pretest (experimental group) and pretest (control group) comparison.
- Post-test (experimental group) and post-test (control group) comparison.

Table 1.
Pretest and Posttest results Control group

#	Pretest evaluation of graphic creativity											Post-test evaluation of graphic creativity														
	Te	Rc	Cf	Or	EI	Cl	Ct	Ce	Fa	Hg	Sh	Fg	Pt	Te	Rc	Cf	Or	EI	Cl	Ct	Ce	Fa	Hg	Sh	Fg	Pt
1	26	5	9	3	5	7	8	3	3	3	0	1,77	46	14	6	9	4	7	9	9	9	3	5	0	4,36	61
2	34	2	8	1	1	0	0	0	3	2	0	0,50	17	15	0	9	2	2	2	0	0	3	2	0	1,33	20
3	16	1	6	3	2	4	2	0	3	2	1	1,50	24	16	2	6	1	1	0	0	0	2	1	0	0,81	13
4	27	7	8	2	2	1	0	0	3	2	0	0,93	25	19	6	9	2	2	2	4	0	3	2	2	1,68	32
5	32	1	9	3	2	9	9	9	5	2	2	1,59	51	20	0	9	4	5	6	9	9	3	4	0	2,45	49
6	23	3	9	2	1	0	0	0	3	2	0	0,87	20	22	0	9	3	5	0	0	0	3	3	0	1,05	23
7	32	3	5	2	1	2	0	0	3	2	0	0,56	18	29	3	5	2	4	2	4	0	3	3	0	0,90	26
8	47	1	6	2	2	0	0	0	3	2	0	0,34	16	24	0	5	1	2	0	0	0	3	2	0	0,54	13
9	44	9	1	2	3	0	0	0	3	3	1	0,50	22	25	0	6	2	2	0	0	0	3	3	0	0,64	16
10	48	2	6	2	3	0	0	0	3	3	0	0,40	19	25	2	6	2	2	0	0	0	3	3	0	0,72	18
11	55	5	9	3	3	0	0	0	5	2	1	0,51	28	38	1	9	7	9	4	9	9	7	7	0	1,63	62
12	58	2	9	7	9	9	9	9	7	7	0	1,17	68	39	2	7	8	9	7	9	3	8	8	2	1,62	63
13	49	0	6	4	7	0	6	0	5	3	1	0,65	32	47	7	4	1	1	0	6	0	3	2	1	0,53	25
14	34	7	9	2	1	9	9	9	4	2	0	1,53	52	42	5	7	2	1	0	0	0	3	2	0	0,48	20
15	44	0	8	2	3	0	0	6	3	2	0	0,55	24	41	0	8	2	1	0	0	0	3	3	0	0,41	17
16	55	4	6	3	4	0	3	0	5	3	0	0,51	28	40	0	9	4	5	0	9	9	3	4	3	1,15	46
17	22	2	6	2	3	0	0	0	3	2	0	0,82	18	39	2	9	2	3	0	3	0	3	3	0	0,64	25
18	21	0	6	2	3	5	7	3	3	2	0	1,48	31	38	5	6	3	6	2	6	0	3	6	0	0,97	37
19	40	2	6	3	7	5	6	0	3	4	0	0,90	36	38	3	6	2	7	6	6	0	3	6	0	1,03	39
20	35	2	7	1	2	2	0	0	3	2	0	0,54	19	34	2	9	3	2	0	0	0	3	2	0	0,62	21
21	48	2	6	4	7	4	6	0	5	4	0	0,79	38	30	6	9	5	3	0	6	0	5	4	0	1,27	38
22	13	4	6	1	1	0	0	0	3	2	0	1,31	17	29	3	8	3	3	0	0	0	4	3	0	0,83	24
23	22	2	8	2	1	0	0	0	3	2	0	0,82	18	19	3	9	2	2	0	0	0	4	3	0	1,21	23
24	10	2	9	3	1	0	9	9	3	2	2	4,00	40	16	3	9	2	1	0	9	9	3	3	2	2,56	41
25	10	0	9	2	2	7	9	9	4	2	2	4,60	46	13	0	9	1	1	8	9	9	3	2	0	3,23	42
26	14	0	9	1	1	9	9	9	2	1	0	2,93	41	11	0	6	2	1	4	6	6	4	2	1	2,91	32
27	32	8	5	2	1	3	2	0	2	2	0	0,78	25	10	4	8	1	1	8	9	9	2	1	0	4,30	43
28	13	9	8	2	1	8	8	9	2	2	0	3,77	49	7	7	8	1	1	8	7	6	2	1	0	5,86	41
29	13	8	3	1	1	0	0	0	2	1	0	1,23	16	8	8	5	1	1	0	2	0	2	1	0	2,50	20

Source: own elaboration.

For the first two comparisons, the analysis carried out in each case corresponds to the t-test for related samples, because in these cases both the pretest and the posttest were carried out on the same group. It can be observed that the comparison made in the pretest and posttest for the control group did not present significant differences in the indicators evaluated, except for the graphic ability (Hg) and in the comparison made between the pretest (experimental group) and pretest (control group) no significant differences were presented in any of the indicators evaluated. For the last two comparisons, the t-test analysis was performed for independent samples, since, in these cases, the results obtained in the tests of independent groups are compared.

Regarding the comparison made in both groups in relation to the post-test (data in the right column of Table 3), according to Sabino (1980), it is possible that the significant differences were presented by saturation of the pre-test and post-test tests carried out on the same group. This is possibly due to the fact that people tend to get tired when they are submitted to answer the same test several times, which could cause responses in the post-test based on what was answered in the pre-test. Bias may also be present in those people who obtain a very good score in the pretest, but for reasons of chance, they tend to lower their score. This case also occurs inversely (those who start with a low score, raise it in the second test). Another aspect to consider is the period between the pretest and posttest, people can remember how they responded in the first ECG test, creating a false appreciation of what they really are (Hernández; Fernández; Baptista, 2014). In the comparison made between the pretest (experimental group) and pretest (control group) shown in Table 3, there were no significant differences in any of the indicators evaluated.

Table 2.
Pretest and Posttest Experimental Group

#	Pretest evaluation of graphic creativity													Post-test evaluation of graphic creativity												
	Te	Rc	Cf	Or	El	Cl	Ct	Ce	Fa	Hg	Sh	Fg	Pt	Te	Rc	Cf	Or	El	Cl	Ct	Ce	Fa	Hg	Sh	Fg	Pt
1	37	0	8	1	1	0	0	0	2	2	0	0,38	14	27	1	9	2	4	0	2	3	4	4	0	1,07	29
2	5	9	0	0	0	0	0	0	1	0	0	2,00	10	26	9	6	2	7	0	6	0	4	4	0	1,46	38
3	35	2	9	3	3	2	0	3	2	3	0	0,77	27	24	2	9	3	7	2	7	9	5	5	4	2,21	53
4	31	1	8	5	6	0	0	0	5	4	4	1,06	33	23	3	8	5	7	0	8	6	5	7	4	2,30	53
5	34	0	9	3	3	0	9	9	4	3	0	1,18	40	18	3	9	3	5	6	9	9	7	7	0	3,22	58
6	29	3	4	2	3	4	0	3	2	2	0	0,79	23	15	0	9	2	2	7	8	6	5	3	2	2,93	44
7	36	8	9	7	7	5	9	9	6	5	0	1,81	65	34	4	9	6	7	3	9	9	8	4	0	1,74	59
8	65	7	8	6	5	0	6	0	5	4	0	0,63	41	32	4	8	5	7	0	9	9	7	5	4	1,81	58
9	27	2	8	2	1	2	7	6	3	3	0	1,26	34	29	4	8	3	4	3	4	3	4	4	0	1,28	37
10	33	2	6	2	1	0	3	0	3	3	1	0,64	21	26	2	5	2	4	2	5	0	4	4	0	1,08	28
11	28	2	7	1	1	5	5	3	3	2	0	1,04	29	26	1	8	2	1	0	0	0	4	3	3	0,85	22
12	44	2	9	1	1	0	0	0	3	2	0	0,41	18	26	0	9	1	2	0	0	0	3	3	0	0,69	18
13	32	4	9	1	2	5	5	3	3	3	0	1,09	35	25	1	9	1	3	4	9	9	3	4	0	1,72	43
14	54	1	9	1	4	0	0	0	3	3	0	0,39	21	25	1	7	2	4	0	8	9	3	4	0	1,52	38
15	32	2	9	3	7	3	9	9	4	4	0	1,56	50	25	7	8	3	8	0	9	9	3	7	2	2,24	56
16	10	5	5	2	2	0	0	0	2	3	0	1,90	19	25	7	7	2	4	0	7	9	3	3	0	1,68	42
17	33	1	9	3	1	5	6	6	4	3	0	1,15	38	24	0	9	2	3	2	6	9	4	3	0	1,58	38
18	47	1	8	2	1	7	9	9	3	2	0	0,89	42	24	4	9	4	8	4	9	9	5	7	2	2,54	61
19	18	4	8	1	2	2	6	0	2	2	2	1,61	29	24	1	7	1	2	0	0	0	3	3	0	0,71	17
20	27	8	2	7	7	0	0	0	5	4	2	1,30	35	21	8	8	3	7	0	8	6	7	5	0	2,48	52
21	25	4	6	1	1	0	0	0	2	2	0	0,64	16	22	4	6	1	2	0	5	0	2	2	0	1,00	22
22	47	2	8	2	3	0	0	3	3	3	2	0,55	26	36	2	8	2	2	0	0	6	2	3	0	0,69	25
23	11	2	6	2	2	0	5	0	3	3	0	2,09	23	15	3	6	2	3	0	6	3	4	3	3	2,20	33
24	47	4	8	3	6	4	4	9	5	6	0	1,04	49	25	3	8	1	1	4	5	3	3	3	0	1,24	31
25	35	0	8	2	3	8	8	9	3	3	1	1,29	45	20	2	8	2	5	3	9	9	3	5	4	2,50	50
26	24	5	5	1	2	0	0	0	3	2	0	0,75	18	40	6	5	3	3	2	6	0	3	3	0	0,78	31
27	49	6	4	2	5	0	0	0	3	4	1	0,51	25	10	8	3	2	4	0	0	0	3	4	2	2,60	26
28	35	7	7	3	3	0	0	0	3	2	1	0,74	26	15	7	7	3	4	0	7	6	4	4	3	3,00	45
29	8	2	6	1	1	0	0	0	2	2	0	1,75	14	14	0	7	4	7	5	7	3	4	6	2	3,21	45

Source: own elaboration.

Table 3.
Summary of results obtained in the comparisons made

Variable	Pretest-Posttest control group		Pretest-Posttest experimental group		Pretest (experimental and control groups)		Post-test (experimental and control groups)	
	Significant differences		Diferencias significativas		Significant differences		Significant differences	
	Yes	No	Yes	No	Yes	No	Yes	No
TE	x		x				x	
RC		x		x		x		x
CF		x		x		x		x
OR		x		x		x		x
EL		x	x			x	x	
CL		x		x		x		x
CT		x	x			x		x
CE		x	x			x	x	
FA		x	x			x	x	
HG	x		x			x	x	
SH		x	x			x	x	
FG		x	x			x		x
PT		x	x			x	x	

Source: own elaboration.

4.2. Parametric analysis of the t-test

The results obtained from the parametric t-test analysis (Table 4) determine whether the differences between the means of the experimental and control groups are statistically significant. This allowed to identify the state of creative skills of individuals working with 3D CAD modeling (Experimental group). All analyses were conducted at a significance level of 0.05 or 95 % confidence interval percentage, i.e., when the t-value is calculated using the SPSS® statistical package, the bilateral significance is provided as part of the results and should be less than 0.05.

According to the results shown in Table 4, the indicators that presented significant statistical differences (bilateral significance less than 0.05) were: elaboration (El), thematic connectivity (Tc), expansive connectivity (Ec), fantasy (Fa), graphic ability (Gh), sense of humor (Sh), graphic fluency (Gf) and total score (Ts). On the other hand, the indicators that did not present significant statistical differences (bilateral significance greater than 0.05) were: resistance to closure (Rc), figurative completeness (Fc), originality (Or), linear connectivity (Lc).

Table 4.
Comparison pretest - posttest experimental group

STUDY GROUP	DIFFERENCES PAIRED					T	GL	SIG. (BILATERAL)	
	Meean	Standard deviation	Mean standard error	95% confidence interval of the difference					
				Lower	Upper				
EXPERIMENTAL GROUP	Processing Time (min) - Pretest - Processing Time (min) - Posttest	8,34	14,07	2,63	2,99	13,69	3,19	28	0,00
	Resistance to closure - Pretest - Resistance to closure - Posttest	-0,03	2,14	0,39	-0,85	0,78	-0,08	28	0,93
	Figurative Completion - Pretest - Figurative Completion - Posttest	-0,58	1,91	0,35	-1,31	0,14	-1,64	28	0,11
	Originality - Pretest - Originality - Posttest	-0,13	1,30	0,24	-0,63	0,35	-0,57	28	0,57
	Elaboration - Pretest - Elaboration - Posttest	-1,48	2,45	0,45	-2,41	-0,54	-3,24	28	0,00
	Linear Connectivity - Prest - Linear Connectivity - Posttest	0,17	2,42	0,44	-0,74	1,09	0,38	28	0,70
	Thematic Connectivity - Pretest - Thematic Connectivity - Posttest	-2,65	4,01	0,74	-4,18	-1,12	-3,56	28	0,00
	Expansive Connectivity - Prest - Expansive Connectivity - Posttest	-2,17	3,75	0,69	-3,59	-0,74	-3,11	28	0,00
	Fantasy - Pretest - Fantasy - Posttest	-0,93	1,30	0,24	-1,42	-0,43	-3,83	28	0,00
	Graphical Ability - Pretest - Graphical Ability - Posttest	-1,31	1,67	0,31	-1,94	-0,67	-4,22	28	0,00
	Sense of Humor - Pretest - Sense of Humor - Posttest	-0,72	1,66	0,30	-1,35	-0,09	-2,34	28	0,02
	Graphic Fluency - Pretest - Graphic Fluency - Posttest	-0,72	0,84	0,15	-1,04	-0,40	-4,63	28	0,00
	Total Score - Pretest - Total Score - Posttest	-9,86	12,17	2,26	-14,49	-5,23	-4,36	28	0,00

Source: own elaboration.

4.3. Distribution of descriptive frequencies

To establish the significant differences between the creative abilities of the individuals under investigation who appropriate 3D CAD modeling (experimental group) and the control group, a descriptive frequency distribution analysis of both groups was carried out for each of the indicators evaluated in the ECG instrument. For the present research, those ECG indicators that presented significant statistical differences in the experimental

group were considered: elaboration (EI), thematic connectivity (Tc), expansive connectivity (Ec), fantasy (Fa), graphic ability (Ga), sense of humor (Sh), graphic fluency (Gf) and total score (Ts). For the control group, the pretest was considered and the posttest for the experimental group.

With the use of 3D CAD modeling, the mean increased from 2.76 to 4.38 (Figure 3) for the indicator elaboration (EI). Out of 37.90 % of students who presented a score equal to 1, only 6.90 % remain with this same rating after working with 3D CAD (Table 5). From 3.40 % of students who obtained the maximum score (9), with the use of 3D CAD Modeling it increased to 6.90 % (Table 5).

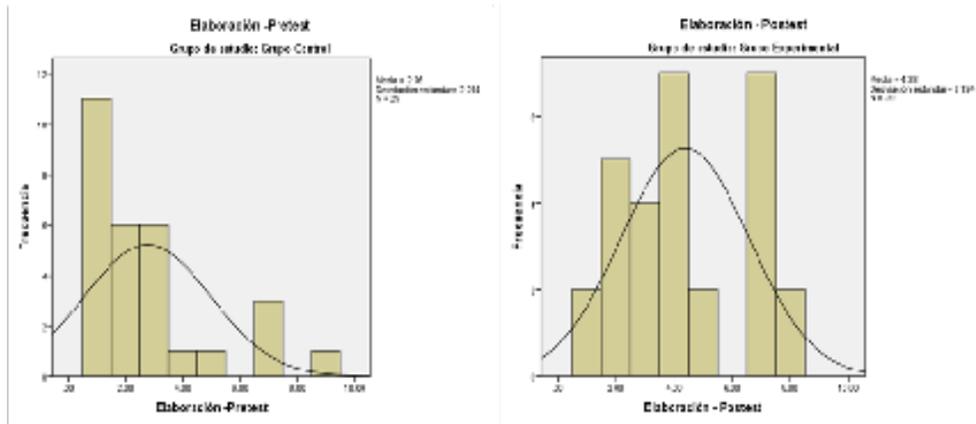


Figure 3. Histograms Pretest -Posttest elaboration (EI)
Source: own elaboration.

Table 5.
Pretest-Posttest frequencies of elaboration indicator (EI)

		Frequency	Percentage	Cumulative percentage
Control Group - Pretest	1	11	37,90	37,90
	2	6	20,70	58,60
	3	6	20,70	79,30
	4	1	3,40	82,80
	5	1	3,40	86,20
	7	3	10,30	96,60
	9	1	3,40	100
	Total	29	100	
Experimental Group - Posttest	1	2	6,90	6,90
	2	5	17,20	24,10
	3	4	13,80	37,90
	4	7	24,10	62,10
	5	2	6,90	69
	7	7	24,10	93,10
	8	2	6,90	100
	Total	29	100	

Source: own elaboration.

For the thematic connectivity (Tc), the use of 3D CAD modeling increased the mean from 3.52 to 5.79 (Figure 4). Also, the standard deviation in the group that worked with CAD modeling has more uniformity with respect to the control group. Now, from 48.30 % of subjects who presented an evaluation equal to 0, with the use of the 3D CAD model this has been reduced to 17.20 % (Table 6), which has represented one of the great differences in this indicator. In addition, it can be observed how the control group presented an accumulated percentage of 60 % with scores less than or equal to 6, while the experimental group with 48.30 % showed a valuation less than or equal to 6 in the individuals. This indicates that, for the experimental group, the number of subjects who presented scores higher than 6 increased.

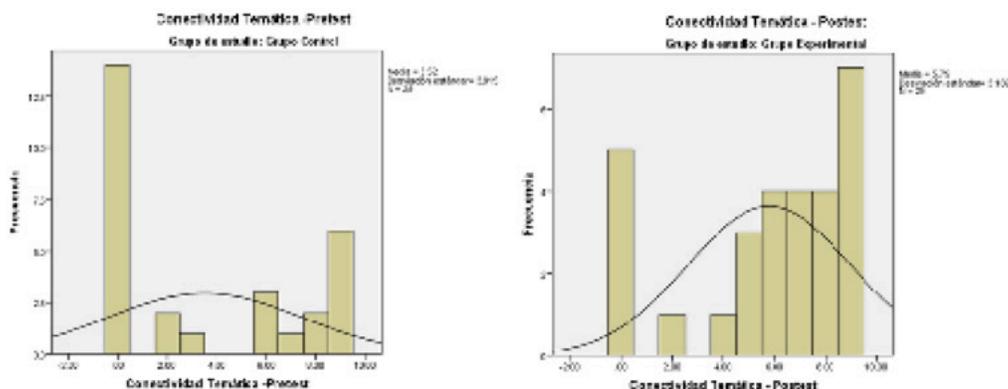


Figure 4. Histograms Pretest -Posttest thematic connectivity (Tc)
Source: own elaboration.

Table 6.

Pretest-Posttest frequencies of thematic connectivity indicator (Tc)

		Frequency	Percentage	Valid Percentage	Cumulative Percentage
Control Group	0	14	48,30	48,30	48,30
	2	2	6,90	6,90	55,20
	3	1	3,40	3,40	58,60
	6	3	10,30	10,30	69
	7	1	3,40	3,40	72,40
	8	2	6,90	6,90	79,30
	9	6	20,70	20,70	100
	Total	29	100	100	
Experimental Group	0	5	17,20	17,20	17,20
	2	1	3,40	3,40	20,70
	4	1	3,40	3,40	24,10
	5	3	10,30	10,30	34,50
	6	4	13,80	13,80	48,30
	7	4	13,80	13,80	62,10
	8	4	13,80	13,80	75,90
	9	7	24,10	24,10	100
Total	29	100	100		

Source: own elaboration.

The expansive connectivity (Ce), using 3D CAD modeling presented an increase in the mean from 2.59 to 4.97 (Figure 5). Also, it allowed to establish that 65.50 % of the subjects who presented a score equal to 0 presented a decrease to 27.60 % (Table 7), explained in another way, of 19 subjects with a score equal to 0, after using the 3D CAD modeling only 8 subjects still present this same valuation. Likewise, there was an increase in the number of subjects with a score equal to 9, from 24.10 % to 37.90 % (Table 7).

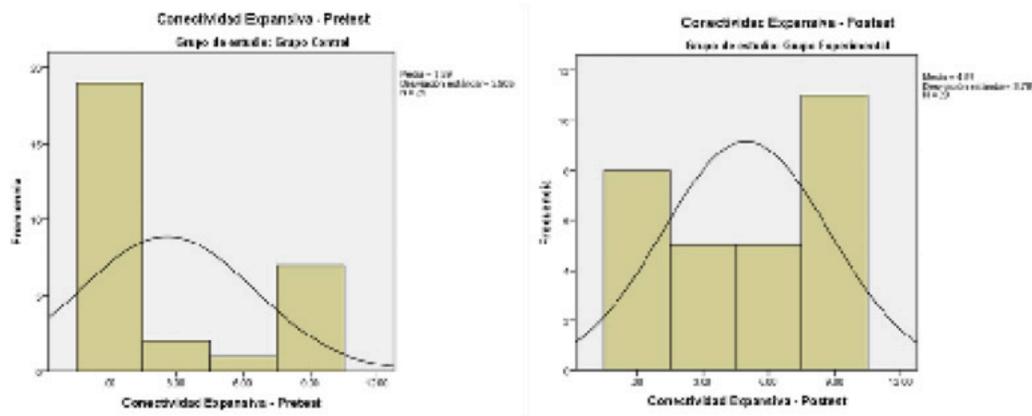


Figure 5. Histograms Pretest -Posttest expansive connectivity (Ec)
Source: own elaboration.

Table 7.
Pretest-Posttest frequencies of expansive connectivity indicator (Ec)

	Frequency	Percentage	Valid Percentage	Cumulative Percentage
Control Group	2	4	13,80	13,80
	3	17	58,60	72,40
	4	2	6,90	79,30
	5	5	17,20	96,60
	7	1	3,40	100
	Total	29	100	100
Experimental Group	2	2	6,90	6,90
	3	10	34,50	41,40
	4	9	31	72,40
	5	4	13,80	86,20
	7	3	10,30	96,60
	8	1	3,40	100
Total	29	100	100	

Source: own elaboration.

For fantasy (Fa), an increase in the mean could be observed, going from 3.41 to 4.10 (Figure 6), largely due to the increase in the percentage of subjects who obtained a rating equal to 4, where, for the control group corresponds to 6.90 %, while for the experimental group corresponds to 31 % (Table 8). An increase was also observed in the number of subjects who presented an evaluation equal to 7, going from 1 to 3 subjects. In addition, even though the standard deviation is more uniform for the control group with respect to the experimental group, for the first group, there was an accumulated percentage of 72.40 % with a rating less than or equal to 3, while for the second group this percentage decreased to 41.40 % (Table 8).

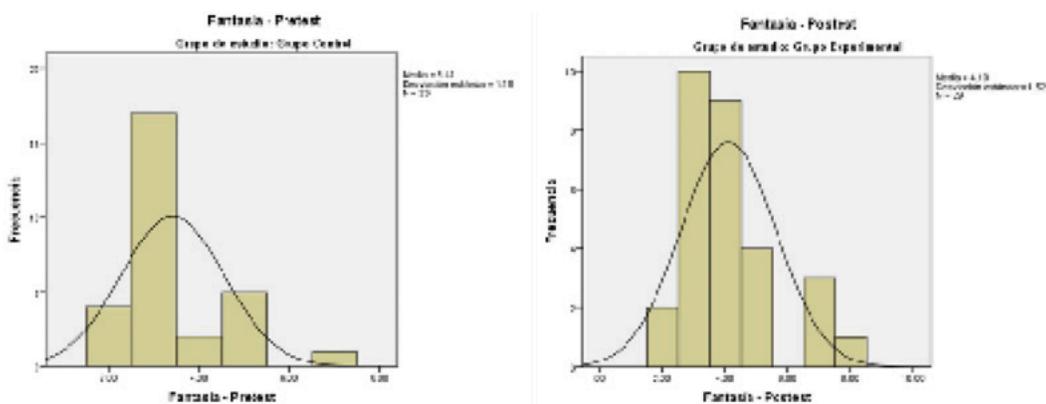


Figure 6. Pretest -Posttest histograms fantasy (Fa)

Source: own elaboration.

Table 8.

Pretest - Posttest frequencies fantasy indicator (Fa)

		Frequency	Percentage	Valid Percentage	Cumulative Percentage
Control Group	0	22	75,90	75,90	75,90
	1	4	13,80	13,80	89,70
	2	3	10,30	10,30	100
	Total	29	100	100	
Experimental Group	0	17	58,60	58,60	58,60
	2	5	17,20	17,20	75,90
	3	3	10,30	10,30	86,20
	4	4	13,80	13,80	100
	Total	29	100	100	

Source: own elaboration.

The graphic ability (Ga) presented a considerable increase in the mean, going from 2.41 to 4.21 (Figure 7). Even though the standard deviation is more uniform for the control group with respect to the experimental group, it can be seen that 72.40 % (cumulative percentage) of the subjects in the control group presented a score less than or equal to 2, while for the experimental group this figure was reduced to only 3.40 % of the subjects (Table 9). Furthermore, of the 3.40 % of the subjects who presented a rating equal to 7, thanks to the CAD modeling, this figure has increased to 13.80 % (Table 9).

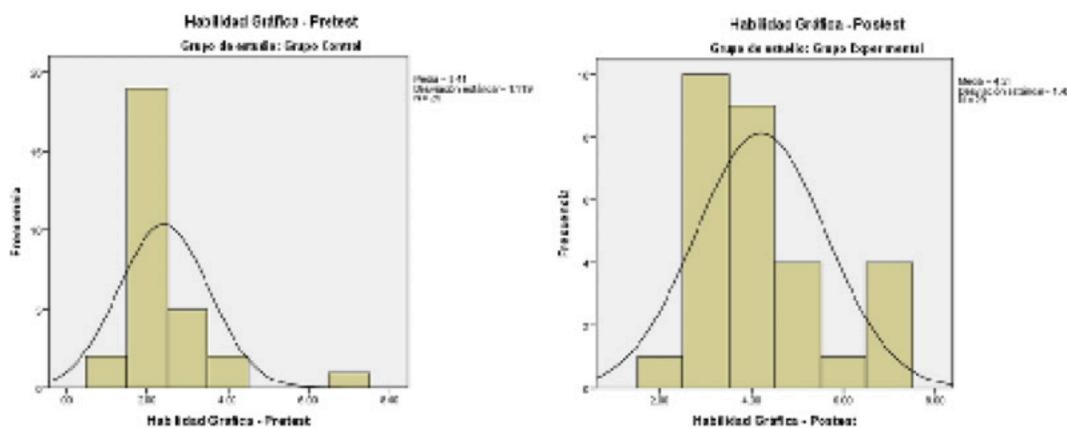


Figure 7. Histograms Pretest -Posttest graphic ability (Ga)

Source: own elaboration.

Table 9.

Pretest-Posttest frequencies for graphic ability indicator (Ga)

		Frequency	Percentage	Valid Percentage	Cumulative Percentage
Control Group	1	2	6,90	6,90	6,90
	2	19	65,50	65,50	72,40
	3	5	17,2	17,20	89,70
	4	2	6,90	6,90	96,60
	7	1	3,40	3,40	100
	Total	29	100	100	
Experimental Group	2	1	3,40	3,40	3,40
	3	10	34,50	34,50	37,90
	4	9	31	31	69
	5	4	13,80	13,80	82,80
	6	1	3,40	3,40	86,20
	7	4	13,80	13,80	100
Total	29	100	100		

Source: own elaboration.

The sense of humor (Sh), despite having lower means with respect to the other indicators, presented significant differences, since an increase in the mean from 0.34 to 1.21 is observed (Figure 8). While the Control group had 75.90 % of the subjects with a score equal to 0, the experimental group had a percentage of 58.60 % (Table 10). In addition, there is an increase in the subjects who presented a valuation greater than 2, which for the control group corresponds to 0 %, while for the experimental group there is 10.30 % with a valuation of 3 and 13.80 % with a valuation of 4, presenting an increase of 24.10 % (Table 10).

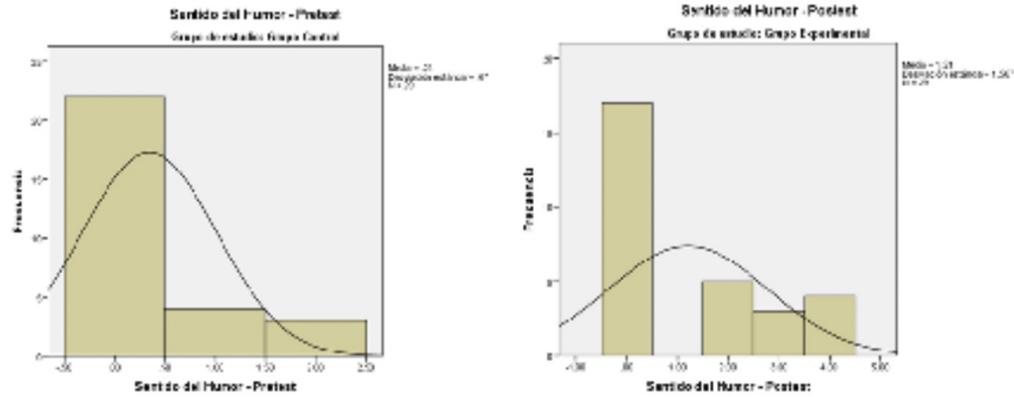


Figure 8. Pretest -Posttest histograms of sense of humor (Sh)

Source: own elaboration.

Table 10.

Pretest-Posttest frequencies for the sense of humor indicator (Sh)

		Frequency	Percentage	Valid Percentage	Cumulative Percentage
Control Group	0	22	75,90	75,90	75,90
	1	4	13,80	13,80	89,70
	2	3	10,30	10,30	100
	Total	29	100	100	
Experimental Group	0	17	58,60	58,60	58,60
	2	5	17,20	17,20	75,90
	3	3	10,30	10,30	86,20
	4	4	13,80	13,80	100
	Total	29	100	100	

Source: own elaboration.

Graphic fluency (Gf) presented an increase in the mean, from 1.30 to 1.80. Another important aspect is that the standard deviation had greater uniformity for the experimental group (0.79) with respect to the control group (1.12) (Figure 9).

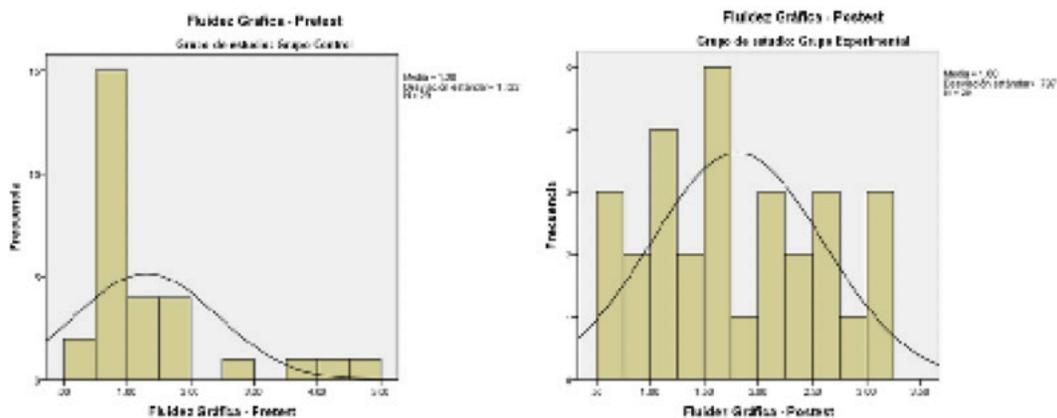


Figure 9. Pretest -Posttest histograms of graphic fluency (Gf)

Source: own elaboration.

Although it is not considered as an indicator of ECG graphic ability, the total score (Ts) provides a holistic perspective of the results of the ECG tests applied to both groups since it corresponds to the sum of each of the scores obtained in the 11 indicators evaluated. It can be seen how there is an increase in the mean, registering 30.48 for the Control group, while for the group that used the 3D CAD modeling (experimental group) a mean of 39.72 is registered (Figure 10). In general terms, this indicates that the use of 3D CAD modeling positively stimulates the development of creative skills in individuals.

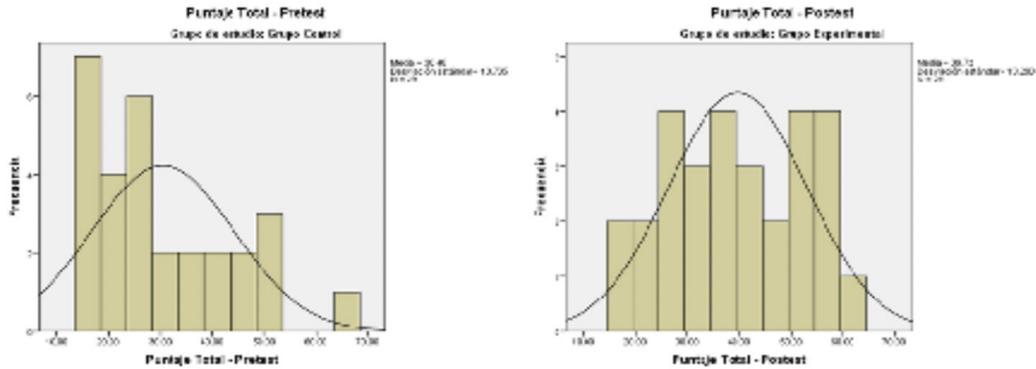


Figure 10. Pretest -Posttest histograms total score (Ts)

Source: own elaboration.

5. Discussion

The elaboration indicator (El) is associated with the individual with more analytical skills and who pays more attention to the secondary elements and skills to express their ideas in greater detail (De la Torre; Violant, 2006). 3D CAD Modeling provides the tools that contribute to the individual to be able to represent more attractive, expressive, aesthetic, and rich in suggestions finishes. These finishes require more dedication and effort. The individual can pay more attention to secondary elements or details, in other words, modeling contributes to the subject to be more analytical, thus improving their ability to evaluate alternatives in problem-solving (Garcia, 2019).

Regarding thematic connectivity (Ct), an indicator associated with the individual's ability to imaginatively represent the scene he/she wants to draw before doing it, with the ability to exceed the stimulus beyond what the graphic structure suggests (De la Torre; Violant, 2006), individuals who work in 3D CAD modeling, according to Armheim (1986) integrate independent elements in a composition, imaginatively representing the model they want to make before doing it and with the ability to exceed the stimulus beyond what the graphic structure suggests. This allows developing the creative ability to establish relationships between elements, referring to the connection between previous ideas or situations towards a new situation or problem that arises (Garcia, 2019).

In relation to expansive connectivity (Ec), an indicator that allows us to recognize in the individual expansion, initiative, and risk acceptance, a certain degree of non-conformism and tolerance to the complex, willingness to break limitations and perceptual blocks, prejudices, conventionalisms, frames of reference, thus making possible to find new solutions to problems (De la Torre; Violant, 2006). CAD 3D modeling allows the individual to find new solutions to problems, developing traits typical of creative people such as initiative, risk acceptance, a certain degree of nonconformity, and tolerance to complexity. This allows the individual to find uses, functions, and applications different from the usual ones, expanding the range of possible solutions to many problems (Garcia, 2019).

For fantasy (Fa), an indicator that allows us to investigate the boundaries of divergent thinking (De la Torre; Violant, 2006), suggests that individuals who spatially represented objects through 3D CAD modeling, took originality to its extreme limits between the relevance of the answer and extravagance, thus managing to give as many possible answers without taking into account the plausibility and without judging all the alternatives generated, characteristic of highly creative people (Garcia, 2019).

Graphic ability (Ga), an indicator associated with the capacity of the individual standing out in originality, connectivity, and fluency (De la Torre; Violant, 2006). 3D CAD modeling allows the individual to possess improved skills in their dexterity and ability to translate mental images into graphic language, where they also tend to stand out in originality, connectivity, and fluency. The development of this indicator allows the subject to show creative skills to generate a large number of answers and solutions to a problem posed (Garcia, 2019).

Sense of humor (Sh), an indicator associated with the individual's ability to generate associations of independent themes or situations (De la Torre; Violant, 2006), with the use of 3D CAD modeling, the individual develops abilities to generate independent associations joined unexpectedly thanks to the flexibility of thought and the use of forced relationships. In addition, the individual categorizes the answers; the products, he can respond to a wide variety of categories and disciplines, this allows not only one argument to be offered, but many and varied (Garcia, 2019).

Graphic fluency (Gf), an indicator associated with the facility that individuals have to express multiple ideas with a given code (De la Torre; Violant, 2006). 3D CAD modeling improves the individual's ability to express multiple ideas with a given code, as long as it is in a specific domain skill. As the factor that most influenced the evaluation of this indicator was time, it can be concluded that the use of 3D CAD modeling, allowed the evaluated group (experimental group) to improve their ability to offer a greater flow of ideas in a shorter amount of time, generating an intense and creative work in a state of focused awareness (Garcia, 2019).

Different factors that develop creativity in individuals with the use of 3D CAD modeling are identified, such as thinking and visual abstraction by visual clues offered by 3D models, expanding creative ideas from those clues, and, according to Villafañe and Mínguez (2014) are given using mental mechanisms such as active exploration, completion, simplification, synthesis, correction, selection, and conceptualization. Problem-solving is initially addressed through mental images, especially visual images in the exercises proposed for 3D CAD modeling, the individual must resort to these images to model and solve the problem posed, starting mainly from a stimulus that is presented through the visual language described by Acaso (2009), which can be a graphic information, a visual product, plastic development, iconic text, a visual artifact, or a visual representation.

6. Conclusions and recommendations

The sample under study consisted of an experimental and a control group, both groups were given a pretest (ECG test), the experimental group was given a stimulus or treatment that corresponded to the teaching of 3D CAD modeling (independent variable), and the control group was given no intervention. Finally, both groups were given a post-test (ECG test) to evaluate their creative skills (dependent variable), which allowed inferences to be made regarding the changes presented because of the stimulus.

The alternative hypothesis is validated where Computer-Aided Design (CAD) forces individuals to the use of complex structures of thought, and therefore there is a development of creativity, which according to the indicators evaluated by the ECG instrument correspond to:

- Elaboration (El).

- Thematic connectivity (Tc).
- Expansive connectivity (Ec).

- Fantasy (F).

- Graphic ability (Ga).

- Sense of Humor (Sh).

- Graphic fluency (Gf).

The total score (Ts), although not considered an indicator of ECG graphic ability, provides a holistic view of the overall test results. An increase in the mean could be seen. Overall, this indicates that the use of 3D CAD modeling generates significant development in creative skills for individuals.

In the exercises proposed for 3D CAD modeling, the individual must resort to mental images especially of visual type (Armheim, 1986), to be able to model and solve the problem that arises, starting mainly from a stimulus that is presented through visual language that for Acaso (2009) can be a graphic information, visual product, plastic development, iconic text, visual artifact, or a visual representation. The development of creative skills is favored when CAD 3D modeling makes use of three-dimensional representations used in the visual language of the program itself; these representations are the configuration tools (size, shape, color, lighting, texture, etc.), and organization (composition of modeling techniques) which give the digital three-dimensional support to each of the components of the solid (Acaso, 2009).

CAD 3D modeling, as a means of graphic expression, allows communication, intervention, transformation, and elaboration on a study environment (object), contributing to the development of design thinking described by Jimenez (1998), who defines it as a process of conceptualization, projection or productive thinking unveiled by visualization, intuition, imagination, generation of ideas, and creativity. The 3D CAD modeling allows solving problems that require spatial information, which is achieved through mental images, especially visual, and is evident when it is intended to distribute spaces, locate specific objects in specific locations, etc. In the exercises proposed for 3D CAD modeling, the individual must resort to these images to be able to model and solve the problem that arises, starting mainly from a stimulus that is presented through the visual language described by Acaso (2009), which can be a graphic information, visual product, plastic development, iconic text, visual artifact, or a visual representation.

To further explore the factors that develop creative skills in students, several research approaches are proposed below:

- According to the Multiple Intelligences test (Sánchez; Andrade, 2014), it is possible to establish the relationship between the creative skills developed by the student with the use of 3D CAD modeling and the intelligences with higher scores. This will allow identifying factors that develop creative skills according to the type of intelligence. The author, in his study with the use of 3D CAD modeling carried out the application of tests such as the guide to identify the multiple intelligences of Kertész (cited by Sánchez González & Andrade Esparza, 2014).
- Another future research that can yield valuable information corresponds to identify the learning styles of the individual (Sanchez; Andrade, 2014), in this way will contribute to the identification of the factors that enhance or coerce the creative abilities of students with the use of 3D CAD modeling, the author in the present project conducted the Felder's learning styles inventory test (cited in Sanchez; Andrade, 2014).

- To corroborate or counteract the results obtained in this research, the use of tests other than the ECG instrument to measure creative abilities is suggested.
- It is also recommended to approach the study of visual or spatial perception (Gutierrez, 1992), to establish its relationship with the appropriation of 3D CAD modeling, an aspect that can directly influence the development of the creative skills of individuals.
- For intervening variables, it is proposed to identify the aspects of nutrition, mood, anxiety, and stress; to identify external aspects that stimulate or discourage the development of creative skills with the use of 3D CAD modeling.
- It is proposed to carry out an analysis of the results obtained in this research, but from the comprehensive approach (of qualitative order).
- It is recommended to continue deepening in this type of studies, whose central axis is the use of other 3D CAD modelers but considering other modelers different from Solidworks®.

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