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Design, Application and Evaluation of a Technological Instrument about Environmental Education

José María Fernández Batanero [1*], Miguel María Reyes [1], Rocío Piñero [1]

[1] *University of Seville, SPAIN*

* CORRESPONDENCE: batanero@us.es

ABSTRACT

The aim of the present work is to provide the results obtained in the suggested study about the design, application and evaluation of a technological-educational instrument capable of increasing awareness and environmental attitude in high school students. The method used was a pretest-posttest experimental design, for which a total sample of 294 students from Seville (Spain) were selected. Among the results drawn, there was a significant increase in awareness and environmental attitude. It was concluded that technological instruments that favour learning in Environmental Education must be designed.

Keywords: environmental education, environmental awareness, environmental attitude, high school, technological-educational instrument

INTRODUCTION

The environment is becoming a research issue as a result of the deterioration of natural resources, and as it affects human life, the international scientific community is now focusing on raising awareness about the urgent need of using responsibly the knowledge of every field of science to provide solutions to the increasing environmental degradation, which not only jeopardises the conditions of life in the planet, but it also endangers the survival and perpetuation of humans themselves as a biological species (Prévot, Clayton, & Mathevet 2018). According to Genc (2015), in order to fight the environmental crisis, a new and suitable education is therefore needed, and he also considers that there will be no real solutions unless there is a transformation of education, in all its levels and modalities, and a change in the educational model. For this reason, this new educational approach requires to contemplate the educational processes combined and develop them in a framework of new approaches, methodologies, knowledge and new relationships between the different educational agents. Environmental education does not emerge from nothingness, but as an attempt to approach proposals for change in view of the crisis and it is important to take into account that, even though it has not been and will never be the only instrument to fight environmental problems, it is created and developed as a very powerful movement capable of transform basic aspects of human interactions with the environment, from the field of education (Liefländer, Fröhlich, Bogner, & Schultz 2013).

In the last years, there has been an increasing interest about the processes of generation and functioning of the attitudes and behaviours related to the preservation of the environment. This is especially due to the fact that it has been demonstrated that there is a direct or indirect relationship between human activities and the state of environmental crisis that humanity is facing nowadays.

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According to experts, we can solve or at least minimise these problems if we act responsibly and change our attitudes and behaviours; that is, we must modify our system of believes and values from which we act unconsciously.

Building sustainability can be done in two ways, which can be simultaneous: 1) by changing a specific environmental behaviour (for instance: recycling) that can be generalised to other actions, contributing to changing our life style; and 2) by adopting a model based on a new system of attitudes, believes and values that can affect individual behaviours and habits.

In the international literature, there are many studies that highlight the importance of education in environmental values (Mullenbach & Green 2016), but a very small number of these publications emphasise the development of environmental instruments and Information and Communications Technology (ICT) (Fauville, Lantz-Andersson, & Säljö 2014).

In our field, generally, the studies performed in the last years regarding the teaching of environmental values in the education system demonstrate the importance of attitude development (Cardona, Leite, & Sánchez 2017). Likewise, studies have been carried out in the different levels of education, such as the ones by Mora and Gómez (2016) in Childhood Education Franco (2014), and Gomera, Villamandos, and Vaquero (2012) in Secondary Education and Núñez, Torres, and Álvarez (2012) in Higher Education, etc. Moreover, there are very few studies that highlight the use of ICT for the development and teaching of environmental education (Paredes & Dias de Arruda 2012), but there are even less publications focused on the development of curricular materials and ICT.

The present study is necessary for two fundamental reasons:

The first reason is our intention to overcome the barriers and difficulties that arise when it comes to teaching environmental awareness and attitudes to high school students, in this case, of the technical-scientific modality. Therefore, this is the root of the issue which leads us to create an educational instrument that helps minimise such difficulties. However, the aim is not only that the students perceive the consequences of their actions, but such perception should also lead them to develop environmental responsibility; the students should not simply question what they can do for the environment, but they should also do it. It is about building significant and functional learning.

And the second reason is the initiative of working with ICT with two purposes: 1) it is intended to motivate teachers to use ICT, since its use in the teaching-learning process can be very beneficial; however, becoming familiar with ICT is often an additional effort that some teachers are not eager to make, and thus this kind of teaching is not as developed as it should be (Cheng & So, 2015; Sureda-Negre, Oliver-Trobat, Catalan-Fernández, & Comas-Forgas 2014). And, 2) it is also intended that ICT constitutes a real benefit for students regarding awareness and acquisition of environmental attitudes, since these have the potential of offering a much more personalised teaching, focused on the student and based on constructivism; also, the students should feel more interactive and as the main characters of their own learning (Liefländer & Bogner 2018).

PURPOSE AND RESEARCH QUESTION

The general objective (G.O.) of this study is to provide the results obtained in the suggested study about the design, application and evaluation of a technological-educational instrument capable of increasing awareness and environmental attitude in high school students.

Through this specific objective (S.O.) we intend to achieve two goals:

S.O.1 To foster the knowledge of the students about the environment, in order to make them aware of the importance of taking care of our planet from human aggressions.

S.O.2 To introduce ICT in the teaching-learning process and educate students through the creation of a significant and functional learning that helps them to better understand the serious problems that threaten our planet so that they are capable of reflecting on and minimise them.

METHOD

Participants

The population at which the present study is targeted are students in the last two years of high school. From this population, a sample of participants was selected, which was composed of 294 students from the

last two years of high school in the technical-scientific modality, with an age range between 16 and 18 years, from six different schools of Seville city and its province (Spain).

Data Collection Instrument

Questionnaire. The instrument´s design is structured as follows: 1. Title; 2. Justification; 3. Users; 4. Objectives; 5. Contents; 6. Methodology; 7. Activities; 8. Human Resources and Materials; 9. Space-time Organization; and, 10. Evaluation. As previously mentioned, it was designed in technological format, specifically *Ardora*, with the structure of the contents section being organised into five blocks about: *Environmental Contamination*, *The Three "Rs"*, *Andalusian Natural Parks and their Birdlife, Sustainable Development, ICT and Environment*. A series of activities from each block is proposed for the student to answer them individually. It is a tool with a set of features (images, audio files, videos, response time…, etc.) that allow the student to interact with the content of the subject in a direct and bidirectional manner.

This environmental instrument is designed for students in the last two years of high school in the technical-scientific modality, with the aim that they develop environmental awareness as well as a set of attitudes and values through the knowledge offered by the different blocks of such educational tool. Why is it necessary to create environmental awareness in today´s students toward the natural environment? The answer is quite simple: young people are the future and, therefore, it is important to educate them in a way that they grow up as conscious people, aware of the problems posed by contamination (whichever source or kind) and spills, or the advantages provided by the rule of the three Rs and a good education toward sustainable development. The planet is our home, and as such, we must all protect and respect it, and we have to begin by understanding that the damage we exert on it may cause the destruction of many species and, although we think that humans are invincible, we can become extinct.

Measuring instruments. The subjects for the experiment were given two questionnaires. In order to find different tests that were suitable for the characteristics of the present study, different documentary sources were searched to locate diverse instruments, specifically two questionnaires, since the dependent variables of this study are two, and they had to be measured with two different instruments. From the Spanish journal *Acción*, we selected the article "*Construcción de indicadores de creencias ambientales a partir de la escala NEP*" (creating indicators of environmental believes from the NEP scale), as well as, we also searched through the journal *Revista de Investigación Educativa*, from which the article "*Dimensionalidad de una escala de actitud hacia el medio ambiente para la Educación Secundaria*" (dimensionality of a scale of environmental attitude for secondary education).

Experiment design. The experiment was designed according to the following procedure:

1. Definition of variables: regarding the use of statistical techniques, the options for validation according to a pretest-posttest scheme, with an experimental group and a control group, are specific; therefore, the techniques to be employed are the ones suitable for the measuring tool used (Likert-type and dichotomous questionnaires). These techniques must refer to each of the variables defined: awareness and environmental attitude. To determine the environmental attitude variable parametric techniques could be used, as long as the normality of the sample is assured; for the awareness variable, despite having over 30 individuals (for some authors 50), the technique to be used would be non-parametric, although there would be a loss of valuable information if the samples are related and the number of subjects is much greater than 50. Thereby, prior to the statistical tests, it was decided to transform both variables, in a way that the variables derived from them were directly comparable, correlational (if applicable) and measurable in a percentage scale with absolute zero, while also ensuring that parametric techniques for related samples could be used for both variables. The transformation was performed in a different manner for each variable, although in both cases an ordinal variable was converted to a scale variable. The advantages, from our point of view, are greater. The process to obtain the derived variables that can be compared for each of the original variables employed formulae that established a final percentage scale (%), which allowed absolute zero. For each variable we had:

Environmental attitude*:*

- Original variable measure: ordinal.
- Derived variable measure: scale (%).
- Technique used in the measure: Likert-type questionnaire.
- Global score frame in the original variable: from 16 to 80 points, low to high valuation.
- Global score frame in the derived variable: 0 to 100%, low to high valuation.

- Formula used in the transformation:

$$y_1 = \left(\frac{x_1 - 16}{64}\right) \cdot 100$$

With x_1 being the original variable and y_1 the derived variable.

Environmental awareness:

- Original variable measure: ordinal.
- Derived variable measure: scale (%).
- Technique used in the measure: dichotomous questionnaire (true or false).
- Global score frame: two score choices, where "0" corresponds to "false" and "1" refers to "true".
- Global score frame in the derived variable: 0 to 100%, low to high valuation.
- Formula used in the transformation:

$$y_2 = \frac{x_2}{16} \cdot 100$$

With x_2 being the original variable and y_2 the derived variable.

In the section that describes the validation procedure, the subsection dedicated to information processing includes some aspects about the questionnaires related to the dependent variables defined.

2. Running the pre-test: both questionnaires were answered by the subjects, individually and anonymously, as a pre-test, to know the starting level of knowledge they had, which lasted as long as a regular lecture; the researchers of the team gathered to analyse the scores obtained. From the quantitative score of the pre-test, the following groups were established: year 12 Experimental Group (81 students), year 12 Control Group (86 students), year 13 Experimental Group (63 students) and year 13 Control Group (64 students). The total number of students in the sample was 294 students.

3. Procedural evaluation: the instrument was evaluated by a group of experts to determine whether it could be used or needed to be modified in order to meet its goal and be efficient.

4. Applying the instrument to the experimental group: the instrument was applied to the two experimental groups, each of them in their classroom, for a period of three months. The procedure was carried out twice per week, according to the timetable established by each school, in the Biology class, and individually, since each of the students worked with a laptop provided by the researchers, due to the lack of these in the schools; although the work was individual, the students could communicate with the researchers in case of doubt. In parallel, the students in the control groups also worked in the classroom, although they did so with their teacher and only with a master lecture.

5. Running the post-test: after the instrument was used by the experimental groups, the students were given again the same questionnaires they were given at the beginning of the experiment.

6. Validating the instrument by analysing the data generated: the method employed to validate the instrument, as previously explained, consists of an experimental pretest-posttest model. The data obtained from the pre-test and post-test questionnaires were analysed as follows: the Student´s T-test allows to detect significant differences in one, or several (in our case, two) dependent scale variables, with the treatment given (or its absence) being the independent variable. In the analysis to find statistically significant differences caused by the treatment in the dependent variables separately, the independent samples hypothesis was used. However, to analyse pairs of variables, when conducting the validation on samples in a pretest-posttest scheme, it is known for sure that the same individual corresponds to the measures before and after the treatment, or in the absence of treatment, for different moments of the experiment. This determines the parametric technique to be used, with the Student´s T-test being suitable for related samples (Murillo & Martínez-Garrido, 2012), allowing to run a quick correlation analysis between pairs of variables (attitude and environmental awareness in our case) with SPSS. It was not correct to use ANOVA as we only had two samples; although they were duplicated by course, they were not comparable. The calculations were done using the statistical software SPSS v17.0.

As basis of calculation, in addition to the recommendations of Murillo and Martínez-Garrido (2012), we adopted the conceptual fundamentals of García (2008). The level of safety was fixed to 95% in the tests conducted, which is suitable for the field of education. The sample size (143 students of experimental groups and 151 students of control groups) is in line with the objectives of the present study, as previously mentioned.

The sample size was calculated using the software MAS II (Manzano, 2000) in a simple random sampling context, reaching a level of confidence assumed: α = 0.05, considering that in order to extrapolate it to very large populations (extrapolation to all the high school students in the year 12 and 13 in Spain) it is required to study the standard deviation (SD) of the population. Adopting a variance no greater than 0.14 (0.374 SD), the conditions for a finite population of 425 students can still be accepted, with a precision error of 6.13%. For the most unfavourable case admitted by MAS II, which is a variance of 0.25 (0.5 SD), the precision error will go up to 8.2%. Variances greater than the values described may require the use of a different type of sampling (e.g. stratified sampling). Other observations:

- Estimated calculations for the population variance of 0.14. More than 33% of the finite population considered was sampled; however, since we worked with an unfavourable population variance hypothesis, the estimated precision error is 5% for the finite population and 6.13% for very large populations. The variance adopted is justified by the fact that students of different schools, from both sciences and humanities, were included in the sample size.
- In every case, the confidence interval was fixed at 95%.
- The size of the control group was 151 students, which were not computable for the sample size, and the total number of participants in the experiment was 294.
- Mathematical base of MAS II (Manzano, 2000) for finite and infinite populations:

Equation 1. Mathematical base of MAS II for finite populations.

$$n = \frac{N \cdot z^2\,\alpha/2 \cdot \pi \cdot (1-\pi)}{(N-1) \cdot E^2 + z^2\,\alpha/2 \cdot \pi \cdot (1-\pi)}$$

Equation 2. Mathematical base of MAS II for infinite populations.

$$n = \frac{z^2\,\alpha/2 \cdot \pi \cdot (1-\pi)}{E^2}$$

Regarding the parametric techniques selected, the Student´s T-test was conducted, as it allows to detect significant differences in one, or several (in our case, two) dependent scale variables, and the treatment applied in each case (the instrument created in this study, or its absence) was the independent variable. To detect statistically significant differences caused by the treatment in the dependent variables separately, the independent samples hypothesis was used. Thereby, it is carried out with the results from the two courses, independently. The aim is to identify significant differences in the dependent variables according to the treatment used, with or without the instrument (independent variable). The points of the test were the following: a. Experimental design of four independent groups (two experimental groups and two control groups). b. Test with an independent variable (treatment with or without the instrument), two dependent variables and large samples (n > 50). c. Level of measurement for dependent scale variables. Student´s T-test conducted for each dependent variable, with independent samples and for each of the high school courses. In total, four Student´s T-tests had to be carried out (two per course) for the post-test. d. Bilateral hypothesis: H_0: There are no significant differences in the dependent variables; H_1: there are significant differences in the dependent variables. e. Parametric contrast. Student´s T-test for independent samples. f. Steps: the significance level is obtained; the bilateral significance is analysed and compared with α, for each group; if the bilateral significance is lower than α, the null hypothesis is rejected (equality of means).

RESULTS

In this section we present the results of the experiment to verify the validity of the educational instrument designed. The design of this research is organised as follows: 1) a description of the experimental model used, 2) the objectives of the study, and 3) the different variables to work with. These are the derivatives obtained (see **Figure 1** for a graphical representation of the data):

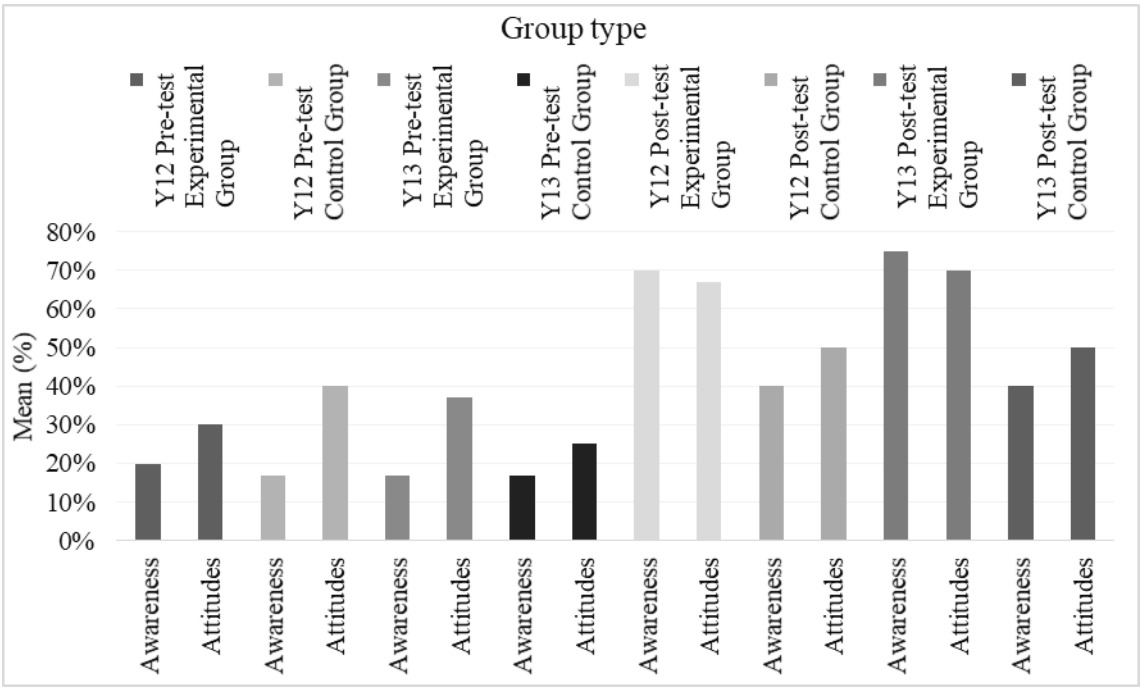

Figure 1. Comparison between global means for each type of group

In the Student´s T-test, for the dependent variable "environmental attitudes", the statistical values achieved were the following:

For students in year 12, for the control group (N=86), which did not receive the treatment (application of the instrument): Mean=37.9724, SD=2.99423, and standard error of the mean (SEM) =0.32288. For the experimental group (N=81), which received the treatment: Mean=71.3927, SD=2.90896, and SEM=0.32322.

For students in year 13, for the control group (no treatment) (N=64): Mean=39.2822, SD=3.40814, and SEM=0.42602. For the experimental group (treatment applied) (N=63): Mean=73.6607, SD=2.50782, and SEM=0.31596.

In the Student´s T-test, for the dependent variable "environmental awareness", the statistical values obtained were the following:

For students in year 12, for the control group (N=86), which did not receive the treatment (application of the instrument): Mean=53.1250, SD=7.65466, and (SEM)=0.82542. For the experimental group (N=81), which received the treatment: Mean=70.6790, SD=10.39465, and SEM=1.15496.

For students in year 13, for the control group (no treatment) (N=64): Mean=54.3945, SD=8.00543, and SEM=1.00068. For the experimental group (treatment applied) (N=63): Mean=71.1310, SD=9.87756, and SEM=1.24446.

Figure 1 shows the significant differences in both environmental awareness and attitudes in the students that received the treatment compared to those who did not. These differences must be understood within the context of the experiment conducted, considering precision and certainty.

The results show that there are significant differences in the mean values of the two dependent variables for the experimental and control groups, in both year 12 and year 13, as shown in **Figure 2**. For each of the four Student´s T-tests conducted, the bilateral significance was lower than α in all cases. This test gave a positive result for the students of both courses, which suggests that the instrument worked properly, regardless of the course to which the students belonged. Moreover, the results do not show any significant differences in the effect exerted in year 12 and year 13.

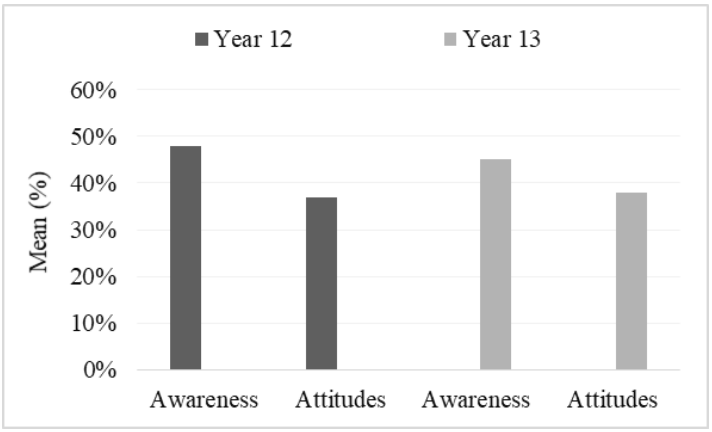

Figure 2. Comparison between the mean values of year 12 and year 13

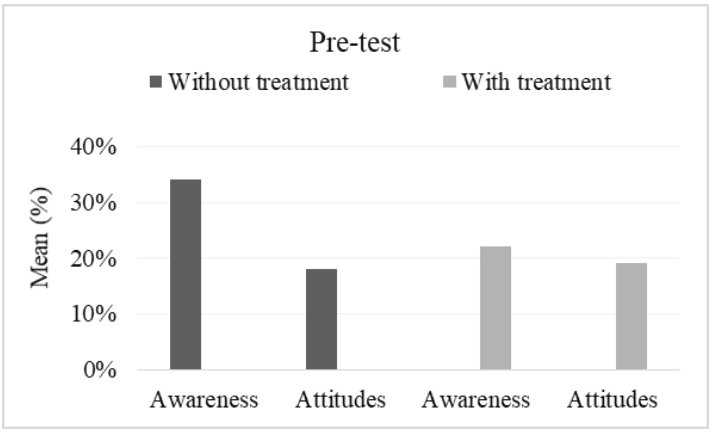

Figure 3. Homogeneity between samples

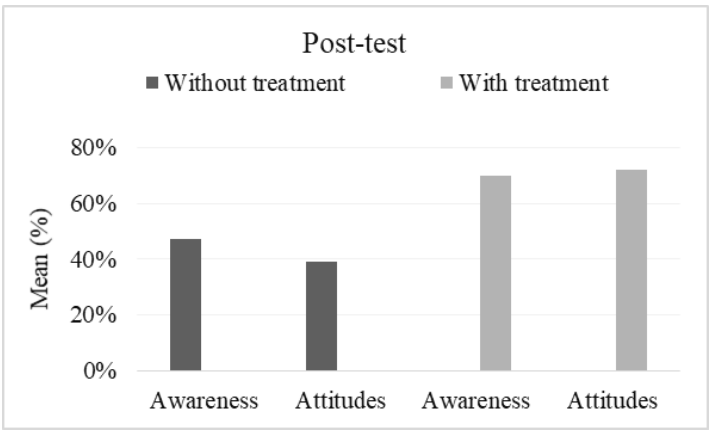

Figure 4. Differences of mean values with and without treatment

As seen in **Figure 3**, the similarity between the results of the mean values in year 12 and year 13 may be due to the fact that there is no significant difference in age and the students of both courses belong to the same cycle of education. However, in view of the results from the pre-test, it is not possible to assert that there were no previous differences before the treatment, since the small fluctuations that took place in the mean values of the dependent variables do not give rise to doubts: there are no significant differences between the students of year 12 and those of year 13 regarding environmental awareness and attitudes. The samples, as expected when working with over 50% of the population considered, showed obvious homogeneity. Considering that there are no significant differences between year 12 and year 13 in the pre-test, we will now discuss the results of the post-test, which are shown in **Figure 4**.

Therefore, the differences are very significant depending on whether or not the student received the treatment. Furthermore, a remarkable fact that could be deduced from the results is that at the pre-test and for all the groups involved (both experimental and control), environmental attitude was clearly lower than awareness. Once the designed instrument was applied, in the experimental groups, a certain levelling of the variables took place. However, this levelling also occurred in the control groups, although awareness and attitude increased less after the master class compared to the use of the instrument. It seems that environmental attitude is more difficult to increase than awareness in the daily life of the students. In fact, a specific learning was required, either through the use of the technological tool or the master class, in order for environmental attitude to reach levels similar to those of awareness. With respect to other non-quantitative observations, there were a series of interesting remarks throughout the experiment.

The application of the instrument involves certain instrumental aspects to consider; for instance, it was observed that some students have clear problems to socialise with their classmates, although this is not a general case. Until future qualitative studies are performed in this sense, it could be said that the designed instrument helped them to bond with their classmates, since sometimes new technologies bring people together. In addition, the students generally showed great interest for the methodology used with the technological instrument.

Lastly, in view of the results of this experiment, the application of the technological-educational instrument was successful, although the validation was only performed in two courses and some high schools. Thereby, the instrument can be defended with the results obtained in the present study, where "there are indeed cases" in which the designed instrument improves both the environmental attitude and awareness of the students in year 12 and year 13, compared to other traditional educational methods.

DISCUSSION AND CONCLUSIONS

The conclusions derived from the previous data, and with regards to the objectives of study, reveal the following aspects:

G.O. With respect to the specific objectives proposed, it is concluded that there are significant differences in both environmental awareness and attitude between the students that underwent the experiment with the instrument and those who did it without the instrument. Therefore, it is inferred that the technological instrument designed is effective, thus also meeting the main objective of the study.

S.O.1 The instrument is set as an effective method to improve environmental knowledge, which is evidenced by the improvement in the dependent variables established. Moreover, it can be more efficient than the traditional expository method, as it requires less time and sessions, as well as being appealing to the students. Thus, the main specific objective proposed is met.

S.O.2 The analysis of the results revealed an improvement in environmental attitude in those students that used the instrument, as well as an improvement in environmental awareness; therefore, it is concluded that there is no clear quantifiable correlation between the two variables from the statistical results. The students that received the treatment with the instrument seemed to be more aware, and according to the tutoring teachers, such students welcomed the sessions, which made these more favourable toward a better learning due to the technological nature of the application. In line with what is stated by Cabero (2016), the development of new ways of learning, in this case with the aid of a technological tool, is a clear advantage over traditional teaching methods.

Ultimately, we have developed an instrument that can breakdown the existing barriers and difficulties that refer to the acquisition of an environmental awareness, as well as the attitudes of 1st and 2nd Baccalaureate students, as this constitutes a need for the planning of a series of strategies that result in the students becoming aware of the importance of the environment. It should be mentioned that it is not only about the students becoming aware of the consequences of their actions, but also about this awareness driving them to become environmentally responsible, not only questioning what could be done for the environment, but also doing it. What is being mentioned here is the acquisition of an already cited component: the attitudes. Therefore, this study is driven into that direction, the shaping of attitudes and the acquisition of a type of awareness that is in agreement with environmental harmony (unselfish, integrating, proactive attitudes, etc.).

According to Novo (2011), the concept of environmental education has remained tightly linked to the environment concept itself during its evolution, which at first was considered from its physical and biological aspects. Afterwards, the concerns were broadened to the urban environment created by man, and the relationships were consolidated in this socio-cultural evolution of the environment. This study will try to minimize the education problem of the students with respect to the environment, and educational technology material will be developed for this, as we should not forget that the ideas and educational principles in the context of environmental education will be transformed into goals and competences for students. In line with Domínguez and Blanco (2018), programs on this subject should be fostered, so that this type of design and application of materials are required in current teaching, for all ages, incorporating technology as a medium that favors learning.

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Disclosure statement

No potential conflict of interest was reported by the authors.

Notes on contributors

José María Fernández Batanero – University of Seville, Spain.

Miguel María Reyes – University of Seville, Spain.

Rocío Piñero – University of Seville, Spain.

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