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Effects of a Project-Based Learning Methodology on Environmental Awareness of Secondary School Students

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Well into the 21st century, the environmental crisis is more relevant than ever. To face this challenge, citizens with pro-environmental attitudes and adequate levels of environmental awareness are needed. As future adult citizens, adolescents should be a priority for environmental educators. The objective of the study is to determine the effectiveness of the Project-Based Learning (PBL) methodology in the improvement of the level of environmental awareness of secondary school students. To this end, a project related to the surrounding environment was designed and applied in the Spanish educational context. The nature of the research methodology was mixed (quantitative-qualitative), with the application of a pretest-posttest single group design. The instrument used was an environmental awareness test with a Likert-type scale and a set of open questions. The results obtained indicate a statistically significant rise in the level of environmental awareness in the participant group-class, leaving the effectiveness of the PBL in the referred level and educative context patent. There were some limitations in the research, including small sample size and the particular conditions of the exposed context, which should be resolved for future research in other educational contexts in order to generalise the findings of this study.

Keywords: project based learning, environmental education, environmental awareness, environmental literacy, secondary education, Spain

INTRODUCTION

At present there is an imbalance between unstoppable human activity and the environmental state of ecosystems, generating changes in the environment that are not reversible either in the short or mid term (Banerjee et al., 2021; Steffen et al., 2015). Some of the parameters that indicate these impacts are climate change, loss of biodiversity, hyper consumption of fresh water, changes in land use, and so on. (Rockström et al., 2009). Human modification of spatial distribution and the functioning of ecosystems at a local, regional and global scale is occurring at an increasing rate. A large proportion of the aforementioned global and regional prejudices have their origins

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in the urban environment (large cities, on the whole) (Girardet, 2019; Ravetz, 2016). It is thus logical to think that a large part of the actions designed to alleviate global environmental problems are implemented from the urban sphere. In fact, we find a number of different experiences in recent years that show that the transition towards urban sustainability is possible, furthermore supposing the necessary germ for achieving change towards sustainability at a global level (Kabisch et al., 2017). Considering all of the foregoing, it is essential to generate development and improvement of levels of environmental awareness in city populations, creating attitudes that are pro-environmental in nature.

Although it is an ambiguous term, according to Ham, Mrčela & Horvat (2016, p. 160) "Environmental awareness can be broadly defined as the attitude regarding environmental consequences of human behaviour". Different strategies have been implemented for its improvement in both the fields of economy and education. In the latter case, those that place secondary students in situations where they are required to confront real environmental problems in their surroundings are especially efficient (Höfner & Schütze, 2021; Araújo et al., 2022).

The appropriate framework for this should as a priority be formal education (secondary education), the setting of which has been used to pave the way for alternative teaching and learning strategies in all areas, including Environmental Education (EE), as a reaction to traditional methods (Nazarenko & Kolesnik, 2018), but also for specifying constructivist approaches to teaching (Mahasneh & Alwan, 2018; Perales & Ayerbe, 2016). One of these methodologies is Project Based Learning (PBL), on which a wide consensus exists as regards its usefulness and effectiveness (Han et al., 2015; Mergendoller et al., 2006). Furthermore, it is presented as ideal for the development of the area of EE considered as transversal within the curriculum. There is however a shortage of studies tackling the effectiveness of PBL in the field of EE, which is even more pronounced in the Spanish educational context if it is compared with other countries (Ayerbe & Perales, 2020).

According to Markham et al. (2003), PBL can currently be understood as: "A systematic teaching method that engages students in learning knowledge and skills, through an extended process of inquiry, structured around complex and authentic questions, and carefully designed tasks and products**"** (p. 14). Moreover, in recent decades there has been a wide range of studies affording evidence regarding its effectiveness and proven teaching benefits such as increased motivation, improvement of learning satisfaction, preparation of students for tackling real situations, obtaining of better qualifications, development of autonomous learning skills and improvement in memory as regards that learned over a prolonged period of time, and the development of skills and competencies such as collaboration, planning, communication, research, creativity, critical thinking, decision making and time management (Yuningsih, Subali & Susilo, 2022; Baran et al., 2018; Setiawan & Supiandi, 2018; Kricsfalusy Nariman & Chrispeels, 2016; Mioduser & Betzer, 2007; Portman & Teff-Seker, 2017; Willard & Duffrin, 2003). On the other hand, it is also essential to be aware of the weaknesses of PBL in order to be able to confront them and apply it with certain guarantees of success.

From the teaching perspective, Van Den Bergh et al. (2006) draw attention to the heavy workload and difficulty in evaluating as negative aspects; Marckham et al. (2003) specify that the mechanics triggered when implementing PBL are less comfortable for teachers, as the level of noise and movement of students in the class increase, also pointing out that curricular certainty can be reduced in comparison with other methodologies. In addition, from the point of view of students, Ayerbe & Perales (2020) and Ruiz-Gallardo et al (2016) highlight the difficulties of working in cooperative groups (unequal workload), adaptation to such a diversified evaluation, knowing what to do at each step of the project and the lack of autonomy on the part of students when carrying out some tasks.

Taking the above into consideration, the aim of our study was twofold: on the one hand, to determine the effectiveness of PBL as a methodology for creating an increase in the level of environmental awareness in secondary school students in the Spanish educational context, and on the other, to contrast the results obtained with those from prior studies in other educational contexts. Regarding the variables used in the study (developed in the data collection and data analysis section), they are the level of environmental awareness, the level of environmental literacy, and the students perception of the state of the urban environment, they are commonly used in studies trying to measure level of environmental awareness (Boca & Saraçlı, 2019; Salvador et al., 2019; Szczytkoet al., 2019).

METHOD

Research methodology and design

The research methodology implemented to determine the effectiveness of PBL in improving the level of environmental awareness had a mixed character, using both quantitative and qualitative data, with the objective of triangulating the results obtained, in such a way as to counteract possible threats to internal validity (Cohen et al., 2000; Hernández-Sampieri, 2018). Furthermore, the research design was experimental in nature and specifically pre-experimental given that the requirement of random assignment of the treatment (participation in the environmental project) to the subjects that comprised the study was not fulfilled, meaning it was not possible to consider the design as purely experimental (Campbell & Stanley, 1963). As such, an intact group was worked with, which corresponded to one of the classes of students at the educational centre where the study was carried out (Campbell & Stanley, 1963; Cohen et al., 2000). The fact of having to intervene with a natural (intact) group, due to the demands of the teaching activity of the secondary school, entailed an important limitation in terms of sample size, which is smaller than desirable in a study of this nature. The compiling of the data used to determine the levels of environmental awareness and their subsequent analysis therefore followed a pretest-posttest single group design.

Contextualisation of the centre and description of the sample

The environmental project was implemented in the Francisco Ayala Public Secondary Education Institute located in the north-central area of Granada, a medium sized city located in the south of Spain. The educational centre serves students from an upper-

middle family, cultural and socioeconomic class. More specifically, the project was carried out in the 4th year of ESO (*Educación Secundaria Obligatoria - compulsory secondary education*) with a group that followed a science path, the optional subjects of which included Biology and Geology, which were used to energise the project. As regards the population that participated in the study, 12 were girls (46%) and 14 were boys (54%). The average age of the sample at the moment the pretest was completed was 15.31 years.

Description of the intervention (Environmental project)

Subject matter

The central subject matter of the project applied was the urban environment. It focused on those parameters that could be tackled easily by students, with direct measures or simple observations in their comprehension. Taking the foregoing into account, five environmental aspects were selected: noise pollution, air pollution caused by gas emissions, situation of urban rivers, urban park surfaces and state thereof, and tourism as an intensifying agent of all of them (Granada is a city with an economy based on the tourism sector).

Curriculum involved

Curricular elements were developed from the environmental project implemented that belonged to three of the subjects taught in ESO year 4, with Biology and Geology predominating, and the participation to a lesser extent of Geography and History, and Spanish Language and Literature.

Development of the environmental project

The project began with a beginning event, serving as a starting point, the purpose of which was to awaken the interest of the students as well as placing it within the project, creating a necessary prior motivation (Markham et al., 2003). The guide question of the project was set out as follows: "*Is Granada a habitable city*?"; moreover, a real and relevant problem was introduced via the presentation of different local news stories relating to pollution and environmental deterioration of the city. In addition, a central challenge or problem of the project was considered: "*How can we improve the urban environment of Granada*?". In consequence this all generated a debate on possible solutions which led into the need to create an environmental improvement plan, which was constituted as the main final product of the project.

Before starting

Groups of four members were created according to criteria of compatibility, parity, homogeneity between and heterogeneity within groups, in accordance with work in cooperative groups in which different roles and responsibilities were also established.

Tasks completed

The participating students carried out a series of tasks, both individual and group, throughout the project. The first consisted in creating a glossary of ecological and

environmental terms, a portfolio, a learning diary and completing a project reflection and evaluation form. The group tasks were on a larger and more complex scale, and destined towards the development of a final product and its public presentation. The former consisted in carrying out a diagnosis of the city environment via the analysis of the aforementioned environmental parameters; to this end a citizen survey was created, air pollution due to gas emissions was determined, there was an analysis of noise pollution (study of noise maps and direct measures), determination of surface area of parks and analysis of its quality, analysis of the state of the city's rivers and a study of the environmental implications of the tourism industry.

The second group task consisted in creating an environmental improvement plan for Granada. Lastly, a presentation was made and shown to an audience with knowledge of the subject, comprising students studying Environmental Education in the Faculty of Educational Sciences at the University of Granada.

Rich Socialisation

One of the keys to the project was its relationship with the "outside world" (people and/or institutions separate from the educational centre), one of the identifying features of PBL according to Larmer & Mergendoller (2010). There was, specifically, a visit by experts in environmental matters. Furthermore, a trip was made to the urban environment involving diverse interactions with different members of the public (interviews, consultations, etc.). Finally, the urban environmental improvement plan was shown to the aforementioned University of Granada students (dissemination of final product).

Urban environment trip

Trips were made to different points in the city, which was one of the key moments of the project. The groups planned the execution of the different activities set out: the surveys created applied to the population, *in situ* diagnosis of the environmental parameters and obtaining of database, images, audio and video recordings for the final product

Resources used

The resources used were highly varied; apart from the habitual facilities of a conventional classroom environment, particularly noteworthy were information and communication technologies (ICT) were used, including internet search engines, multimedia, podcasts, email, blogs, e-portfolios, educational platforms and digital tools for creating and editing materials. Diverse instruments for measuring environmental parameters (noise, physical-chemical parameters of water, etc.) were also employed.

Project timeline

The project had a total duration of 24 one-hour sessions and a complete morning (Table 1), spanning approximately two months of the school year.

Table 1
Project phases and duration

Phase	Sessions
Beginning event and project presentation	2
Learning of concepts	4
Chat with experts (Council)	1
Urban environment diagnosis	4
Urban environment trip	1 morning
Chat with experts (Ecologists)	1
Processing of information and determination of environmental state	2
Creation of final project: Urban environmental improvement plan.	5
Preparation of presentation for showing to audience	4
Showing of presentation	1
TOTAL	24

Evaluation

Evaluation was diversified and endorsed with rubrics, and the areas taken into consideration were a digital portfolio, daily activities, learning diary, the functioning of cooperative groups, the final products and their public presentation.

The evaluation involved various tools of wide ranging typology (Table 2). It was divided into two types, one formative during the carrying out of the project, and another from the final product, in this case being the valuation and exhibition thereof.

Table 2
Different tools used in evaluation and contribution to evaluation

Project Evaluation								
	Description	Grouping*		Moment*			Evaluation
		I	G	S	C	E	
Formative evaluation	Initial prior knowledge test.	**X**		**X**			Informative (0%)
	Learning diary: reflections, doubts, difficulties, decisions, etc.	**X**			**X**		5 %
	Portfolio Review: recollection of different products created.	**X**			**X**	**X**	15 %
	Register of actions: calls made, emails sent, etc.		**X**		**X**		Informative (0 %)
	Cooperative learning rubric (group workings)		**X**		**X**		10 %
	Correction of activities completed throughout project	**X**			**X**		10 %
Final produ	Final written product (document)		**X**			**X**	30 %
	Oral presentation: presentation, format and appropriateness evaluated.	**X**	**X**			**X**	20 %
	Multiple choice contrast test: same as initial to see degree of progress achieved.			**X**	**X**		10 %
	Self-evaluation and reflection: questionnaire completed by student			**X**	**X**		Informative (0%)

*Grouping: Individual (I), Groups (G). *Moment: At start (S), Continuous (C), At end (E).

Data collection instrument

As shown in Table 2, the dependent variable in this study was Environmental awareness, which was measured by the means of several instruments in order to increase its validity.

Environmental awareness test

The pretest was applied a day before the project commenced and the posttest two days after it was completed. The objective of the test was threefold: firstly, to measure the level of entailing environmental awareness of each student; secondly, to determine the level of environmental literacy, before and after the project; and thirdly, there was also a desire to find out the perception the participating students had of the urban environment. The test had three sections. The first was a Likert-type test, where it was decided to use a pre-prepared and pre-validated scale (Álvarez et al., 1999). This scale comprised a total of 16 items and two factors: the conservation of the environment and behavioural intention. The items covered the dimensions to take into account in terms of environmental awareness (affective, cognitive, conative and active). There were five categories to choose from in each item: *Strongly agree*, *agree*, *neutral*, *disagree* and *strongly disagree*. The maximum score on the scale was 80 and the minimum was 16. The second section consisted of three open questions extracted from a previous study on environmental perception (Perales, 2010), which were adapted to the context of this study: *1. Outline what, in your opinion, are the main environmental problems currently affecting Granada, 2. What personal practices do you think may contribute to improving the environment?* and *3. What measures should public institutions adopt to improve the environment?* Lastly, a multiple choice question adapted from Perales (2010) was used, with the objective being to determine what perception the participating students had of the environment. The multiple choice question was: *Do you think the current environmental situation of our city is: very good, good, average, poor or very poor?* The instrument used consisted, therefore, of a Likert-type scale, a set of open questions and a multiple choice question, being these tools widely used in similar studies due to their good performance in measuring the level of environmental awareness (Alexandar & Poyyamoli, 2014; Dada et al., 2017; Liefländer & Bogner, 2018; Maurer et al., 2020; Nizaar et al., 2020). Responses of the test were anonymous, and participants provided informed consent.

Data analysis

The analyses and statistics employed in the different sections of the environmental awareness test are shown in Table 3.

Table 3
Analysis and statistics used in the different sections of the environmental awareness test applied after the environmental project

Section	Analysis	Statistics
Likert Scale	Pretest-posttest comparison of mean scores obtained by students (in total scale and subscales)	Cronbach's alfa coefficient[1]: Level of questionnaire reliability (internal consistency) Student-t of a single group for related samples[2]: Evaluation of environmental project effectiveness Cohen's d[3]: Effect size via
Open questions	Comparison of average number of valid responses per student (pretest-posttest)	Student-t of a single group for related samples[2]: Evaluation of environmental project effectiveness Cohen's d[3]: Effect size
	Comparison of average number of occurrences per each category (pretest-posttest)	Cohen's kappa[4]: Level of concordance between researchers Wilcoxon related samples test[5]: Evaluation of environmental project effectiveness r[6]: Effect size
	Pre-post comparison of mean level of environmental literacy (lexical richness and abundance)	Student-t of a single group for related samples[2]: Evaluation of environmental project effectiveness Cohen's d[3]: Effect size
Multiple choice question	Comparison mean level of perception of state of environment	Wilcoxon related samples test[5]: Evaluation of environmental project effectiveness r[6]: Effect size

[1] Tavakol & Dennick, (2011)
[2] Ravindra et al. (2018)
[3] Dankel & Loenneke (2021)
[4] Byrt et al. (1993)
[5] Gouvêa et al. (2017)
[6] Tomczak & Tomczak (2014)

Both the total scale (16 items) and the behavioural intention and environmental conservation subscales were applied in the Likert scale; the total scores from the scale and the averages per student (dependent variable) were obtained. Regarding the questionnaire with the three open questions from the environmental awareness test, the valid responses of each student were counted to determine the existence of statistically meaningful differences between the averages of the number of answers before and after the intervention. Secondly, the responses from the open questionnaire were categorised (deductive-inductive type process) from the categories proposed by Negev et al. (2009) (deductive action). Following this, one of the study researchers treated and completed them with new categories that emerged from the responses of the participating students (inductive action). The two researchers then independently carried out the classification of the responses according to the established categories, determining the level of concordance to reinforce the internal validity of this phase of the study, finally obtaining the absolute frequency of responses per category of the complete group in each question (pretest-posttest), and the mean per student and category (dependent variable). Thirdly, the level of environmental literacy was determined. On the one hand, there was a specification of whether the number of different words with an environmental

connotation used in the open questionnaire responses (lexical richness) rose significantly in the posttest compared to the pretest for the three questions. On the other hand, there was likewise a specification of the total number of environmentally related words used by the students (lexical abundance). In order to obtain the data, the procedure detailed in Figure 1 (Bertaut et al., 1992; Rodríguez et al., 2005; Pardo et al., 2012; Aguilera, 2017), was followed, obtaining the means for both lexical richness and abundance. Lastly, to analyse the multiple choice question on the environmental awareness test an assignation of scores was carried out (very good = 5, good = 4, average = 3, bad = 2, very bad = 1). The average level of perception of environmental state was deemed to be a dependent variable, comparing the differences before and after the applied environmental project.

Normality analyses were applied to all the comparisons and were carried out on the means of the differences between the pretest and posttest (Chan, 2003), using the Saphiro-Wilk statistic applicable to smaller n<50 sample sizes (Razali & Wah, 2011). For all the comparisons the differences were deemed significant with $p<0.05$ (Di Leo & Sardanelli, 2020). The statistics package employed for the analyses was SPSS version 25.0 for Windows.

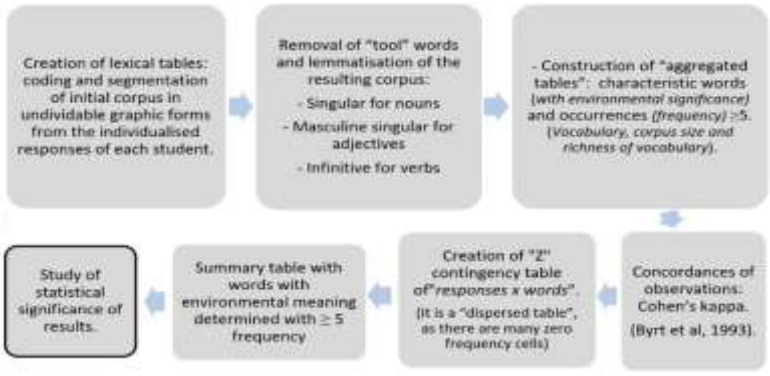

Figure 1
Steps followed in processing questionnaires for determining lexical richness and abundance

FINDINGS

Pre-post comparisons in the environmental awareness test

The total number of completed questionnaires both before and after the intervention stood at 26.

Likert Test

The value of the Cronbach's alfa coefficient for the questionnaire as a whole was 0.615 in the prestest 0.705 in the posttest, considered acceptable for our study (Peterson 1994). With regard to the scores of the Likert scale at group level there was an increase of 100 points in the total score (Table 4). Furthermore, there was a score improvement

in 19 of the 26 students (69.23%) following the application of the environmental project. After determining the normality of the data, the student-t for related samples revealed a statistically significant increase (t = -4,326; p < .001) of the average value for level of environmental awareness in the posttest (M = 64.50; SE = 1.28) compared to the pretest (M = 60.65; SE = 1.23) (Table 4), with the effect size being d = .84, considered as high (Cohen, 1988). There was also a significant increase in the conservation of the environment subscale (t = -4.276; p < .001) with an effect size of d = .83 in the posttest (M = 37.46; SE = 0.73) compared to the pretest (M = 34.46; SE = 0.67). Finally, there was a significant increase in the behavioural intention subscale (t = -2.51; p < .05) of the mean scores obtained in the posttest (M = 26.19; SE = 0.71) compared to the pretest (M = 27.03; SE = 0.78), with the effect size being d = .49 (moderate effect).

Table 4
Likert test scores and statistical analysis results

Moment	Score	Mean	t	p	d	Shapiro-w	p
Pretest total	1577	60.65	-4.33	.000	.84	.961	.418
Post-test total	1677	64.50					
Pretest conservation	896	34.46	-4.28	.000	.83	.974	.719
Post-test conservation	974	37.46					
Pretest intention	681	26.19	-2.51	.019	.49	.931	.083
Post-test intention	703	27.03					

Open questions

Of the 26 students, 22 (85%) increased the number of valid responses in the posttest for all of the three questions. The Student-t for paired samples determined statistically significant differences (t = -7.287; p < 0.01) between the means of number of valid responses in the posttest (M = 10.62; SE = .36) compared to the pretest (M = 8.12; SE = .36), with an estimated effect size of d = 1.42 (Table 5)

Table 5
Number of responses to the open questionnaire (pre-post) and result of statistical analysis

	Answers	Mean	*t*	*p*	*d*	*Shapiro-w*	*p*
Pretest	210	8.12	-7.287	.000	1.42	.962	.443
Postest	275	10.62					

Regarding the result of the categorisation of the responses to the open questionnaire, 13 categories were obtained in the first question, 14 in the second and 11 in the third, and categories with ≤ 2 frequency were included in "Others" (Table 6). The Cohen's kappa index concordance values following the classification of responses in the different categories by the two study researchers for each moment (pre-post) and question (1, 2 and 3) were above 0.8, considered to be a very good level of concordance (Byrt et al., 1993). The classifications made by the main researcher of the study were used for the statistical analysis.

Table 6
Categories created from the open questionnaire responses

1st question (Environmental problems)	2nd question (Personal practices for environment improvement)	3rd question (lnstitutional measures)
Category-code	Category-code	Category-code
Green spaces-*GreSp*	Mobility-*Mobi*	Mobilty/Trasnport-*MobTr*
Air *pollution-AirPol*	Water consumption-*WatCo*	lnvestment/Grants-*InvGr*
Water pollution-*WatPol*	Power consumption-*PowCo*	Waste management-*WastMan*
Noise pollution-*NoiPol*	Recycling-*Recy*	Volunteering-*Volu*
Soil pollution-*SoilPol*	Sustanaible food-*SusFo*	Green spaces-*GreSp*
Hunting-*Hunt*	Discharges-*Disc*	Noise pollution-*NoiPol*
Pollution in general-*PolGen*	Noise pollution-*NoiPol*	Rivers management-*RivMa*
Light pollution-*LighPol*	Sustanaible tourism-*SusTo*	Legislate/Punitive-*LegPu*
Climate change-*ClimCh*	Raise awareness-*RaiAw*	Recycling-*Recy*
Energy-*Ener*	Volunteering-*Volu*	Education/Awareness-*EduAw*
Recycling-*Recy*	Reuse-*Reu*	Others-*Oth*
Tourism-*Tour*	Nature caring-*NatCa*	
Others-*Oth*	Consumption in general-*ComGe*	
	Others-*Oth*	

The Wilcoxon paired samples test determined a statistically significant increase or decrease, in the posttest, in the frequency of responses in the categories shown in Table 7. The estimated effect sizes were medium or high for the categories mentioned (Fritz et al., 2012).

Table 7
Categories in which there were significant statistical differences between the pretest and the posttest in the three open questions

Question	Category	Frequency Pre	M Pre	Frequency Post	M Post	z	p	r
1	GreSp	3	.12	16	.62	-3.61	.000	.71
	WatPol	4	.15	14	.54	-2.89	.004	.57
	NoisPol	1	.04	20	.77	-4.15	.000	.81
	Recy	7	.27	0	0	-2.65	.008	.52
	Tour	0	0	10	.38	-3.16	.002	.62
2	SusFo	6	.23	0	0	-2.12	.034	.42
	NoisPol	0	0	4	.15	-2	.046	.39
	SusTo	0	0	4	.15	-2	.046	.39
	RaiAw	0	0	6	.23	-2.45	.014	.48
	Reu	7	.27	0	0	-2.33	.020	.46
3	WastMan	4	.15	0	0	-2	.046	.39
	Volu	0	0	4	.15	-2	.046	.39
	NoisPol	0	0	5	.19	-2,24	.025	.44
	RivMa	0	0	5	.19	-2,24	.025	.44
	Oth	7	.27	2	.08	-2,24	.025	.44

Note1: Only those categories with pre-post differences of a $p < .05$ statistical significance are shown.
Note2: The "others" categories collect the responses with ≤ 2 frequency.

Regarding the environmental literacy study, it should be mentioned previously that the level of concordance in the filtering process of environmental type words, determined by Cohen's kappa index, between the two researchers stood at .772 in the pretest and .792 in the posttest, which are acceptable values (Byrt et al., 1993). With regards to the differences in the level of lexical richness between pretest and posttest, there was a significant increase in the average number of different words with an environmental connotation used in the posttest responses (M = 10.76; SE = .50) compared to the pretest (M = 6.30; SE = .34) (Table 8). In addition, for the lexical abundance parameter was a significant increase per student in the posttest (M = 12.80; SE = .58) compared to the pretest (M = 8.07; SE = .56). The number of words with environmental connotation was greater and more diverse in the posttest (Figure 2).

Table 8
Results and statistical analysis of the difference in lexical environmental richness and abundance in the responses per student in the test (open questions) before and after the project

Measurement	Moment	Words	Mean	t	p	d	Shapiro-w	p
Lexical Richness	Pretest	164	6.30	- 8.115	.000	1.59	.984	.942
	Posttest	280	10.76					
Lexical abundance	Pretest	210	8.08	- 5.809	.000	1.13	.949	.225
	Posttest	333	12.80					

Words	Pretest Frequency	Postest Frequency
Abuse	5	-
Acoustic pollution	-	13
Air pollution	8	15
Automobile	24	18
Bike	11	22
Bus	11	5
City	5	3
Cleaning	-	18
Educate	-	16
Electric car	-	10
Environment	5	7
Gases	-	17
Green spaces	-	33
Ground	5	5
Lectures	-	8
Noise	-	26
Parks	2	13
Pollution	8	-
Private transport	-	31
Problem	8	3
Public transport	23	15
Raise awareness	6	17
Recycle	31	22
Reduce	5	8
Rent	-	3
Reuse	6	-
Rivers	2	21
Road traffic	-	30
Take care of	-	15
Throw out	9	11
Tourism	-	34
Traffic	6	4
Trash	17	14
Water	13	5

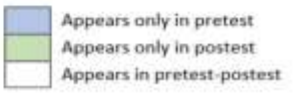

Figure 2
Frequency of words with environmental connotation appearing in pretest, posttest or both moments

Lastly, the results obtained following the multiple choice question to determine the level of perception of the environmental situation on the part of the students before and after the project determined a statistically significant reduction (Wilcoxon paired samples test) of said level following its application ($z = -3.900$; $p < 0.01$) with effect size $r = .76$ (Table 9), which supposed a worsening of perception.

Table 9
Responses of the students before and after the project to the multiple choice questionnaire and results of the statistical analysis

Answer	Pretest Frequency	Posttest Frequency	Pretest Mean	Posttest Mean	t	p	r
Very good	0	0	2.92	2.27	.000	.76	
Good	3	0					
Average	18	8					
Bad	5	17					
Very bad	0	1					

DISCUSSION

If we return to the objectives that we set ourselves in this study, they sought to determine the effectiveness of PBL as a methodology to increase the level of environmental awareness of secondary school students in the Spanish educational context, and to contrast the results obtained with those of previous studies in other educational contexts. The analyses carried out on the environmental awareness test before and after the application of the environmental project drew different scores, with the determination of statistically significant differences in a large number of them, meaning a prevalence of the idea that the use of PBL was an important contribution to a raising of environmental awareness amongst the students who were the object of the study. This concurs with a number of previous studies that shared this objective in the context of secondary education, but in educational environments different to those in Spain (Al-Balushi & Al-Aamri, 2014; Kioupi & Arianoutsou, 2016; Risnani & Astina, 2017; Son et al., 2011). Nevertheless, in order to clarify this section, attention should be drawn to these results according to the instrument employed.

Likert Test

The results with significant differences and high effect size values (pre-post) were key both at global scale and at the environmental conservation and behavioural intention subscales, the latter related to the conative dimension of environmental awareness, essential in the materialisation of actions that are pro-environmental in nature (Rivera-Torres, 2018). This result agrees with previous studies in other educational contexts that use the Likert scale to measure the level of environmental awareness after applying the PBL methodology in the same or different educative level than our study. (Genc, 2015; Nanni & Allan, 2020; Perrault & Albert, 2018).

Open questions

Regarding the open questions, we consider that the significant increase in the number of responses registered in the posttest is an indicator of the increase in the level of environmental awareness that occurred following the application of the project, due to the fact that the questions made explicit reference to problems and/or solutions directly related to the environmental problem (Perales, 2010).

As regards the categorisation of the responses to the three open questions, worthy of note is the significant increase in the posttest of a large number of categories. Attention may be drawn to the case of the "Noise Pollution" category, the references of which are continuous in the posttest; this is in accordance with previous studies where it is indicated that concern about noise pollution is seldom consistent amongst young Spanish people (Moreno-Fernández & García-Pérez, 2018). Regarding the "Green spaces" category, the students better specified in quantitative terms some of the problems in the posttest, such as the lack of green spaces or scarce environmental quality thereof.

Moreover, the significant increase in the posttest of the "Educate-Raise awareness" category supposes that the students identify EE as a useful means of creating improvements in the environment. Also interesting are the posttest responses to the "Volunteering" category. There are prior contextualised studies in Spain that use this tool to favour improvement in environmental conditions, and also improvement in environmental awareness in the population (Esteban et al., 2012). Regarding the state of the riparian ecosystems in the city ("River Management" category), in their responses the students demand responsibility from institutions in terms of the ecological recovery and monitoring of this type of ecosystem, which coincides with the main actions in this regard that have been carried out in many of Europe's large cities with river ecosystems (Selman et al., 2010). It is also worth highlighting the significant decrease in the frequency of some categories in the posttest. In the case of "Recycling" or "Reuse", this could be due to the fact they were not central aspects of the project, there being a predominance of the study of other urban environmental problems with consequences more visible to the students. For the "Sustainable Food" category, these types of habits have a greater environmental impact at a regional or global than urban level (Ranganathan et al., 2016). In the case of this and other categories, the environmental project seems to have occasioned a necessary "adjustment" in the perception of environmental problems that were perceived as local and which, however, are global or regional in scale.

In terms of level of environmental literacy (lexical richness and abundance), it was considered as a valid indicator of the level of the students' level of environmental awareness (Staples et al., 2019). Therefore, the results obtained, with statistically significant differences (pre-post) in both parameters support the idea that the environmental project had a notable effect on the level of environmental awareness in the participating students. It is of interest to highlight the great number of environmental terms employed by the students exclusively in the posttest. Their increase responds to project tasks related specifically to the parameters referred to, for example the notable increase in allusions to noise and noise pollution in the posttest, undoubtedly due to the different tasks carried out in the project on the subject (study and analysis of noise maps, measurements with sound level meter in different zones of the city, etc.). In this regard, Pesis (2005) argues that a greater development of level of environmental literacy leads to a better identification of anthropogenic alterations of the environment; Yavetz et al. (2009) hold that the environmentally literate person possesses the values, attitudes and skills that enable conversion of knowledge into action. All of the foregoing lays

down the foundations for developing pro-environmental attitudes in the adolescent population that are considered essential in the current environmental crisis (Krettenauer, 2017). On the other hand, it is worth mentioning that in previous studies in other educational contexts, PBL is presented as an efficient methodology in increasing the level of environmental literacy, which coincides with the result obtained in our study (Abdillah et al., 2021; Baran et al., 2021; Suryawati et al., 2020)

Multiple choice question

The significant worsening in the posttest of the perception of the city's environmental state was somewhat expected, given that perceptions of the situation of familiar environments are normally better than the reality, and that of more removed places. That fact can be appreciated in different studies relating to the idea of environmental hyperopia (García-Mira & Real, 2001). Thus, it is expected that if a group of students is exposed to a specific methodology (PBL in our case) to promote the level of environmental awareness at urban level, this will be more effective a priori the more the perception on the situation of the nearest environment worsens (reducing the environmental hyperopia effect), and this could in part be due to an improvement in knowledge of local environmental problems, resulting in an adjustment of such a perception more in tune with reality.

CONCLUSION

PBL was shown to be an effective methodology for increasing environmental awareness in the participating students within the context described in this study, the environmental project was particularly effective in improving the affective dimension of environmental awareness, as well as determined facets of the urban environment such as noise pollution and green spaces, for which prior awareness was almost non-existent. Moreover, the project was quite effective in increasing the level of environmental literacy, an aspect linked to high levels of awareness. Therefore, the application of environmental projects (PBL) is presumed as an effective educational strategy to increase attitudes of an environmental nature that are considered essential in the current global crisis.

These results should be interpreted with prudence, given the reduced sample size and the particular conditions of the context setting, to which any generalisations of the obtained outcomes in other educative contexts should be reserved for future studies with greater sample sizes and spatial and socioeconomic heterogeneity.

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