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Cooperative Learning on Promoting Creative Thinking and Mathematical Creativity in Higher Education

Aprendizaje Cooperativo para Promover el Pensamiento Creativo y la Creatividad Matemática en la Educación Superior

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Creativity is an indispensable competence for the future of higher education students. Creative thinking skills play an important role in modern society. Creativity is acknowledged as a crucial aspect of business, research and development or arts. This study presents the assessment results of an intervention using cooperative learning and the conventional teaching method in order to promote creative thinking in higher education. The design used was quasi-experimental pretest and posttest intervention using the Creative Intelligence test (CREA), with experimental and control groups of higher education students of the Communication and Multimedia course in a Linear Algebra class. The participants were 50 students from a Portuguese public university. Results showed that students who participated in the intervention scored significantly higher in the creativity test at the end of the intervention and indicated that creative thinking, and divergent thinking abilities in particular, can be enhanced through the kind of intervention that was proposed in the study.

Keywords: Creativity; Collaborative learning; Higher degree research; Critical thinking; Mathematics.

La creatividad es una competencia indispensable para el futuro de los estudiantes de educación superior. Las habilidades de pensamiento creativo juegan un importante papel en la sociedad moderna. La creatividad es reconocida como un aspecto fundamental en el campo de los negocios, la investigación y desarrollo y las artes. Este estudio presenta los resultados de la evaluación de una intervención que utiliza el aprendizaje cooperativo y el método de enseñanza convencional para promover el pensamiento creativo en la educación superior. El diseño utilizado fue cuasi-experimental con la aplicación del test de Inteligencia Creativa (CREA) antes y después de la intervención, con grupos experimentales y de control de estudiantes de educación superior del curso de Comunicación y Multimedia en una clase de Álgebra Lineal. Los participantes del estudio fueron 50 estudiantes de una universidad pública portuguesa. Los resultados mostraron que los estudiantes que participaron en la intervención obtuvieron puntuaciones significativamente más altas en el test de creatividad al final de la intervención e indicaron que el pensamiento creativo, y las habilidades de pensamiento divergentes en particular, pueden mejorarse a través del tipo de intervención que se propuso en el estudio.

Descriptores: Creatividad; Aprendizaje colaborativo; Investigación de grado superior; Pensamiento crítico; Matemáticas.

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1. Literature review

The social and technological evolution of 21st century society requests for the need to prepare young people for a life in constant and rapid change. Employers are very critical on young people's readiness to enter the labour market. They consider that many employees do not possess the knowledge and skills to be competitive in a rapidly changing world. Since the world is not likely to return to stable times with permanent jobs and steady economic development, the key competences needed in the future have to reflect more than before, as has insisted, flexibility, risk-taking, creativity and innovation (Hargreaves, 2003).

Today, creative thinking skills play an important role in modern society. Creativity is acknowledged as a crucial aspect of business, research and development, arts (Kim & Song, 2012), and many other social domains like Science and Technology (e.g., Badran, 2007).

According to Casner-Lotto and Barrington (2006), the Partnership for 21st Century Skills, a consortium focused on infusing 21st Century Skills into education, conducted a study to determine the skills employers found essential to performing in today's workplace. From the employers' responses, the study grouped a list of twenty skills and categorized them as basic skills or applied skills. In such list, we find nine basic skills and eleven applied skills. One of the basic skills is 'Mathematics' and one of the applied skills is 'Creativity/Innovation'. Thus, we verified the importance that Mathematics and creativity should have in any curricula of the Science and Technology area in higher education. Also, Johnson and Johnson (2014; p. 841) highlight: the 21st century brings four important challenges in which cooperation plays a central role: (1) a rapidly increasing global interdependence that will result in increasing local diversity as well as more frequent and intense conflicts, (2) the increasing number of democracies throughout the world, (3) the need for creative entrepreneurs, and (4) the growing importance of interpersonal relationships that affect the development of personal identity

Therefore, this determines a challenge for formal education in general and lifelong learning in particular. It is important that the education system adjust to the changes that are emerging and aims to prepare society and people for new changes, promoting innovation and creativity.

Education systems have consequently been shifting from paradigms focused on knowledge to others that focus on developing competencies that mobilize knowledge, skills and attitudes, suitable to the demanding challenges of these times, which require educated and socially integrated citizens: young adults capable of thinking critically and creatively, adapted to a society of multiliteracies, empowered for action either autonomously or in collaboration with others, in a global world that has to be sustainable (Ministério da Educação, 2017).

1.1. Creativity

Nowadays in any profession, creativity and creative thinking must be factors to take into account, because only then we can be different, capable of playing the profession with innovation, creating new things and solving problems in certain situations (Ball, 2003; Costello, 2000). We can then question what creativity is, and in particular what is mathematical creativity and what influence can have on a future career.

It is difficult to find an exact definition of the term creativity. According to Cardoso and others (2015), the creativity is an essential ingredient of modern societies. It is associated with progress in the general welfare of the population level, since it may give answers to the present and future requirements. Klausen (2010) presents some recent attempts to define and understand creativity, informed by the methods and debates of contemporary philosophy. According to Starko (2014), creativity is defined as the development of ideas that are novel and appropriate, as well as Hennessey and Amabile (2010). Also, Torrance (1970) suggested that creativity is the ability to produce something novel, something that is unique and original. Sternberg and Lubart (1996) are of the opinion that creativity is an ability to generate behavior, and Brown (1989) and Runco (2007) consider creativity as an attribute of a product while others consider it a trait or state of an individual.

About the concept of creativity, Kaufmann (2003) agrees that there should be made the distinction between novelty on the stimulus and novelty on the response end. According with this proposal, Beghetto and Kaufman (2007) claimed to approach creativity as a distinction between 'Big C' (eminent) creativity and 'Little c' (everyday) creativity (Louca et al., 2014). For Hennessey and Amabile (2010, p. 572) the 'Big C' (eminent) creativity is 'relatively rare displays of creativity that have a major impact on others' and the 'Little c' (everyday) creativity is related with 'daily problem solving and the ability to adapt to change'. According to Louca and others (2014, pp.133-134), 'Big C' (genius-level) creativity is associated with truly original ideas and ground breaking ideas and 'Little c' creativity has two main reason to be seen as appropriate and valuable for the development of students' creativity: 'it's acknowledged significance as a driver in the new or digital economy' and 'technological and digital advances brought with them a change in the way students learn'.

Similarly, there is no specific formal definition of mathematical creativity, although in the literature there is an attempt to present a set of various definitions for its concept, with the aim of better understanding and clarification. There are studies about the conceptions that the students have about these terms: creativity and mathematical creativity (Rodrigues et al., 2018a, 2018b).

Several authors in the literature present different definitions of mathematical creativity (Haylock, 1987; Sriraman, 2005). However, such definitions are vague and ambiguous. In the work of Nadjafikhah, Yaftian and Bakhshalizadeh (2012), we can find some definitions and characteristics of mathematical creativity. These authors state that a creative act in mathematics could consist of creating a new fruitful mathematical concept, discovering an unknown relation and reorganizing the structure of a mathematical theory. Creativity in mathematics, at the school level, is generally related to problem solving and or problem posing.

Harpen and Sriraman (2013) explore (with students from China and USA) high school students' creativity in mathematics by analyzing their problem-posing abilities in geometric scenarios. Their study has indicated that learners should be 'presented with problem-posing opportunities in different areas of school mathematics, with the goal of stimulating creativity in intra-mathematical thinking' and 'diverse mathematical thinking to generate problems that are contextually different' (p. 218).

According to Leikin (2013), the evident importance of mathematical creativity follows from the characteristics of mathematics, as a scientific area with advances in different branches 'which research mathematicians bring to life, reflect human intellect' that allows 'sustaining social technological and scientific progress in a variety of areas through offering scientists and Hi-tech specialists a powerful apparatus and models for the analysis of situations, prognoses and processes' (p. 386).

Most current researchers tend to agree that creative potential can be fulfilled and maximized (Craft, 2001; Craft et al., 1997; Csikszentmihalyi, 1997; Gardner, 1983; Kaufman, & Beghetto, 2009; Nickerson, 1999; Plucker, Runco, & Hegarty, 2011; Richards, 2007). Moreover, it is widely accepted nowadays that creativity can be enhanced specifically through training (Amabile, 1996; Clapham, 1997; Scott, Leritz, & Mumford, 2004a, 2004b; Sannomiya & Yamaguchi, 2016).

Investigations (Leikin, 2009) in the area of mathematics have shown that students' creativity can be promoted through new teaching methodologies that pass through the implementation of investigative and exploratory nature tasks, where the student takes on a more active and autonomous role. According to Albert and Kim (2013), Ayele (2016), and Plucker, Beghetto and Dow (2004), a pedagogical practice that can support students' conceptual development of mathematics content is the problem solving. They understand that collaborative problem solving can be a medium to develop mathematical creativity. Collaborative problem solving is a method of mathematics pedagogy by which students work together in small groups scaffolding each other's mathematics learning, while working towards achieving a common goal. When students engage in collaborative problem solving, they create and maintain knowledge to help them make sense of the mathematics they are learning. Cooperative learning is crucial for better learning and achievement in mathematics (Ayele, 2016; Mehra & Thakur, 2008).

The creativity does not develop only for the learner, but also such development can happen through structured coaching and activity with others. This is the case of cooperative learning where students are trained how to perform as creative thinkers who make meaning of mathematics content for themselves and with others, which is a crucial idea for the development of students' mathematical creativity (Albert, & Kim, 2013).

1.2. Cooperative learning

Cooperative learning is often defined as a pedagogical strategy where small, heterogeneous groups of students are requested to work together for a given period to accomplish shared learning goals, fulfilled if all group members are committed to their assignments (Johnson, Johnson, & Smith, 2014).

Cooperative learning is a teaching and learning method that aims to achieve a common goal through collaboration with group members (Johnson, & Johnson, 1989). Students encourage and support each other, assume responsibility for their own and each other's learning, employ group related social skills, and evaluate the group's progress (Dotson, 2001). Working together also promotes the students' skills for their learning autonomy (Lopes & Silva, 2009; Zimmerman, 2000). It is an effective teaching method for students to acquire problem-solving skills, critical thinking skills and creativity instead of fragmentary knowledge acquisition.

Woo, Lee and Kim (2009) suggested that cooperative learning depends on not only group members' capability but also quantity and quality of interaction. Therefore, appropriate team composition strategies are necessary to enhance creativity within the group.

Many researchers have a tentative conclusion that heterogeneous group composition is more effective than homogeneous group composition (Sawyer, 2007). Also, group creativity is optimized when group members have different perspectives (Nemeth, & Kwan, 1985).

There are reports that discussion between team members increases probability of finding novel and appropriate solutions (Nemeth et al., 2004). However, Woo (2010) warned extreme diversity is harmful to group creativity. Based on his finding, he recommended that group composition through cognitive diversity is one of the most effective methods. Also, Kim (2007) suggested that different working styles maximize synergy among group members. In conclusion, heterogeneous group composition creates a complementary relationship among group members so that group creativity is maximized.

Cooperative learning, compared with competitive and individualistic learning, tends to increase the number of novel solutions to problems, results in the use of more varied reasoning strategies, generates more original ideas, and results in more creative solutions to problems (Hattie, 2009; Johnson, 2003; Johnson & Johnson, 1989, 2005, 2009). A collaborative learning environment encourages students to actively explore problems using their own ideas and strategies. Student contributions are contingent upon the creation of a supportive environment in which students feel comfortable to take risks in decision making, asking questions and defending ideas (Bray, 2011; Sharma, 2015).

The use of questioning technique, as reciprocal questioning and guided peer or cooperative-questioning (King, 1990, 1994), is crucial to encouraging students to improve their creative and critical thinking and become more active and prepares them for the current challenges of the society and the world. The questioning in the classroom leads to transformation of the students' thinking and ideas (King, 1994). Etemadzadeh, Seifi and Far (2013), for instance, assert that by incorporating higher-level questions into the classroom, students would be encouraged to effectively develop their critical thinking skills. Also, the questioning technique can promote the mathematical creativity (Runco, 1993; Sheffield, 2009). The creativity can be considered as a multifaceted construct involving both divergent and convergent thinking, and questioning attitude.

According to Louca and others (2014), the importance of educating for creativity in higher education can be derived from arguments in favour of a focus on student empowerment and employability. Then it is important to study innovative strategies that develop creativity in students' teaching-learning processes. The cooperative processes are essential to the development of creativity and creative thinking, helping in several areas of our life, such as 'design, engineering and invention, which can be both undercut and reinforced by competitive dynamics' (Louca et al., 2014, p. 142).

As long as we know, there is no study that has used Trade Questions cooperative method in order to promote the creative thinking in higher education. Therefore, we think that our study has originality in this education area and our research question is to evaluate the benefits of cooperative learning in the promotion of creative thinking in higher education. Our research aims to complement previous research on creativity not only in higher education but also in all levels of education, such as the works of Haylock (1987), Cheung and others (2004), Hongli (2004), Claxton, Pannells and Rhoads (2005), Garaigordobil (2006), Jackson and Shaw (2006), Oliver and others (2006), Sannomyia and Yamaguchi (2016), among others.

Our goal is to investigate if there is a relationship between the implementation in the classroom with students of higher education of an intervention program with the use of cooperative learning and the development of creativity and creative thinking.

2. Method

Participants

The participants were 50 students from a Portuguese public university that integrated two groups (experimental and control group) of the curricular unit of Linear Algebra of the 1st year of the Communication and Multimedia course. As for gender, 52% were male and 48% female.

The experimental group consisted of 23 students and the control group of 27. The average age was 20.2 years (SD = 3.1), ranging between 18 and 35.

Instruments

It was applied in pre-post-intervention moments the CREA Test, Creative Intelligence (Corbalán et al., 2003). The theoretical basis of the CREA test is supported by the independent factors of creativity (originality, fluency, flexibility, divergent production, and reformulation) and approaches to problem formulation, lateral thinking and the study of cognitive styles (Corbalán & Limiñana, 2010). To evaluate the openness and versatility of the creative psychological style, the CREA test uses a measurement based on the capacity of an individual to elaborate questions from a supplied visual stimulus. The CREA test is a timed four-minute divergent thinking test that contains a picture and asks respondents to generate questions about the picture. Responses are given in writing. A single score is based on the total number of appropriate responses. The test manual reports strong reliability, convergent validity with Guilford's divergent thinking tasks, and discriminant validity with academic aptitude measures in children and adults (Corbalán et al., 2003). The reliability of the CREA test result was sought. Inter-raters reliability was achieved by determining the value of the test according to its own definitions of creativity (Amabile, 1983). Raters were unaware of the purpose of the study, the contextual conditions in which the instruments were applied, the research questions and the objectives. The inter-rater reliability, using a Pearson's bivariate correlation, was $r = 0.95$, $p = 0.001$, which is well within the expected range (Amabile, 1990).

Procedure

The quasi-experimental design compared a control group using only conventional teaching method with an experimental group using conventional teaching method and cooperative learning activities. In the conventional teaching method, the students worked individually solving practice problems.

The CREA pretest was given to both experimental and control groups with the purpose of identifying their ability of creative thinking. The control and experimental groups were guided by the same teacher who had more than fifteen years of teaching experience in mathematics. The CREA posttest was also given to both experimental and control groups.

The students answered the CREA test, before (first theoretical-practical class) and after the intervention (last theoretical class), in the context of the classroom, being the teacher of the curricular unit present at the time of the application, which took 4 minutes.

Data were gathered in class, conducted by a properly trained psychologist. Participants were volunteers, and they did not receive economic retributions. Everyone signed an informed consent. Results confidentiality was securely guaranteed, as well as data anonymity, informing participants about the possibility of stopping responses at any moment of the assessment. The study obtained institutional endorsements. The intervention occurred in 7 of the 13 theoretical-practical lessons that lasted 2 hours each.

In the experimental group, students were grouped together as three or four member teams through heterogeneous grouping. In this group, an activity of cooperative learning was carried out in the middle of the theoretical-practical class using the Trade Questions cooperative method (Kagan, 1994; Lopes & Silva, 2009), which lasted 15 minutes of the total theoretical-practical class time (table 1). In the remaining time of the class the conventional teaching method was used in a similar way as in the control group.

Table 1. Syntax of trade questions method

STRUCTURE OF THE ACTIVITY	TASKS TO BE EXECUTED BY THE GROUP MEMBERS
Arrangement of heterogeneous groups with three or four elements by the teacher	The group chooses the clerk and the spokesperson
Presentation of a stimulus (drawing or a photo on Linear Algebra) by the teacher	Students in each of the cooperative groups elaborate as many questions as possible for four minutes (Divergent thinking- Fluency). The clerk in each group records the questions.
Exchange of questions between groups	Each cooperative group analyses the questions elaborated by another group
Oral presentation of the questions elaborated by the different cooperative groups	The spokesperson for each cooperative group communicates to the class different questions from those elaborated by their group

Source: Developed by the authors.

The activities carried out using the Trade Questions cooperative method consisted of the analysis by the different cooperative groups of an image related to the contents of Linear Algebra on which they had to elaborate the greatest possible number of questions during four minutes. Two examples of the images used in this experience are presented in figures 1 and 2.

There was a sharing of the issues raised by the different groups. There was also a discussion of the image in which the teacher tried to relate this to the contents of the class and to answer some of the questions posed by the students.

The images presented were related to the topics of the syllabus of the course of Linear Algebra, such as matrices, row ladder matrices, Gaussian elimination method, and matrices of a linear application. It is known the importance that the use of images can have in the classroom, especially in math class, motivating the students (Maciel, Rêgo, & Carlos, 2017; Rozal, Santo, & Chaves, 2015).

The statistical analyses were performed with the software IBM SPSS, version 22.0, for Windows.

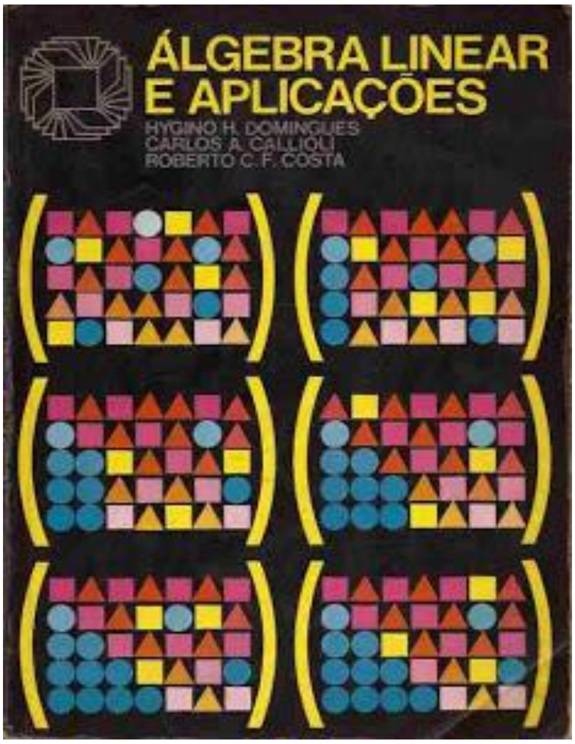

Figure 1. Example of an image used in the experience
Source: Retrieved from http://www.brasilmix.com.br

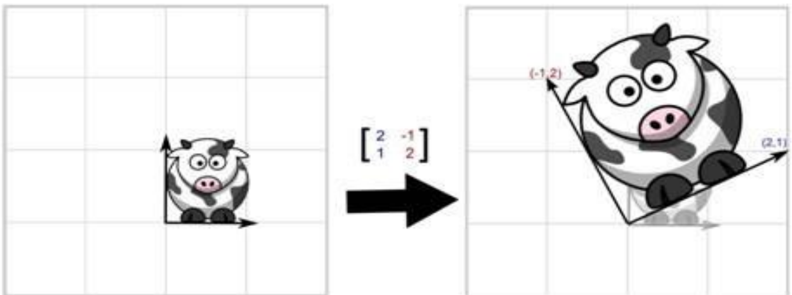

Figure 2. Example of an image used in the experience
Source: Retrieved from http://pontov.com.br

3. Results

The basic descriptive statistics for the pretest and posttest scores for the creative thinking test (CREA) are provided in table 2.

Table 2. Descriptive statistics for the participants' CREA pretest and posttest scores

	Pretest Scores					Posttest Scores				
	N	M	SD	Min	Max	N	M	SD	Min	Max
Experimental	23	8.13	2.96	4	15	23	13.65	4.26	0	12
Control	27	6.41	2.64	7	22	27	9.78	5.09	0	19

Source: Developed by the authors.

In order to compare if there is a significant difference between mean pretest scores of the experimental and the control groups, the difference of the scores in the posttest and in the pretest, the gain scores, for the students of the experimental and control groups are illustrated in the diagrams in figure 3. The descriptive statistics for the gain scores are presented in table 3.

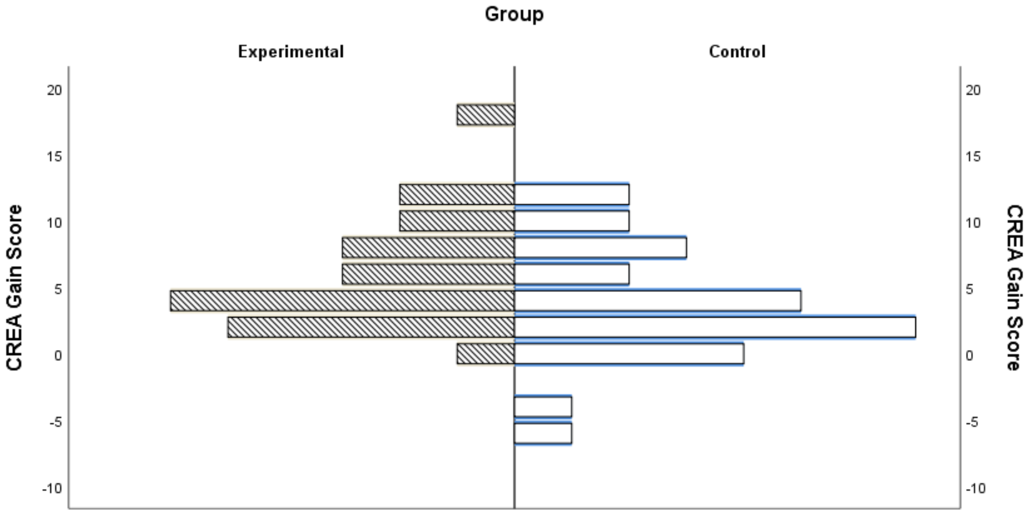

Figure 3. Creative thinking test (CREA) gain scores for the experimental and control groups
Source: Developed by the authors.

Table 3. Descriptive statistics for the participants' CREA gain scores

	MEAN	N	STD. DEVIATION	STD. ERROR MEAN	MIN	MAX
Experimental	5.52	23	4.144	0.864	0	17
Control	3.37	27	4.378	0.843	-6	12

Source: Developed by the authors.

These data show that no student of the experimental group regressed in the CREA test (raised between 1 and 17 points). On the other hand, two students (7.4%) in the control group lowered their CREA test result (the largest regression was 6 points, the highest increase was 12 points).

Table 4. Tests of normality for the participants' CREA pre-posttest scores

	GROUP	KOLMOGOROV-SMIRNOV[A]			SHAPIRO-WILK		
		Statistics	Df	Sig.	Statistics	Df	Sig.
Pretest scores	Experimental	0.170	23	0.084	0.949	23	0.276
	Control	0.111	27	0.200*	0.980	27	0.863
Posttest scores	Experimental	0.168	23	0.091	0.949	23	0.279
	Control	0.149	27	0.127	0.939	27	0.112
Gain scores	Experimental	0.165	23	0.105	0.910	23	0.041
	Control	0.147	27	0.142	0.960	27	0.367

Note: * This is a lower bound of the true significance, a Lilliefors significance correction.
Source: Developed by the authors.

The normality assumptions of the scores are sustained according to the results presented in table 4, thus the possibility to use parametric tests to compare the differences of the means of the pretest and posttest scores.

The results of a t-test show that the CREA pretest scores were significantly higher at the 0.05 level for the experimental group ($M = 8.13$, $SD = 2.96$) than for the control group ($M = 6.41$, $SD = 2.64$), $t(48) = 2.18$, $p = 0.034 < 0.05$, $d = 0.613$, but there is no difference at the 0.01 level. As for the two groups' scores on the CREA posttest, the experimental group scores ($M = 13.65$, $SD = 4.26$) is significantly higher at both levels of significance than the control group scores ($M = 9.78$, $SD = 5.09$), $t(48) = 2.89$, $p = 0.006 < .05$, $d = 0.825$.

The evolution of the CREA mean scores of the experimental and control groups is illustrated in figure 4. Despite the higher mean score in the pretest, the experimental group was able to increase the mean score in the posttest more than the control group (the experimental group increased 5.52 versus 3.37 for the control group).

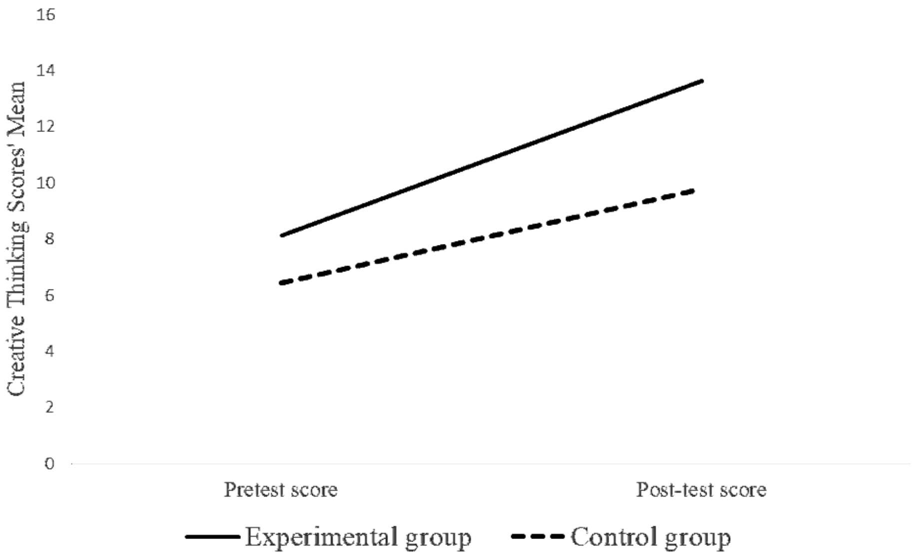

Figure 4. Creative thinking test (CREA) scores' mean for the experimental and control groups

Source: Developed by the authors.

A paired-sample t-test indicated that there was a significant gain of the experimental group' CREA scores in the posttest ($M = 5.52$, $SD = 4.14$), $t(22) = 6.39$, $p < 0.001$, $d = 1.33$. The overall effect size is 1.33 which is associated with a 41-percentile-point gain (Marzano, 2010). This means that on the average, the instructional strategies used (cooperative learning) in the experimental group represent a gain of 41 percentile points between the pre-posttest. For the control group, the gain in the CREA scores were also significant ($M = 3.37$, $SD = 4.38$), $t(26) = 4.00$, $p < 0.001$, $d = 0.77$. The overall effect size is 0.77 which is associated with a 28-percentile-point gain for this group. From these results, Cohen's effect size values suggested a large significance of the CREA scores gains for the experimental group and a moderate significance for the control group (Cohen, 1988).

4. Discussion

The findings of the present study support the research question that the cooperative learning method improves students' creative thinking skills of Communication and Multimedia course in Linear Algebra. The students that were in the experimental group which performed activities with the Trade Questions cooperative method improved their creative skills (divergent thinking-fluency) better than the students in the control group, where it was only used the conventional teaching method.

The results show that the cooperative method gives the students the possibility to improve more efficiently their thinking skills, working together than individually using only the conventional teaching method. These conclusions allow us to conclude that the cooperative method is a valid method and that the intervention was effective in improving higher education students' creative skills.

Studies have proven that cooperative learning strategies do help in improving students' higher-order thinking skills. A meta-analysis of all studies indicates that cooperation results in significantly higher achievement and retention than do competitive and individualistic efforts. It was found that besides higher productivity and retention, cooperation resulted in higher-order reasoning, creative thinking, transfer of learning, wanting to invest time on task, and persistence to take on more challenging tasks (Johnson, Johnson, & Stanne, 2000). In short, according to Johnson and Johnson (1989), the more problem solving required, and the more creative the decisions need to be, the greater the superiority of cooperative over individual and competitive efforts (Johnson, & Johnson, 1989). Researchers have also assessed the impact of cooperative learning on problem solving. After reviewing forty-six studies, Qin, Johnson and Johnson (1995) concluded that students of all age levels (elementary, secondary, college, adult) who worked cooperatively outscored students who worked competitively. A study conducted by Marashi and Khatami (2017) showed the significant positive effect of cooperative learning on English as a Foreign Language learners' creativity and motivation. John and Meera (2014) investigation compared the cooperative learning strategy to the activity oriented method of teaching mathematics to the secondary school students, and concluded that cooperative learning was more effective in fostering of creative thinking skills. In a study of Lince (2016), junior high school students that performed Numbered Heads Together cooperative learning activities improved more their ability to think creatively in mathematics than students who received conventional learning.

Creativity is usually a social product advanced through mutual consideration of diverse ideas in a cooperative context; it does not emerge very well in a competitive or individualistic context. There are two steps in promoting the development of creative entrepreneurs. The first is to place students in cooperative learning groups and giving them a series of higher-level reasoning problems to solve and projects to complete.

A cooperative learning style (other educational approach) can develop students' critical and creative thinking skills. Vijayaratnam (2009) has considered critical thinking 'as encompassing both logical and lateral thinking as both critical and creative thinking are interrelated and complementary aspects of thinking' (p. 1).

Paulus (2000) suggested that interaction in groups can be an important source of creative ideas and innovations. The products of creativity are main factors in the survival of an organization. In addition, in this highly-specialized age, the collaboration of each group members is becoming important components of work. Generally, according to Sternberg and Lubart (1996) creativity is the ability to produce work that is both novel (i.e., original, unexpected) and appropriate (i.e., useful, adaptive when it comes to task constraints). However, creative innovations occur within a socio-cultural context rather than at an individual level. Ayele (2016) expresses the opinion that 'the essence of mathematics is thinking creatively, not simply at the right answer' (p. 3522). The collaborative problem solving is crucial for developing mathematical creativity, in which students can work together in small groups, thinking and learning together in order to achieve a common objective (Albert, & Kim, 2013). Also, Ayele (2016) shares that 'creative problem solving can be developed through integration of the arts and student-led problem solving strategies' (p. 3532).

Thus, we need to empirically evaluate the creative potential (Paulus, 2000) of groups and identify the conditions under which high levels of creativity are realized by groups. Woo, Lee and Kim (2009) suggested that cooperative learning depends on not only group members' capability but also quantity and quality of interaction. Therefore, appropriated team composition strategies are necessary to enhance creativity within the group.

This quasi-experimental study allowed us to approach a field practically unexplored in Portugal: the results of interventions with the objective of promoting creative thinking in higher education. The data collected show there was a significant improvement of the ability of creative thinking of students that, instead of making use exclusively of the individual work in class, were engaged regularly in cooperative learning activities. The referred studies support and validate our conclusion that these gains have been enhanced by the interaction provided with the cooperative groups activities because in the cooperative groups students have to exchange opinions and to argue. Although the number of participants was small, these results seem to emphasize and reinforce the advantages of cooperative learning. Further investigation of this topic should overpass some of the limitations we found on this study. In the future, we suggest interventions that include a larger and diversified group of students, in different degrees of higher education and from different curricular areas (Sciences and Technology, Social Sciences, or Arts and Humanities), with other approaches that allow us to investigate whether an individual intervention leads to improvements in creativity.

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