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Analysis of Creativity Following Educational Intervention with Secondary School Students

María José Cuetos[1], **Natalia Serrano**[2], and **Adán Manuel Yanes**[3]

1 Faculty of Education, Universidad Internacional de la Rioja, La Rioja, Spain, ORCID: 0000-0002-9555-8765
2 Faculty of Education, Universidad Internacional de la Rioja, La Rioja, Spain, ORCID: 0000-0002-8337-7211
3 Colegio Salesiano San Isidro, Plaza Franchy Alfaro, Santa Cruz de Tenerife, Spain, ORCID: 0000-0002-7862-8987

ABSTRACT

Creative and critical thinking skills are in high demand in 21st-century society and schools should foster students' creative potential all through their time in education. This study analyses results of an educational intervention in biology and geology based on the POPBL (problem-oriented and project-based learning) model to improve creative thinking of 83 students in year one of secondary education. To this end, the creativity variable was analysed using the CREA Creative Intelligence Test (Corbalán et al., 2015) with a pre-test/post-test design and ANCOVA was used to establish whether there was significant difference between the group taught using an active methodology and the group taught with a traditional one. Creativity scores and subject grades were used as covariates. Having matched initial creativity and performance values, the results showed that the designed intervention was effective in improving creative thinking and problem-solving skills. Classroom learning provides an ideal opportunity for students, moderated cognitively and emotionally by the teacher, to master knowledge of the content and creatively apply that knowledge, an important skill for success in any 21st century environment.

KEYWORDS:

Creativity; educational intervention; teamwork; secondary school teacher; sciences

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Corresponding author at:

María José Cuetos E-MAIL: mjose.cuetos@unir.net
Natalia Serrano E-MAIL: natalia.serrano@unir.net
Adán Manuel Yanes E-MAIL: adan.yanes@salesianos.edu
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INTRODUCTION

Creativity is the capacity to generate new, valuable, and practical products or ideas (Supena et al., 2021), emphasising identification of problems and formulation of relevant questions (Liu & Schonwetter, 2004). It is regarded as a vital skill in the 21st century (Albar & Southcott, 2021; Binkley et al., 2012), because it enables us to adapt to a rapidly changing world. Indeed, in the most recent edition of the PISA (Programme for International Student Assessment) report, from 2022, creative thinking is assessed as a new competence (OECD, 2024). This comparative international assessment promoted by the OECD (Organisation for Economic Co-operation and Development) usually focusses on assessing mathematical and linguistic competences.

There is no doubt that encouraging creativity plays an important role in the progress of society (Johnsen, 2021). The children of today will have to face challenges and use technologies that are as yet unknown. Indeed, creativity is considered crucial for preventing negative consequences at both a social and personal level (Gómez-Pérez et al., 2014), and businesses that prioritise innovation need creative people to generate valuable ideas (Horkoff et al., 2019).

Creativity is innate to human beings. It is not just an inherited condition but can be learnt (Hernández et al., 2020) and it must be stimulated from early childhood. Indeed, it can be increased if done adequately (Bermejo et al., 2014; Stevenson et al., 2014). Schools are an optimal environment for promoting creative thinking, both thanks to their opportunities for socialisation and expressing creative talent (Beghetto & Kaufman, 2014), and because of the strong link between individuals' creative potential and academic results (Cuetos Revuelta et al., 2024; OECD, 2024).

Therefore, to contribute to the general development of society, schools should help young people foster their creativity and train them to be capable of successfully solving the different challenges that they will face in future (Tanggaard, 2018). Numerous authors agree that individuals need a variety of elements to produce creative work. These include 1) creative thinking processes, 2) relevant knowledge and skills, 3) motivation for the task, and 4) a pleasant and supportive setting (Amabile, 1983; 2012; Amabile & Pratt, 2016).

Therefore, programmes to incentivise creativity and help with students' comprehensive development must consider cognitive and emotional aspects (Martínez-Aìlvarez et al., 2020; Mezcua-Hidalgo et al., 2019), as creativity is a complex aptitude that encompasses cognitive, personal, and perceptive processes (Antoñanzas-Laborda et al., 2015). Along these lines, the literature (Fitzgerald, 2020) indicates that using socio-constructivist methodologies favours development of creativity, because they foster self-discovery and self-regulation, allowing students to manage their metacognitive processes and their learning (Orozco-Gómez et al., 2023). Furthermore, as intrinsic and extrinsic motivations have a positive effect on creative thinking and help prevent academic failure (Yuvaci & Daglioglu, 2016), educational methods that strengthen these skills should be promoted (Jakubakynov et al., 2021).

One of the main problems, at least with Spain's education system, is that playful and motivational activities are usually only used with students in their first years of school. Therefore, it is necessary to emphasise creation and application of intervention programmes that are as specific as possible. It is also important to develop creative thinking from the earliest ages and also foster students' creative potential throughout all of their time in education (Cuetos Revuelta et al., 2024). Given this context, the aim of this study is to examine the impact of an educational intervention designed for biology and geology on the development of creativity in secondary students, and to compare the results with a control group that will follow a traditional working methodology. Creativity in biology and geology teaching is a key aspect that improves students' comprehension of the subject.

Indeed, the traditional teaching model, which does not help incentivise creative thinking, remains dominant in science teaching in general (Cañal et al., 2013; Porlán, 2018). In contrast with this model, an intervention will be carried out based on diverse strategies to foster creative thinking, following a student-centred pedagogical focus and making it possible to address a problem from different perspectives, discovering it naturally and intuitively (Khanolainen et al., 2021). In this way, a constructivist learning environment (CLE, Jonassen, 2008) will be pursued, improving students' problem solving and development of concepts. CLE models start from a project, problem, or question at the heart of the environment and offer students various interpretation systems to find answers to the questions asked. They encourage exploration and discovery, which can also increase students' interest and motivation for learning, focussing primarily on solving the problem in open and non-structured experiments, with the aim that students will strengthen their skills and ideas (Amineh & Asl, 2015; Leibold & Schwarz, 2015). These models avoid other teacher-centred teaching methods as well as activities that suppress students' spontaneity.

Problem-oriented and project-based learning (POPBL), which has a constructivist-sociocultural focus (Kolmos & de Graaf, 2007), is used in this case. POPBL is derived from problem-based learning (PBL; see Lehmann et al., 2008; Uziak et al., 2010) and is a hybrid practice. Students are first exposed to a problem from the real world, then they develop a project to solve it. While PBL principally focusses on the students generating a particular product to resolve a problematic situation (Reinking & Martin, 2018; Yakman & Lee, 2012), POPBL focuses on the process in itself: cognitive learning, collaborative learning, and content (Latada & Kassim, 2017).

Many schools are exploring these opportunities for learning in different stages, applying POPBL to the fields of science, engineering, and architecture with good results for developing the ability to generate creative thinking. This is also generating innovative educational scenarios that enhance development of 21st-century skills (Binkley et al., 2012). For example: Hawari and Noor (2020) explored the potential of POPBL in a multidisciplinary art classroom that included STEAM (science, technology, engineering, art, and mathematics) education in a primary school, improving students' leadership skills and creativity; Kuo et al. (2019) applied an interdisciplinary project-based learning (IPBL) approach in STEM to university students, improving the motivation for learning and overall creativity of students in the university's engineering and design departments; Shatunova (2019) developed a model for building STEAM education, which was based on creative spaces and promoted an active methodology, directly motivating schoolchildren and university students to participate in their own education; and Suwistika et al. (2024) determined the effectiveness of the POPBL learning model in improving critical and creative thinking skills with secondary school students.

The mechanisms or theoretical assumptions of these authors explaining the relationship between POPBL and the development of creativity among pupils are varied. Including how these projects help students to understand lessons, provide the ability to manage processes, system thinking, the ability to work in an environment of high uncertainty and rapidly changing task conditions. However, all studies highlight students' ability to work in groups, cooperate, and actively participate in class, as POPBL allows them to improve their communication and social skills, as well as enhance their leadership skills and solve real-world problems. Following this line of work, there is a need to help clarify whether group work in POPBL strategy helps students to promote creative thinking and problem-solving skills, so the working hypothesis of this study will be that students who have received the intervention have increased their creativity versus a control group follow a traditional working methodology primarily individually.

METHODOLOGY

The present study used a quasi-experimental design with comparison of non-equivalent groups. The independent variable was whether students studied biology and geology in a group where an intervention that favoured creativity was used or were taught using a traditional methodology. Academic achievement and creativity became dependent variables. Students' performance was measured at the start through their academic results in the subject. Specifically, various studies affirm that logical/mathematical intelligence and verbal/linguistic intelligence are the types of intelligence that best predict academic performance in secondary school (Anandarasu & Vaiyadurai, 2018; Shahzada & Khan, 2018). Therefore, the average of the students' marks from final evaluation of the 22/23 academic year in the subjects of mathematics, science, and Spanish were used as a variable for academic performance. Students' creative intelligence was then measured using the Creative Intelligence Test (CREA) by Corbalán et al. (2015), the results of which are expressed in percentiles (from 1 to 99).

This study was done in accordance with the principles of the Helsinki Declaration. The procedures used in this study were approved by the ethics committee of the Universidad Internacional de La Rioja. Informed consent was obtained in writing from the parents or guardians for participation, data collection, and publication of results.

Participants

The sample comprised a total of 83 participants from two schools. One of them is a private school attended by upper-middle-class students. From that school, 25 students (44% female and 56%

male) formed the control group. The other is a state-subsidised school for middle-class students, where 58 participating students (50% female and 50% male) received the intervention (experimental group). All of them were in the first year of obligatory secondary education (ESO) (age 11–12 years) in La Orotava (Canary Islands) during the 2022–23 academic year.

Instrument

As stated above, the CREA Creative Intelligence Test, which is widely used in professional practice and research, was used to assess participants' creativity. This test was developed by researchers from Spain and Argentina, and it's been used in studies with people from Spain, Argentina, and the United States. Results obtained have indicated that it is a reliable and valid test of creativity (Corbalán et al., 2015). The CREA test is based on such classical factors of creativity as divergent thinking, flexibility, fluidity, and originality (Corbalán et al., 2015; Corbalán & Limiñana, 2010). Correlations were found between creative abilities measured with CREA and measurements taken with the Torrance Test and the Guilford Battery (Clapham & King, 2010; López-Martínez & Navarro-Lozano, 2008). It involves participants formulating as many questions as they can in four minutes based on a specific visual stimulus (version A, B, and C of the test), The more questions formulated, the greater the development of creativity.

The present study used version C (applicable to children and adolescents). Since 2021, there have been two options for administering the test: on paper or digitally. The digital option facilitates analysis of the results obtained in each test. This research used the digital version of the test. The questionnaires were created anonymously and administered online so that each student could complete them using his or her tablet in class time.

Process

In the traditional model for teaching biology and geology, a teacher imparts content by following the textbook or by having students read it. The teacher then gives an example and sets exercises for the students to do at home individually or in class in pairs. Then, the teacher goes over those examples in a group setting during class.

In the experimental group, the students were put into groups of three or four members through heterogeneous grouping. The intervention was carried out in the "Science Project: How to Do Science" content block during the first term of the year in 12 theory–practice sessions of 50 minutes each. They were taught by the regular teacher of the subject at each of the centres analysed.

The study of this subject is closely related to the processes of problem solving in the real world. That is why it is important to promote creativity, as pupils need to find solutions based on the knowledge they have acquired through projects carried out in situations that reflect real life. Thus, the first application of the test (pre-test) was done in the second week of September. The second application of the test, after the intervention with the experimental group (post-test), was done in the third week of December. In both cases in parallel in the control group and in the experimental group.

Design of the intervention

The study made use of the fact that the "Science Project" block introduces students to scientific thought and methods. Following the POPBL strategy, the students carry out a process of solving problems outlined in the following steps (Mora et al., 2015; Suwistika et al., 2024): orientation, brainstorming and planning, research and development, and synthesis and verification. It should be noted that throughout all of the process, the teacher encourages students to produce and combine new and different ideas, formulate profound questions, and respond in unusual ways to questions or problems, challenging conventions and assumptions and thinking independently. To do so, the teacher uses "Socratic maieutics" and guided discussion after carrying out experiments and/or using manipulatives. In this method, the "master" (teacher) has the role of mediator and facilitator of the knowledge while the role of the "disciple" (student) is to answer their own questions. Socrates believed that they could do so because of the existence of an inner knowledge that each individual must bring to light (Aceituno-Ramos, 2020). In addition, it has a notable function in the emotional aspect of instruction by motivating it and providing feedback. The informal comments and recognition stimulate students to develop new ideas (Amabile, 2012; Zhou & Su, 2010).

Next, each of the phases is explained and the role of the teacher in the instructional method is underlined:

- Orientation: Students clarify the problem presented, which revolves around the central question. In this phase, the teacher's role is to guide the students in the task to be carried out; something that helps them to review and reflect on their prior knowledge (Kordaki, 2011) and means that their learning is more structured and motivating.
- Brainstorming and planning: students discuss in groups how to solve the problem through brainstorming and/or meetings. Students must use a focus based on critical thinking in the creative sphere (Costa, 2006) and attempt to enumerate any possibilities, diverse points of view, as well as decision and solution options. This stage is expected to help students improve their creative skills, especially in the dimensions of creativity fluency and originality, encouraging them to generate ideas spontaneously. This can lead to the discovery of more creative or innovative solutions (Robson, 2014). Activities in the project are planned, including aims and objectives, way of working, and expected results. The teacher helps plan the group's work flow, enriching the students' own ideas to resolve the scientific challenge better and more creatively (Sun et al., 2023).
- Then, research and development are carried out. Students explore their knowledge in groups to understand basic concepts relating to the problems proposed in the subject through different learning resources that they need (books, articles, and by searching for information in a range of sources, including the internet), as well as experimentation in the classroom (using the scientific method), and they write the results as a summary or conceptual map (to generate mind maps). Using a variety of data enables students to experience working as "real scientists" by developing skills relating to accessing data, visu-

alising data, and overall scientific cooperation (Smith et al., 2009). In addition, students must connect the concepts they have learned with the problems they have previously formulated themselves. Therefore, at this stage of the POPB, it is expected that the flexibility indicator in students' creativity will improve, thus generating relevant ideas from different perspectives and developing them in the project topic (Robson, 2014).

- Finally, in the presentation and evaluation of the project results, the students test their solution, synthesise their findings, and fill in any gaps. In this case, a scientific focus through carrying out experiments will help students test hypotheses and think critically (Fatimah, 2018). This can enhance students' creativity, especially in the dimension of elaboration of creativity, as students provide more in-depth and detailed arguments when answering questions from their classmates.

A sample lesson plan that follows the POPBL framework is included:

- Introduction/Participation (5 minutes): Introduction of the topic to spark students' interest.
- Research/Analysis (25 minutes): Students work in small groups to read the articles provided, to identify the issues presented, and then to summarise the concepts learned by freely writing them in the form of concept maps.
- Solution Development/Presentation (15 minutes): Groups share their solutions and participate in a brief class discussion.
- Exit Ticket (5 minutes): Quick assessment of learning (e.g., a one-paragraph summary of the lesson).

RESULTS

Statistical analysis was performed, using the SPSS v22.0 software and an analysis of covariance (ANCOVA) was performed to determine whether there is a significant difference between the group taught using an active methodology and the group taught using a traditional one. ANCOVA allows us to calculate the adjusted means of the dependent variable for each group, after controlling for the effect of the covariate. If the difference between the adjusted means is statistically significant, we can conclude that the methodology (active or traditional) has a different effect on the dependent variable, after taking into account the initial differences represented by the covariate.

The mean scores from the CREA test for the experimental and control groups were 43.64 ($SD = 25.98$) and 47.60 ($SD = 16.34$), respectively as Table 1 below shows. Meanwhile, as can be seen in Table 1, CREA test values after the intervention were 56.66 ($SD = 60.00$), remaining at 45.76 ($SD = 40.00$) in the control group.

Table 1. Descriptive data of the study

Categories	Group	*N*	Mean	Median	Standard Deviation (*SD*)
Pretest	Control	25	47.60	50.00	16.34
	Experimental	58	43.64	35.00	25.98
Post-test	Control	25	45.76	40.00	24.85
	Experimental	58	56.66	60.00	28.98
Academic performance	Control	25	7.87	7.82	1.02
	Experimental	58	7.39	7.45	0.89

According to the data in Table 2 below, no significant differences were found between means of the control group and the experimental group in the pre-test (Student's $t = 0.70$, $p = .48$, with an effect size of Cohen's $d = 0.17$) or in the post-test (Student's $t = -1.64$, $p = .11$, with an effect size of Cohen's $d = -0.39$). Despite the lack of significance of these differences in the post-test, the strength of the effect measured by Cohen's d may indicate the practical importance of these differences and requires the use of more sophisticated analytical methods, such as ANCOVA, which would allow for more accurate comparisons between the control group and the experimental group, given the hypothesis of differential diversification of the variables analysed at the pre-test level.

Table 2. Differences between control group and experimental group (independent samples *t* test)

Categories		Statistic	*df*	*p*	Difference of means	Effect size	
Pretest	Student's *t*	0.70	81.0	.48	3.96	Cohen's *d*	0.17
	Mann–Whitney *U*	622		.31	10.00	Rank-biserial correlation	0.14
Post-test	Student's t	-1.64	81.0	.11	-10.89	Cohen's *d*	-0.39
	Mann–Whitney *U*	575		.14	-10.00	Rank-biserial correlation	0.21

An ANCOVA was then used, taking the initial academic performance and creativity scores as covariables and considering their influence on students' creativity in the later test to analyse the difference between the scores from the final creativity test of the experimental and control groups. The mean effect size for the ANCOVA was the partial eta squared (η^2_p).

Tables 3 and 4 below show results of applying the ANCOVA analysis. They are related to the increase in CREA scores at post-test between experimental and control groups when taking into account their variation at pre-test and when taking into account control academic performance.

Table 3. ANOVA test data

Categories	SS	*df*	F	*p*	n^2	η^2_p
Model	20568	3	12.26	< .001	.32	.32
Group	3767	1	6.73	.01	.06	.08
Pretest	14228	1	25.43	< .001	.22	.24
Academic performance	1006	1	1.80	.18	.02	.02
Residuals	44193	79				
Total	64761	82				

$R = .32$ and adjusted R-squared $= .29$

An ANOVA was performed on the model (see Table 3 above) to study the significance of each of the elements: the principal independent variable (group) and the two covariables (initial academic performance and creativity). It can be seen that the group and creativity were significant in the pretest ($p < .001$ and $p = .01$, respectively, as they are < .05 in both cases).

Table 4. Characteristics of the effects

Data	Effect	Estimate	Standard Deviation	Lower limit*	Upper limit	β	df	t	p
Intercept	Intercept	42.82	4.83	33.21	52.42	.000	79	8.87	< .001
Group	Experimental–Control	15.11	5.82	3.52	26.70	.54	79	2.60	.01
Pretest	Pretest	0.58	0.12	0.35	0.81	.48	79	5.04	< .001
Academic performance	Academic performance	3.91	2.91	-1.89	9.71	.13	79	1.34	.18

*95% significance

The assumptions of normality and homogeneity of the variance were also tested, and no violations were found in any cases ($W = .97$, $p = .09$ for the Shapiro–Wilk test and $W = .82$, $p = .37$ for the Levene test), with the results (see Table 4 above) that creativity scores improved by 15.11 points in the intervention group compared to the control group (which in the estimated model was 42.83). This value is statistically significant as $p = .01$ ($p < 0.05$) with an eta squared effect size of .06, which is equivalent to a Cohen's d of 0.49 – a significant effect size, which confirms what was previously estimated with the independent samples t test.

DISCUSSION

The results show that the students who participated in the planned intervention in this work had improved results in creativity compared with the students from the control group, verifying our starting hypothesis. The POPBL strategy was used to achieve this, and the results obtained reflect the positive effects of this model for fostering creativity. This is in line with the existing literature (Hawari & Noor, 2020; Kuo et al., 2019; Shatunova et al., 2019), as implementing programmes in an EAC setting has a favourable effect on the development of the four dimensions of creativity: fluency, elaboration, flexibility, and originality (Kuo et al., 2019).

One of the principles of the POPBL model is to prioritise social skills and group work (Yasin & Rahman, 2011). This learning model actively involves students in the process of thinking. Indeed, emphasising active participation by students is a necessary condition for fostering creative thinking and for them to construct their own knowledge (Anastasiades, 2017; Manchekar, 2015).

This strategy makes it possible to work on these skills and develop them to levels that would be hard to reach with traditional methodologies. POPBL enables students to confidently evaluate the works of other groups from the start of the project, the development process, and the presentation stage, with better guidelines.

Setting objectives to pursue and giving students autonomy to carry out tasks are elements that significantly contribute to facilitating creative thinking (Amabile, 2012; Zhou & Su, 2010). This is because they enable students to interact in working and discussion activities (brainstorms and/or meetings) relating to the provision of ideas and alternatives to resolve the problem posed both with their own experiences and with scientific knowledge (Kim et al., 2015). Involving students in a research-based scenario promotes creative skills regardless of their prior knowledge and thus it helps reduce their initial differences (Sun et al., 2023).

In addition, we should note interaction with the teacher, which has an important role, not just in the cognitive aspects of fostering creativity but also the emotional ones. Teacher-student interaction allows students to deepen their understanding and knowledge of the proposed topic and the methods for solving problems (Kim et al., 2015). Teachers can change the class "culture," moving from a culture of transmission to one of creative and collaborative work (Seitamaa- Hakkarainen et al., 2010), where all participants are respected and heard, and their opinions are valued to pursue a collective learning outcome. A recent study by Sun et al. (2023) categorises various strategies for teacher–student interaction: on the one hand, guidance and feedback that help students to think better and appropriately do the procedures for solving problems; and on the other, motivation and continued monitoring that can facilitate students' elaboration of learning tasks by incentivising them to ask questions, express opinions, and find creative solutions (Leibold & Schwarz, 2015; Yuvaci & Daglioglu, 2016).

CONCLUSIONS

In Spain, interventions to increase science-technology students' creative skills have been based on the construction or design of highly creative end products by the students. So, Casado Fernández and Checa-Romero (2020; 2023) used STEAM projects and robotics with learners from years five and six of primary school as educational tools in their studies. Checa-Romero and Pascual (2018) assessed their students' creative production with Minecraft in the classroom in the first year of secondary education. Also, Saorín et al. (2017) asked engineering students from the Universidad de La Laguna to design and apply their ideas to a digital creation using 3D-printing. All of these studies reject rote learning and foster processes of inquiry, discovery, critical reflection, creation, and imagination. They are all based on constructing or designing a new product with the support of technology in science teaching.

The innovative aspect of our findings is that, unlike previous works, we focused on resolving problems relating to real scientific content and not the construction or design of a new product. Instead of merely dealing with pre-structured problems, broken up by thematic area, young people carry out enquiry for themselves and participate in real research relating to the scientific topics raised. This offers students the opportunity to learn to collaborate in evaluating solutions, something that is in line with one of the essential competences that the OECD (Organisation for Economic Cooperation and Development) determines young people must acquire in our current society. Namely, to "make informed decisions to act based on evaluation of diverse sources of evidence and application of creative and systems thinking to regenerate and sustain the environment" (White et al., 2003, p.16), the elements of which will be measured in 2025 by the science assessment of the Program for International Student Assessment (PISA).

This article has several limitations. Firstly, the sample size means that the results cannot be generalised. Also, the measurement instrument used does not enable the different components of creativity (such as fluidity, flexibility, and originality) to be examined separately (Corbalán et al., 2015). Future studies using instruments that do allow for this are needed.

Moreover, it is vital to make education professionals aware of the findings reported in this study to promote creativity as a collective educational tool. We agree with Cotter et al. (2022) that teachers should incorporate pedagogical strategies and actions that include different mechanisms for creative interaction and metacognition in their classes. For example, encouraging students, identifying good ideas, or creating an environment that promotes creation of ideas about different phenomena that help their students to accept their responsibility to contribute to creative work in groups. However, all of this is based on the teachers' belief that creative thinking can be developed in the classroom. Therefore, to continue with this research, it would be advisable to design and apply an intervention programme for teachers that helps boost their creativity and to apply strategies that not only ensure that their students pass the subject but that prepare them for the future.

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20 Swierkowa St., 15-328 Bialystok, Poland
tel. +48 857457283
e-mail: creativity@uwb.edu.pl
http://www.creativity.uwb.edu.pl