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Scientific and Linguistic Creative Domains in Secondary Education. A Case Study in Spain

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Abstract

Creativity has been included as one of the four C's of 21st-century skills essential for students to succeed both in school and in the workplace. Thus, many countries are including this topic in their educational policies. This is the case of Spain, where the last educational law (LOMLOE) states that creativity must be worked out in all subjects. In the process of assessing the real situation of the Spanish educational system in terms of creativity development and observing future changes regarding its implementation, this work presents a cross-sectional quantitative study. The performance of 223 students of the four grades of compulsory secondary education in both the scientific and the linguistic domains of creativity was evaluated. Two instruments were used to measure daily and specific microdomains of scientific creativity and verbal-metaphorical microdomain of linguistic creativity. Results show a moderate to low development of creativity in secondary students in all studied domains of creativity. There were statistically significant differences according to gender, with women being the ones with greater creative skills. A progressive increase in creativity was observed up to the third year of compulsory secondary education, with a decrease in the last year. Finally, a positive correlation between scientific and linguistic creativity was established, in addition to an even higher correlation between both microdomains of scientific creativity. This study shows that there is still work to be done to promote creativity in the Spanish educational system, attending to the different subjects and creative domains. Some proposals are discussed, which highlight the importance of teacher training to achieve this goal.

Keywords: creativity assessment, Compulsory Secondary Education, creativity domains, scientific creativity, linguistic creativity.

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1. Introduction

Research on creativity has experienced an exponential development since the mid-20th century (Torrance, 1959; Guilford, 1967). Currently creativity is considered a transversal and essential macro-competence in education (Kaufman, Sternberg, 2019). Despite the difficulty of specifying a satisfactory definition, it has been agreed that creativity is an inherent capacity of the human being, which implies novelty or the production of something new and useful within a given context (Stein, 1953; Guildford, 1967). Research in this field is focused in two different areas: personality characteristics associated with creativity and the different creative domains.

Regarding the personality characteristics of creative people, studies highlight that openness is one of the factors that has a more consistent and contrasted link with creativity. Specifically, this factor is related to the curiosity to experiment, discover, and learn, in such a way that it encourages the ideas or products generated to be varied and unusual (Sánchez-Ruíz et al., 2017; Dollinger et al., 2004). It is worth mentioning that the most recent works suggest that creativity has a componential nature, and it is influenced not only by personality characteristics, but also by affective, motivational and sociocultural aspects (Kaufman, Glăveanu, 2019).

On the other hand, the existence of different creative domains constitutes a hot and controversial research topic. In this context, a domain is understood as a specific area of knowledge, such as scientific, mathematic, linguistic, artistic, etc. that can be divided into different subdomains. Thus, the discussion centers on whether creative people are creative in everything they do, or only in those activities pertaining to a certain domain. Pioneering works in this field defended the existence of general creativity and, therefore, its transferability from one domain to another (Torrance, 1959). However, subsequent studies point to the existence of different creative domains, with a person having different performances in each of them (Runco, Bahleda, 1986).

In this sense, the Amusement Park theoretical model (Baer, Kaufman, 2005), which includes both general and specific elements, is worth mentioning. It is based on a hierarchical structure in four levels: initial requirements, general subject domains, specific domains and microdomains. In the first place, initial requirements such as intelligence, motivation or the appropriate environment make it possible for creativity to appear in any domain. Second, the general thematic areas are associated with different areas of knowledge. The controversy is to establish how many and which domains exist. For example, Kaufman (2012) distinguishes five domains: everyday, scholarly, performance, scientific/mechanical, and artistic. Third, there are specific domains. Thus, within the general artistic domain, music, painting or dance are located. Finally, microdomains are associated with more specific creative tasks. For example, within writing, different microdomains can be distinguished depending on whether the generated product is a poem or a novel. In short, this hierarchical model is a powerful theory, but limitations have also been noted, which stem mainly from the fact that distinction between levels and domains is not very precise.

Regarding the two domains analyzed in this study, more attention has been given to scientific creativity when compared to linguistic creativity. Research on scientific creativity is based on the fact that science and its generation of knowledge is based on creative processes. A recent meta-analysis (Julmi, Scherm, 2016) reinforces the idea of the existence of a specific scientific/mathematical domain, and it is known that mathematical education has an impact on the development of students' creative potential (Kontrová et al., 2021). In any case, there is a strong consensus that scientific creativity is based on domain-specific knowledge (science knowledge) and other skills (Huang et al., 2017), and there are different instruments to measure scientific creativity in secondary education (Hu, Adey, 2002; Sak, Ayas, 2014; Hu et al., 2010). On the other hand, the linguistic domain of creativity is closely related to the ability to generate metaphors and analogies (Veale, 2006). These are used to create new ways of thinking about issues that may be familiar, but which involve exploring the boundaries separating conceptual categories to structure the world and, consequently, the use of words to communicate it (Ortony, 1993). It should be noted that construction grammar, one of the main cognitive linguistic theories, has also recently been added to research on linguistic creativity (Hoffman, 2019).

Thus, it can be concluded that creativity is present in many different areas. It not only allows the production of works of art or musical pieces, but also business actions or cutting-edge scientific-technological advances. Furthermore, all these creative outputs in different domains share three characteristics: novelty, fitness for purpose, and utility. For all these reasons, the development of creativity is a key objective of education, since it has been explained that education directly influences six aspects affecting creativity: cognitive abilities, specific knowledge,

the struggle to excel, openness to new ideas and experiences, collaboration, and motivation. This role of education in creativity might also be extrapolated, since the degree of creativity of the students influences not only their own person, but also the social and economic context (Tang, 2017). From this more global perspective, creativity helps individuals to identify problems and seek new solutions or improvements and, therefore, increases the probability of achieving individual and collective goals. In addition, it helps students to function in a constantly changing society. It seems clear that the future will generate the need for new professional profiles and especially an ability to adapt to a versatile world that depends largely on creativity (Kaplan, 2019).

This key role of creativity in the training of people has clearly been reflected in political-educational institutions. It is worth highlighting the relevance that the OECD has granted to creativity (OECD, 2019). It has configured a competence framework for creativity and has incorporated the measurement of different domains of creativity in the 2022 edition of its PISA Tests. The OECD insists on the need to grant the space that creativity deserves in curricula. And this is what is happening in the case of the Spanish curriculum. The first mention to creativity can be found in the LGE law (BOE, 1970), but only for the Early Childhood Education stage. In the subsequent laws there is no mention to creativity but in the LOCE law (BOE, 2002) creativity is considered as a fundamental value for the development of society. It is established as a quality principle and as an objective to be achieved both in the Primary Education stage and in Baccalaureate. The LOE law (BOE, 2006) established creativity as an objective to be achieved in all educational levels. Finally, the LOMLOE law (BOE, 2020) highlights the transdisciplinary character of creativity, pointing out that "creativity will be worked on in all subjects" (p. 1222874). However, much work remains to be done to achieve this goal, starting with teacher training, the design of didactic materials to foster creativity and, finally, a better conceptualization of creativity and its importance in core aspects such as problem-solving.

With regard to the aforementioned 2022 PISA Tests, these must be interpreted as a turning point. It will allow us to have a global idea of the state of the development of creativity in Spain with respect to other countries (it is expected that the results are released on 2023) and it will also offer very sensitive data when discussing and triangulating complementary measurements. At this point, it should be noted that creativity assessment is still developing, since the construct of creativity, the debate over its distribution in domains, and even the assessment instruments require further development. The case of Spain is not an exception because there are not many studies on student's creativity and rather located in specific populations, such as gifted students (Bermejo et al., 2010).

In this context, the present study aims to evaluate the creativity of 223 students from the four compulsory secondary education levels, taking into account the scientific and linguistic domains. Two specific objectives are proposed: (1) to study the possible differences according to gender or level; and (2) to establish the degree of correlation between scientific and linguistic creativity. The focus of this research makes it possible to determine the current situation of different creativity domains in Spanish classrooms. This is an essential prior step to design an educational plan focused on the development of creativity (Beghetto, 2019), which will be detailed in the conclusions section.

The hypotheses nurturing this work are that creativity performance, at both scientific and linguistic domains, of compulsory secondary education students is low-to-moderate with no differences according to gender, with an increase in creativity as the student progresses in the educational system. A positive correlation between both scientific domains is expected, whereas no correlation is expected between both scientific domains and the linguistic domain.

2. Method

This work presents an exploratory, cross-sectional, quantitative research design. It was developed in an educational center in the province of Valencia (Spain). The educational center is located in a medium size town (around 23.000 inhabitants) at 21 km of the capital of the province, with an average income close to 30.000 euros. Participants were 223 students homogeneously distributed in the four levels of compulsory secondary education. Table 1 shows the demographic characteristics of the sample.

Table 1. Demographic characteristics of the sample studied

Level	Number of students	Age		Men	Women
		Mean	Standard deviation		
1st	57	12.38	0.49	28	29
2nd	55	13.21	0.46	22	33
3rd	57	14.44	0.50	29	28
4th	54	15.48	0.54	36	18

Data was collected in 50-minute sessions during the 2021-2022 academic year, the year before the implementation of the new LOMLOE law (BOE, 2020). Prior to the sessions, school management teams, legal guardians, and participants were informed about the treatment of the data and the scope of the research. Two previously validated instruments were used to assess the creativity of the students. They were presented as paper-based questionnaires, with the visual support of the projection of the corresponding statements on slides.

The first instrument, to assess scientific creativity, was developed by Hu et al. (2010) and is based on the establishment of scientific problems. It is inspired by the Torrance Test of creative thinking (Torrance, 1966), and assesses fluency, flexibility and originality. Fluency refers to the number of generated questions, flexibility to the number of knowledge areas in which these questions are framed, and originality arises from the statistical treatment of the data. This instrument includes two items. In the first one, participants are asked to generate scientific questions based on their life and daily observations (daily scientific creativity, DSC). In the second one, students are asked to formulate scientific questions related to an image of an astronaut on the moon (specific scientific creativity, SSC). Time was limited to 8 minutes per item, as in the original research. Hu et al. (2010) described the instrument as robust and reliable (with interrater reliabilities between .69 and .85).

The second instrument focuses on the linguistic domain of creativity, specifically the verbal-metaphorical microdomain, which is considered a central core of creativity (Kasirer, Mashal, 2018). In summary, the ability to create metaphors is related to the linking of two apparently unrelated concepts, which reflects the ability to break the most conventional or obvious links, to establish new, more creative ones (Dietrich, 2004). An instrument developed by Levorato and Cacciari (2002) and later adapted by Kasirer and Mashal (2018) has been used. It includes ten items, each of which corresponds to a feeling or emotion, such as joy, sadness, euphoria, or frustration. Five of these are presented to the participants with the aim of promoting figurative reformulation, such as "love is...", while the other five are presented as an analogy, such as "feeling frustration is like...". Time was limited to 8 minutes in total. Two judges coded the data independently, with an agreement rate of 89 %. Any case of disagreement was discussed by both coders.

The procedure for data analysis of the answers to the first instrument was similar to that described by Hu et al. (2010). Fluency was scored as the number of (valid) generated questions. To assess flexibility, a prior categorization of the questions was carried out (Pont-Niclòs et al, 2023), which resulted in 12 categories for DSC (the most common were “astronomy” and “functioning of the human body”) and 7 categories for SSC (the most common were “characteristics of the moon” and “physical-technical aspects of the trip to the moon”). Flexibility was scored as the number of categories used per participant. For the originality assessment, the frequency of appearance of each question in the total sample was calculated. Those questions with a frequency of less than 5% received a score of 2; those with a frequency between 5 % and 10 % obtained 1 point; while those with a frequency of more than 10 % did not add any points. Finally, the total scientific creativity score was obtained as the sum of the scores obtained for fluency, flexibility and originality. Regarding the second instrument, we proceeded as explained in Kasirer and Mashal (2018). The questionnaires of each participant were evaluated independently, first discarding invalid answers (out of context or empty). Next, the answers were quantified according to three categories: literal answers (1 point), conventional metaphors (2 points) and new metaphors (3 points). The score for verbal-metaphorical creativity was obtained by adding the total scores obtained.

All collected data were treated anonymously and SPSS Statistics v26 program was used to carry out the pertinent statistical calculations. Normality of the distributions was determined using the Kolmogorov-Smirnov test (Table 2). As it can be observed, specific scientific creativity (SSC)

displays a normal distribution (p > .05), whereas daily scientific creativity (DSC) and verbal-metaphorical creativity are non-normally distributed (p < .05). For the non-normally distributed variables (DSC and verbal-metaphorical creativity), values for skewness indicate a slightly positive-skewed distribution (DSC: .19; verbal-metaphorical: .05), while kurtosis correspond to light-tailed distributions with few outsider data points (DSC: .08; verbal-metaphorical: -.4). In the case of the normally distributed variable (SSC), value for skewness indicates a symmetric distribution slightly left-skewed (skewness = -.06) and the kurtosis value corresponds to typically platykurtic distribution (kurtosis = -.08). Those values have been considered acceptable for a normally distributed sample (Burdenski, 2000).

Table 2. Kolmogorov-Smirnov tests results and values for skewness and kurtosis for the studied microdomains

Microdomain	Test statistic	p	Skewness	Kurtosis
DSC$^{\phi}$	.07	.02	.19	.08
SSC	.05	.2	-.06	-.08
Verbal-metaphorical$^{\phi}$	.06	.03	.05	-.4

$^{\phi}$ Non-normally distributed variable

An inferential statistical analysis was carried out to assess the existence of significant differences between the variables. Thus, for the comparison between genders Mann-Whitney U test was used for non-normal distributions, and Student's t-test for independent samples for variables with normal distributions. For the comparison by level, Kruskal-Wallis test was used for non-normal variables and one-way ANOVA test for normal variables. The effect size was calculated using Hedges' g. To study the correlation between the different domains of creativity studied, Spearman's correlation coefficient was calculated. In all cases the level of statistical significance was set at 0.05.

3. Results and discussion

3.1. Scientific domain of creativity

In this study, two components of scientific creativity have been addressed: daily and specific. The first one was evaluated by means of an open question, while for the second one a closed question was used. These two components were analyzed according to the three variables described above (fluency, flexibility and originality); the sum of which gave rise to the total score. For DSC a high number of questions were related to wireless connections and ICT tools. Other recurring questions were related to the Universe, life on Earth or on other planets, or with means of transportation. On the other hand, for SSC the most common questions were linked to gravity, the presence of air on the moon or the possibility of life in the moon.

The total score for the two domains of scientific creativity studied (daily and specific) according to gender are shown in Table 3. Women generally show greater creative ability to formulate problems and scientific issues. This result is in line with other studies, according to which self-concept greatly conditions the creativity of students, who have assumed a certain social role marked by their gender (Nakano et al., 2021).

Table 3. Differences according to gender on the scientific creativity microdomains

Micro-domain	Gender	Mean	SD	Median	IQR	Statistic	p	Hedges's g
DSC$^{\phi}$	Female	21.79	7.10	22	10	z = 3.39	.001**	.45
	Male	18.41	7.95	17	10			
SSC	Female	20.39	5.37	21	7	t = 3.73	.000***	.50
	Male	17.30	6.83	17	10			

$^{\phi}$ Non-normally distributed variable

** There are significant differences with a significance level of 0.01

*** There are significant differences with a significance level of 0.001

To check if the observed differences were statistically significant, Mann-Whitney U test was performed for DSC, and t-Student test was performed for SSC (see Table 2). As can be seen, there are statistically significant differences according to gender for both types of scientific creativity ($p < 0.05$). The effect size was found to be moderate for DSC and strong for SSC, according to the classification provided by Cohen (1988) for behavioral sciences.

The results depending on the level of the students are shown in Table 4. For the non-normally distributed variable DSC, the Kruskal-Wallis test was used, whereas for the normally-distributed variable SSC, ANOVA test was applied. In the latter case, the homogeneity of the variances was corroborated by using the Levene test ($F = .3$; $p = .8$). Since $p > .05$, verifying the ANOVA applicability criterion of homoscedasticity. It can be observed that, in both microdomains, these values are similar for the first two years, with a slight increase in the third year and a slight decrease in the last level of compulsory secondary education. The first increase can be justified by the development of the knowledge and skills in this stage since they have a positive impact on the performance of the creative processes. On the other hand, the decrease in the fourth year may be related to the disagreements typical of the adolescent age and a low motivation (Hu et al., 2010). As can be seen, no statistically significant differences were found between courses for the two microdomains of scientific creativity studied ($p > 0.05$).

Table 4. Differences according to level on the scientific creativity microdomains

Microdomain	Level	Mean	SD	Median	IQR	Statistic	p
DSC$^{\phi}$	1st year	19.56	7.47	18.0	9.5	H = 1.75	.63
	2nd year	19.40	8.60	19.0	11.0		
	3rd year	21.00	7.02	20.0	10.5		
	4th year	20.20	7.83	20.5	10.0		
SSC	1st year	18.72	6.30	19.0	7.5	F =1.92	.13
	2nd year	17.62	6.46	18.0	10.0		
	3rd year	20.39	6.40	21.0	9.5		
	4th year	18.41	6.03	17.0	8		

$^{\phi}$ Non-normally distributed variable

3.2. Linguistic domain of creativity

The total scores for verbal-metaphorical creativity according to gender are shown in Table 5. As happened for scientific creativity, women obtain better scores. Although these results are contrary to those presented by Kasirer and Mashal (2018), it should be considered that their sample was small (54 participants). In addition, there are other studies in the literature supporting the existence of significant differences between genders, derived from self-concept and pre-established social roles (Nakano et al., 2021) and similar results were obtained in a sample of Spanish first-year secondary students (Pont-Niclòs et al., 2023). Results of Mann-Whitney U test show that these differences are statistically significant, with a moderate effect size.

Table 5. Differences according to gender on the verbal-metaphorical microdomain

Micro-domain	Gender	Mean	SD	Median	IQR	z	p	Hedges's g
Verbal-metaphorical$^{\phi}$	Female	15.65	5.69	16	8	2.95	.003**	.33
	Male	13.65	6.42	12	9			

$^{\phi}$ Non-normally distributed variable

** There are significant differences with a significance level of .01

Regarding differences between levels, the total scores for verbal-metaphorical creativity are shown in Table 6. The trend is similar to that detected for scientific creativity, with the increase in this case between first and second years, similar values for second third years and a decrease in fourth year. This could be similarly explained by the development of knowledge and skills typical of the stage in the second year of compulsory secondary education and low motivation in fourth-year students. In this case, and unlike what happened for scientific creativity, Kruskal-Wallis test indicates that the observed differences are indeed statistically significant. To determine where the

differences laid between groups Bonferroni test was applied. For $\alpha = 0.05$, the *post-hoc* analysis indicated statistically significant differences between fourth year and second year ($p = 0.033$) and fourth year and third year ($p = 0.046$), but not between the other groups ($p \geq 0.942$).

Table 6. Differences according to level on the verbal-metaphorical microdomain

Microdomain	Level	Mean	Standard deviation	Median	IQR	H	p
Verbal-metaphorical $^{\Phi}$	1st year	14.07	6.45	14.0	8.5	10.13	.018**
	2nd year	15.47	6.25	17.0	10.0		
	3rd year	15.67	6.11	15.0	9.0		
	4th year	12.41	5.44	12.0	8.3		

$^{\Phi}$ Non-normally distributed variable
** There are significant differences with a significance level of .01

3.3. Correlation between scientific and linguistic creativity

In the context of this research, it is essential to study a possible correlation between scientific and linguistic creativity. This is especially relevant attending to the intense debate on the existence of specific domains of creativity, or the consideration of creativity as a general construct. Huang and Wang (2019), for example, found positive correlations between general creativity and scientific creativity, but Bernal et al. (2017) pointed to domain-dependent creativity, having found no correlation between scientific and figurative creativity. Thus, the Spearman correlation coefficient was calculated for each of the microdomains studied. Table 7 shows the corresponding results.

Table 8. Spearman correlations between the different microdomains of creativity

Micro-domain	DSC		SSC		Verbal-metaphorical	
	r_s	p	r_s	p	r_s	p
DSC	1	-	.71	< .001***	.42	< .001***
SSC	.73	< .001***	1	-	.42	< .001***
Verbal-metaphorical	.42	< .001***	.42	< .001***	1	-

*** Correlation is significant at the .001 level

As can be seen, there is a positive and significant correlation in all cases ($p < 0.05$), which indicates that students who are creative in one microdomain are also creative in the other two microdomains. Even though this result, a priori, could point out to the non-existence of creativity domains, a deeper analysis is needed. First, a very high correlation is obtained between the two aspects of scientific creativity studied ($r_s > 0.7$), which indicates a presumable relationship between daily and specific scientific creativity. However, the correlation between the two types of scientific creativity and verbal-metaphorical creativity, although positive, is clearly lower ($r_s \approx 0.4$). This means that a particular student can show a good creative capacity that will be greater or lesser depending on the students' skill in that area of knowledge.

4. Conclusion

As explained, there is a certain difficulty in conceptualizing, measuring and, in short, understanding creativity in depth. There is, however, a consensus in the idea that creativity is fundamental for the development of people and their ability to function in different spheres of life. Thus, there is no doubt that creativity must occupy a nuclear space in educational debates and curricula. This will undoubtedly benefit from the impulse of the OECD and its PISA 2022 Tests.

This context legitimizes the interest in evaluating creativity in educational contexts, and, particularly, in Compulsory Secondary Education, which is the educational stage that PISA takes as a reference. Thus, the present investigation allows to measure and interpret very sensitive aspects related to the development of creativity of these students in the scientific and linguistic domains. There are some limitations, however, derived from the sample size and representativeness, as well

as the deficiencies that, although validated and widely used by the scientific community, the assessment instruments used may have.

Firstly, it has been possible to verify that the Spanish students generally present a moderate to low level of creativity. Secondly, statistically significant differences were found according to gender, being female students those showing greater creative skills, which is contrary to the initial hypothesis. Also, statistically significant differences have been detected between levels in daily scientific creativity and verbal-metaphorical creativity, obtaining similar trends for all the studied variables. Finally, positive correlations have been established between all the studied microdomains of creativity, with a greater correlation between both scientific creativity microdomains than between these and the verbal-metaphorical microdomain. These results are partially in line with the proposed hypothesis. Thus, it can be deduced that students have a greater capacity to develop creatively in those domains in which they are more proficient.

It is essential to reflect on how and when to develop creativity in the educational system. Being creativity a very important macrocompetence, it is not correct to address it just in general terms or circumscribe it to specific domains such as art. The teacher training faculties have to intensify a reflection on the development of creativity, which is specified in three proposals. The first one is related to the training of preservice and in-service teachers. They must conceptualize creativity and its metacognitive processes, taking into account aspects such as students' cognitive styles (Prosekov et al., 2022), as well as understand the teaching materials able to foster it. The second proposal involves a need to discriminate which didactic materials are able to develop creativity, using qualitative studies with a categorization taking into account the different creative domains. This is a preliminary step to verify that there are interesting materials that can be used, but also that it is urgent to design new didactic materials to foster a transdisciplinary development of creativity. Transdisciplinary because, as the last Spanish educational law (LOMLOE) specifies, it has to be carried out in all areas or disciplines. This could be done assimilating didactic approaches related to problem-solving or divergent thinking, for example. However, it is also interesting to design specific materials regarding a particular subject, knowledge field, or creative domain (Hu et al., 2013; Soboleva et al., 2022).

Finally, the third proposal implies a true transfer effort, with the most important conclusions of the theoretical and empirical studies on creativity having their projection in instructional and didactic changes. The legislative change of the LOMLOE is a propitious context because it not only highlights the importance of attending to creativity in all subjects, but also the autonomy of centers and teachers to decide how the syllabus should be implemented. The aforementioned transfer can also rely on manuals, courses or even workshops conducted by experts in creativity that can be a point of support for teachers. Then, they will become aware of the current state of creativity in the Spanish educational system, which the present study has contributed to outline.

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