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Emotional Performance of a Low-Cost Eco-Friendly Project Based Learning Methodology for Science Education: An Approach in Prospective Teachers

Miriam Hernández-Barco * , Jesús Sánchez-Martín , Isaac Corbacho-Cuello and Florentina Cañada-Cañada 

Departamento de Didáctica de las Ciencias Experimentales y Matemáticas, Facultad de Educación, Universidad de Extremadura, 06006 Badajoz, Spain; jsanmar@unex.es (J.S.-M.); icorbacho@unex.es (I.C.-C.); flori@unex.es (F.C.-C.)

* Correspondence: mhdelbarco@unex.es

Abstract: Enhancing the emotional dimension of prospective teachers in science subjects—which has become increasingly important in recent decades—is a responsibility of higher education institutions. The implementation of active methodologies has the potential to modify the traditional student-teacher roles that are encouraged by the educational policies implemented in the Bologna Process. Simultaneously, it is possible to promote knowledge of sustainability, as well as the attitudes and behaviors required by UNESCO. The main aim of this work is to describe a project-based learning methodology with a transversal sustainability approach (low-cost and eco-friendly) and to introduce this as a potential resource for the emotional and cognitive improvement of 19 prospective primary teachers enrolled in scientific subjects. This is a qualitative study in the context of a research line focused on higher education for sustainable development. A questionnaire was designed and filled in by students at two different stages, before and after implementation of the activity. The initial feedback from students was surprisingly enthusiastic due to the fact that they were working with rockets, despite this not being considered a common emotion expressed by students in science lessons. The results show the emotional improvement of prospective teachers after implementation of the activity. It is concluded that a good science education, with implementation of sustainable approaches is necessary during the training of teachers, taking into account their emotional dimensions and social repercussions as a consequence of future transmission.

Keywords: project-based learning; science education; preservice teacher; emotions; active learning; higher education for sustainable development



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1. Introduction

The main concern which drove us to carry out this research was the need for scientifically competent education for citizens. Citizens should be capable of decision making and adapting to a scientific-technological world in an environmental crisis. We live in a context of over-information, where we have all the information we want in any given moment, but where disinformation and misinformation are also prevalent [1]. Scientific knowledge helps us to position ourselves in the world with a critical eye. In recent times, several anti-science movements have emerged, including “flat-earthers” [2] and climate change deniers [3]. Such developments reinforce the need for an adequate level of science education, including environmental awareness. Higher education is essential for the social, economic, and cultural development of society, as it not only provides academic knowledge but also enhances individual dimensions that represent a necessary basis for a civilized society [4].

Here, the findings of research conducted with prospective primary teachers in a general science subject, analyzing the emotions reported before and after implementation of a project-based learning (PBL) methodology, are presented. PBL places the learner as the

focus, making them the builder of his/her own learning and encourages the individual to learn to solve certain problems or challenges autonomously [5], while teachers provide the necessary supervision and support [6]. In this work, this has been done in the context of a research line focused on higher education for sustainable development (HESD), which has been encouraged by the United Nations Educational, Scientific and Cultural Organization (UNESCO) specialized in promoting world peace and security establishing international cooperation in education, sciences, and culture through different programs [7] and by Agenda 2030 [8]. Higher education has a decisive role in training responsible citizens. Sustainable practices and policies should be developed to promote green attitudes at university and higher education institutions, as well as to favor the acquisition of sustainable management models [9] to generate a sustainable way of thinking by learners.

First, in the introduction, the authors reflect on how science is taught in higher education to non-scientific audiences [10], according to scientific methods. In detail, to facilitate the future reply, a step-by-step description of the methodology is given. A qualitative analysis of the emotional dimension of prospective teachers and the results are shown. To finish, the paper presents a discussion, where the authors compare the results obtained here with other research that has also implemented PBL and other active methodologies at the level of higher education, the limitations of the study—since it is a case study—and finally, considerations of the social implications. In this paper, the authors encourage the implementation of active methodologies for HESD, particularly at the level of primary education degree.

The main objective of this research was to describe a PBL experience and to assess the student's perceptions and emotions when a PBL setting is followed as an instruction methodology. The study was conducted in a general science course, in the sophomore year of a primary education bachelor's degree in the Faculty of Education of the University of Extremadura (Spain) during the academic year 2018/2019.

2. Background

The background section is structured in four sub-sections. Firstly, (a) introduces the implications and the need for scientific literacy at the primary education degree level in the context of the 2030 Agenda for Sustainable Development Goals, which is required for HESD. The second part (b) concerns the emotional dimension in education. (c) Presents a summary of the transition to a primary education degree and an overview of the particularities found in such students, including some consideration of difficulties faced, with an emphasis on their emotional dimensions. Finally, in section (d), a description of the methodology implemented—PBL—is given, analyzed from the point of view of “nature of science” and the most suitable way for teaching science as determined from the literature review. The authors reflect on the need for a methodological change due to the future repercussions of teacher training practices and the requirement of a good standard of science teaching. This is achieved by hands-on activities based on scientific methods that help to reverse negative past experiences of prospective teachers, with a sustainable approach.

2.1. Implications and Need for Scientific Literacy at Primary Education Degree

In the undoubtedly highly scientific and technological societies we live in, with the associated major environmental challenges to be solved by future generations, scientific literacy is necessary for enabling citizens to effectively participate in the real world. Scientific literacy includes (a) intellectual aspects, referring to conceptual knowledge, explanations and analysis of the interactions between science, technology and society; (b) attitudinal and behavioral aspects, consisting of being able to apply scientific research, knowing how to communicate and showing curiosity about the world; (c) social and ethical aspects, situating science and technology as human constructs, recognizing the strengths and limitations of science and taking responsible actions; (d) and interdisciplinary aspects, connecting science, arts, technology, history, humanities, economics, and all the other

global issues [11]. To reach that goal it is necessary to know prospective teachers' beliefs, attitudes and behavior towards science and towards science learning [12].

The current planetary emergency situation we are living [13] is increasing its importance in social media and in every living context, to convey this message to future generations is urgent and crucial. The present is endangering the future; some alarms show that our system is unsustainable (people are dying, our aggressive consumption patterns, the environmental degradation...) [14] and global warming has increased global economic inequality [15]. However, an education that ignores the affective dimension of learners is also unsustainable. Educating in sustainability consciousness enables the development of the right attitudes and behaviors to protect the Earth and reduce pollution or climate change [16,17]; for this, institutions (and all stakeholders) should combine the current concern for the environment and what is explicitly required by 2030 Agenda [8] (teaching for Sustainability) and adapting to the new contexts of education.

Education has a key role in the development of societies, and educators act as "change agents" to achieve sustainability [18,19]. Higher education institutions are undergoing major transformation due to the internationalization and globalization of education, the ambiguity and the change of the space and time conceptions, new paradigms of knowledge production, the transformation of societies and science and the inclusion of new technologies [20]. Technological development in recent decades has led to changes in the way we teach and we learn. Higher education has also been affected by technology [21] which is a major challenge to universities [22]. Some adaptations include the implementation of the Bologna Process [23] in Europe. This requires students and teachers to adapt to a new "competences" model that is reflected in new subjects syllabus [24–26], transferring the central role of teachers to student-centered teaching [27].

International assessment tests such as Programme for International Student Assessment (PISA), that tests students aged between 15 and 16 years [28] and Trends in International Mathematics and Science Study (TIMSS) [29], that assesses students aged between 9 and 10, revealed that science teaching and learning are at a critical juncture. These studies summarized the student's science literacy level in OECD countries. The level of performance of Spanish students in mathematics and science subjects is lower than the average level of OECD countries. In the present work, a scientific method has been chosen for teaching science in the Primary Education Degree, which trains and qualifies prospective teachers for the profession. Science is introduced in all primary school grades. Despite the fact that during their instruction, the official curriculum of Primary Teachers Degree at the University of Extremadura (Spain) only has to take three subjects (representing 18 European Credit Transfer System (ECTS), the standard means for comparing academic credits, each ECTS stands for 25–30 h in European Union (EU) [30].

The prospective teacher's profile has been defined in previous research [10,31]. Generally, they tend to have a low self-efficacy perception, and have serious difficulties in understanding the importance of scientific knowledge. Prospective teachers have a low motivation and often experience negative emotions towards sciences (such as anxiety, boredom, or rejection) [32]. They often lack scientific characteristics such as curiosity, perplexity, or surprise. Prospective teachers often come from upper secondary studies related to social sciences or arts, which implies a low scientific knowledge background. Moreover, the scientific literature shows that prospective teachers generally do not like science, they feel uncomfortable when they have to teach it, and think it is difficult to learn and boring [33]. Marcos-Merino, Corbacho-Cuello and Hernández-Barco [34] described the sustainability consciousness of a Spanish prospective teachers sample, including knowledge, attitudes and behavior in the three dimensions of sustainable development (environmental, social and economic), and their results suggested that prospective teachers, despite having high levels of sustainability attitudes, do not report high levels of sustainability behavior. The authors manifested the need to teach about sustainability in initial teacher training to improve not only knowledge, but also to modify their behavior.

Why not use science for science teaching? The authors think that when prospective teachers learn science, they should do so by following the same process as the construction of science: making observations, asking questions, planning, conducting investigations, thinking critically and logically, communicating scientific arguments... Minds so trained will contribute to the improvement of society and scientific development [35]. Understanding the nature of science would help the development of scientific literacy, where knowledge is not the main focus but personal attributes and social development [11]. This would help them to enjoy the creation of science and to live new experiences that place them in the scientific role. Bellová, Melicherčíková and Tomčík [36] went into how to increase the effectiveness of teaching natural sciences subjects, and revealed that understanding how science works involves a synthesis of *content*—the knowledge of the facts, concepts, ideas and theories, *procedural*—the procedures scientist use to establish scientific knowledge and *epistemic* knowledge—which refers to understanding the role of specific constructs and defining features that are essential to the process of knowledge building in science. The challenge is to stimulate positive and exciting emotions, to initiate some of these scientific principles during prospective teachers' instruction, and to train prospective teachers who know how to do science.

2.2. Emotions in Education Process

Interest in emotions and what they generate in human behavior is practically inherent to human existence. In the civilizations of ancient Greece, philosophical theories and metaphors were put forward that reflected on the emotional aspect of the human being [37]. Since their origin, emotions and mind have been at odds with each other and at opposite poles [38]. However, emotions and the cognitive dimension have been considered independently, considering aspects such as memory, learning and attention on the one hand, and on the other hand, the emotional and cognitive response [39–41].

In our time, the association between the affective and cognitive dimensions in human beings is undeniable [42] and educational processes are replete with affects. Emotions influence students' learning and achievement [43,44] as they help to direct attention, which is a prerequisite for learning [41]. Emotional events that occur in the classroom help to establish or obstruct concepts in the memory [45].

Many classifications and taxonomies of emotions can be found in the literature. Darwin started the biological study of emotions [46], describing and comparing diverse universal facial expressions. Many authors such as Ekman [47], Damasio [48] or Goleman [49] have tried to establish classifications of basic emotions. However, there is still no established categorization. In this paper we use the definition of emotion proposed by Bisquerra [50]:

Emotion is a complex state of an organism characterized by an excitation or perturbation that predisposes to an organized response. Emotions are generated in response to an external or internal event. (Bisquerra, 2003, p. 12)

The classification used by Dávila-Acedo et al. [32] has been followed, based on that proposed by Fernández-Abascal et al. [51], in positive: confidence, enthusiasm, fun, joy, satisfaction and surprise; and negative emotions: anxiety, boredom, fear, nervousness, rejection and worry. According to this classification, positive emotions are those that ensure well-being, but the fact of classifying emotions into positive and negative has no connotation of "good" and "bad": emotions increase the evolutionary fitness for the individual [52].

Robert Plutchik, following an evolutionary perspective, affirms that feeling states tend to be followed by impulses to action: emotion is a chain of events and part of a social regulation process [52]. In order to construct a model of the affective system, Díaz and Flores [53] gathered a selected group of terms into sets of related ideas, and then the authors classified emotions on two axes of coordination: pleasant-unpleasant emotions on the vertical axis, and the opposite relaxation-exciting emotions on the horizontal axis. Therefore, there are emotions that incite us to act, while others paralyze us [40]. Within our selection, the emotions classified as exciting (and thus promoting action) are fun, enthusiasm, joy,

nervousness, surprise, anxiety and worry [54]. The opposite ones (paralyzing) are boredom, confidence, rejection and fear.

2.3. Project Based Learning for Science Education

Traditionally, science lessons have been taught through passive methodologies, in which the lecture has the main role and students only receive information [55]. The request for integration of the model competences brought with it a didactic and pedagogical challenge characterized by a constructivist understanding of education, focused on empowering students to address complex problems and future challenges (diverse conditions involving a multidimensional approach and immersion of different disciplines) [56]. Learning is an integrative and constructivist progress, not just receptive. It is highly stimulating to provide students with new opportunities and conditions (science, problems, activities) that help them to actively participate in the classroom by linking the content to their real life.

In fact, there are several and multidisciplinary tools and numerous pedagogical instruments that help to make science lessons more comprehensible while students improve other skills and competences [57]. In this paper, we present PBL as a methodology to teach science successfully, oriented towards self-learning and aimed at empowering prospective teachers. In the Figure 1, we present the steps to develop a PBL [58]:

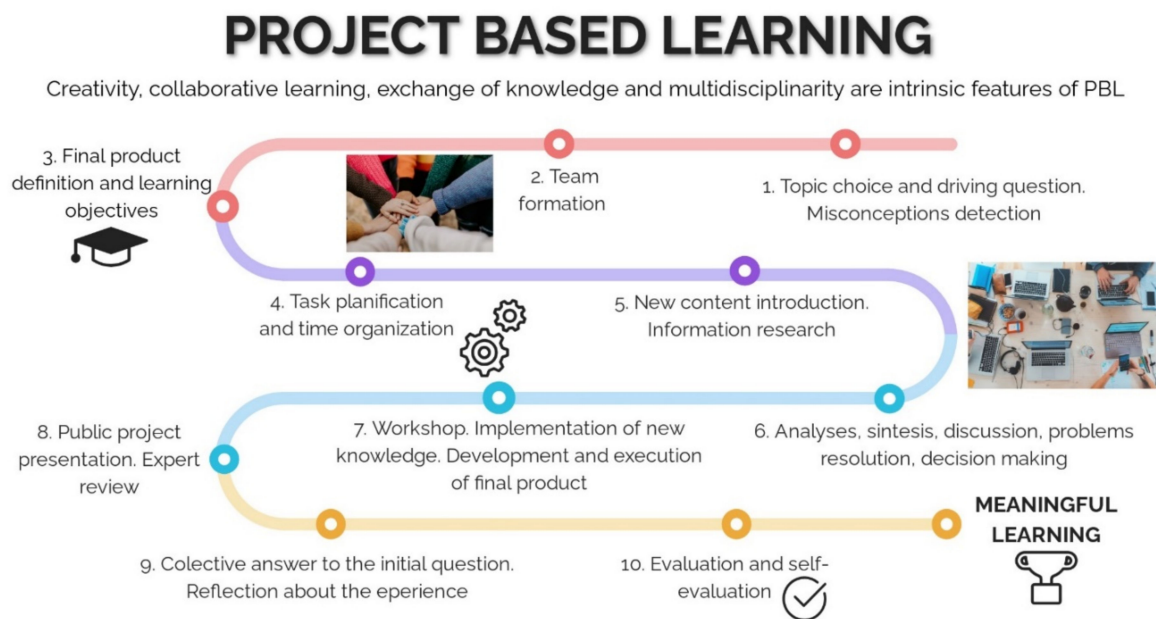


Figure 1. Steps of Project Based Learning. Own elaboration. Source [58].

PBL is a pedagogical methodology that places the learner in the focus as the builder of his or her own learning, being able to solve specific problems or challenges autonomously [5]. Teachers provide the necessary supervision and support [6]. Some advantages are that (1) it enables meaningful learning, helping to modify prior knowledge; (2) it is extremely versatile, easily applicable to any content and subject; (3) it stimulates autonomous learning, improving decision-making and increasing responsibility; (4) it is motivating and joyful, setting challenges that arouse curiosity; (5) it can be used to prepare them for future problems, placing them in real contexts; (6) it develops digital competences, developing web search and information selection in different languages and formats [59].

There are many references about the benefits of using active learning methodologies in science teaching [31,60–63]. However, there still exists a gap in characterizing how these methodologies, different from traditional exclusively orally-based lessons, affect the learning experience [10,31,60]. A few authors have already pointed out the main role the

methodology has on the learning experience, rather than other factors such as the content itself [64] or the academic background [65].

When designing a good PBL, these emotional considerations should be taken into account, so the entire didactic proposal is not only a matter of cognitive learning, but also an emotional and behavioral changing learning (See: CLIL for Young European Citizens. Project No. 2019-1-it02-ka201-063222).

The key to start making changes in the teaching practice may be to know how to stimulate emotions in the classroom through active methodologies such as PBL, and to take advantage of current knowledge about the brain within the constructivist paradigm so as to lead to more meaningful learning [66,67].

2.4. *The Activity for HESD: Hydro Propulsion. Historical Context and Scientific Content*

Humans beings are born inquirers. Astronomy arouses public interest [68]. The investigation of the universe has always been fascinating to humans, many children dream of becoming astronauts, space is attractive and exciting to study. Satellites, galaxies, and planets are very motivating for students. The National Aeronautics and Space Administration (NASA) has created a Rockets Educator's Guide [69]. All rockets, whether they are the biggest ones or a small model, work according to the same laws, so by understanding and employing these rules all rockets could function correctly as expected.

Rocket development represents human curiosity (a basic human trait that has ensured both our survival as a species and our continuous cultural evolution [35]) and the need to explore and discover through experimentation. We wanted to take advantage of this to include the design of a rocket for the subject of Didactic of matter and Energy whose content is related to (1) the current challenges of science education (interdisciplinarity and didactic projecting in relation to science, technology and society), (2) learning to teach sciences in Primary Education through different methodologies (inquiry-based learning, problem solving, hands-on approach or project-based learning...) and (3) science content in primary education. This subject is taught in a sustainability transversality-oriented way to break down the barriers between life and school, and to empower learners to take decisions and to promote sensible behaviors for ecological integrity, economic viability and a fair society, for current and future generation. UNESCO has developed a guide with several competencies for sustainability that HESD should work to achieve, including (a) systems thinking, (b) anticipation, (c) collaboration, (d) critical thinking, (e) self-awareness and (f) integrated problem-solving competency [70]. The aim of this project was to unify these soft skills in the building of water rockets from recycled soft plastic drink bottles, so students would verify if the bottles could fly over a hundred meters. The rocket building comprises two parts: the rocket itself, which consists of a recycled bottle partially filled with water and pressurized with compressed air supplied by a hand pump, and a specially designed launch pad required for holding the rocket while it is being pressurized. When the precise pressure is attained, the rocket is launched by being released from the launch base [69]. The launch base is constructed from recycled materials for an eco-friendly and low-cost hydro-rocket, thereby promoting environmental consciousness.

Other subjects can be worked on through this intervention, and it becomes an interdisciplinary learning Science, Technology, Transformative learning, Engineering, Arts, and Mathematics (ST²EAM) that provides prospective teachers with fruitful educational experiences that help them to develop knowledge and skills across disciplinary boundaries needed to solve today's challenges [71,72]. For example:

Philosophy and history of science. The real world can be studied from two different perspectives: a microscopic one (atomic or molecular scale) offering a discontinuous nature, and a macroscopic one (including continuous material systems detected by our senses). Epistemologies, ontologies, the scientific method and the integration of ST²EAM disciplines can be taught through the hydrojet intervention. Archimedes and the origin of mechanical physics—kinematic, statics, and dynamics; then how Kepler and Galileo initiated mechanics as an experimental science and finally Newton's laws of motion [73].

Newton summarized the whole of rocket science in three scientific laws published in “*Philosophiae Naturalis Principia Mathematica*” [74].

- Modern and contemporary history and the paradigm shift in scientific thinking. The world’s first artificial satellite, Sputnik I, was launched on 4 October 1957, leading to a reform of science teaching [75]. There are many recent anecdotes linking scientific and economic development: the space race to be the first colonizer of the Moon, or the global Cold War between the United States and the Soviet Union that brought the world to a standstill.
- Bioethics and the way science is influenced by morality and economy can also provide food for thought. Months after the Sputnik’s launch, the United States also successfully launched Explorer 1 on January 31, 1958. Finally, on July 20, 1969, it was the first time in history that humans explored other surfaces, in this case the Moon by Neil Armstrong. However, science does not always bring good ends: World War I and World War II have fostered the development of science and not for the benefit of humanity. Ethical issues can be raised here.
- Art and the development of the aesthetic sense. Besides the undoubtedly technological and scientific component of the intervention, the hydrojet design is also assessed. Students who found science learning uninteresting or boring, by using art, can find the attractions of physics along with its difficulties [76]. Izadi [76] reflects on how to guide students to learn science from their own creativity in art, suggesting that teachers can design inquiry workshops focused on developing students’ problem-solving skills and then students can provide solutions by using their creativity.
- Mathematics and technology. In science, it is quite common to make the measurements used in a calculation to find a value. A recurrent story is the 1998 destruction of the “Mars Climate Orbiter” due to a mistake in the unit conversion. It is very important that prospective teachers have a good knowledge of unit conversion and the metric system, which should be taught in Primary Education. With this project, prospective teachers are introduced to the study of scientific method and begin to manipulate laboratory material. The creation of a rocket and its base offers the inclusion of technology in the project.

The entire project must be carried out involving aspects related to environmental awareness. The fact of choosing a hydrojet (instead of a liquefied petroleum gas (LPG) or combustion jet) gives the teacher the opportunity to argue about the need for eco-friendly technologies. In addition, since we are working with recycled materials, concepts such as 0-residue, circular economy (science) or 3R’s can be also included in the lesson.

3. Materials and Methods

3.1. Sample

The sample consist of 19 pre-service Primary teachers (78.9% female). Regarding their background studies, 84% of participants studied a modality of Humanities, Social Sciences or Arts in Upper-Secondary Education, whereas 16 % of them attended a Science, Health Sciences or Technology course to access university studies. This sample has been intentionally chosen, not randomly, from the population of Primary teachers in training, all of them enrolled in a subject called Didactic of Matter and Energy. Participants were informed about being part of an educational research, the duration, the process, and the anonymity of their data. By the fact of being a human investigation which involves data collection from individuals, all actions made were in agreement with the ethical standards with the 1964 Helsinki declaration. Written informed consent was obtained from participants and the study was authenticated by the ethical committee (Comisión de Bioética y Bioseguridad, Universidad de Extremadura). All the information about bioethics and ethics in research activity at University of Extremadura can be retrieved from [77].

3.2. Survey Design and Data Collection

For data collection we decided to draft a questionnaire specifically for this study (see Appendix A). We used Google Forms to manage the data instantly and easily. The design was inspired by previous research with a similar sample [32]. The questionnaire consisted of two parts, the first one with socio-demographic data (gender and background studies), and the second referring to the emotions they expected to feel during the rocket fabrication. This section is composed of a list of twelve emotions (six positive and six negative) to answer if they felt them or not, and explain why. In the literature review one finds several emotions classification and taxonomies. Paul Ekman [47] determines six basic emotions: anger, dislike, frightened, joy, sadness and surprise. Other authors, such as Damásio [48], Goleman [49] or Bisquerra [78] have also tried to establish a categorization of emotions but it is hard work [79]. The emotions carefully chosen for the present study belong to a classification used by Dávila-Acedo et al. [32], based on that proposal by Fernández-Abascal et al. [51] which consist of (6) positives emotions: confidence, enthusiasm, fun, joy, satisfaction and surprise, and (6) negatives emotions: anxiety, boredom, fear, nervousness, rejection and worry. The questionnaire was provided on two occasions: just before and after the PBL implementation.

3.3. Data Process and Analysis

A descriptive analysis was selected as the most appropriate way to characterize, describe, and draw conclusions from the sample data, based on the content analysis proposed by Bardin [80], which consists of a technique for interpreting text in a systematic, objective, replicable and valid way. The comments provided by the participants to justify their responses were transcribed and analyzed. Both explicit (what prospective teachers write) and latent data (what it says unintentionally) make sense and are captured within a context. We wanted to take advantage of a small group of participants to aid the qualitative analyses.

3.4. Material and Resources for PBL Implementation

The prospective teachers were asked to bring all the elements they wanted to use: for the water rocket, two empty and clean 2-L and 1.5-L soft plastic drink bottles were needed, at least two of different capacities (this is interesting for students trying and experimenting with different measures), a cork stopper, a meter stick and a bicycle pump. Eye protection was also recommended. Some resources were provided for the launch platform construction: a tile, duct tape or scissors. Other materials for the holding device, such as woods, were recommended. A launch record sheet was provided, and they should bring their own computer for recording each launch. Water was available on the premises.

4. Results

4.1. Project-Based Learning Description

The experience was developed in a course called Didactic of Matter and Energy. This course is taught as part of the Primary Teacher Degree, specifically in the sophomore year (third semester, eight semesters in all) and it is compulsory. This subject requires 150 h of students' personal work (6 European Credit Transfer System), which are divided into large group (45 h) and small group (15 h) learning activities, the rest (90 h) are autonomous learning. It is the first science subject that prospective teachers receive at the start of their university studies.

The PBL activity has been implemented in small group activities, using 9 h (three sessions of three hours, spread over three weeks) in the context of a gamified science subject, therefore winners were awarded. The project consists of a rocket launching competition designed and constructed by prospective teachers using recycled materials.

4.1.1. First Session: Warm-Up, Organization and Information Research Time

At the beginning, the project was introduced; students were informed that they were going to build a rocket. At this point, the questionnaire was provided to know

what emotions they felt towards the rocket fabrication. Then, all stages, activities, and a chronological process of what they were going to do in all sessions were presented. The students organized themselves into teams of three or four members. The students documented themselves and gave the general direction of the work, followed by the design of the experimentation planning, and rocket model they were going to build based on research (Youtube, personal blogs or scientific articles). Later, the students decided on the kind of launch platform, including the drawing or pictures they found. Research on the best combination of variables to win the competition was performed. Next, they designed a sequence of experiments to obtain criteria to decide which values of the variables would be determinants: how much water, what kind of bottles or the angle of inclination of the base. All steps were documented in an essay.

4.1.2. Second Session: Problem Resolution and Decision Making

During the second session, each team built their rocket, their launch site and the students started with experimentation. The manufacturing was done in the laboratory, and the launches were done outside. There were different tasks: one member of the group acted as the launcher, another had to count the time and measure the launch distance, document and send back the rocket to the launch site for the next flight. The students repeated the launches over and over, trying different combination of the variables. The experimental variable was the launch angle, and the students compared it with the distance travelled by the rocket. The distances were recorded and averaged according to the angle of throw and the volume of water on the data collection sheet. They did not have to complete a minimum or maximum number of launches, but rather determine the best launch angle to obtain the greatest distance from the launch site. For high launch angles, the arc is steep and for low angles it is wide. The wind becomes an uncontrolled variable. If students work carefully, they observe that their furthest flights came from forty-five-degree angle launches.

4.1.3. Third Session: The Rocket Launching Competition

Finally, the day of the competition. They had time to make the last decisions or to think about how to improve the model they had initially chosen. The final challenge took place on a football field and a team of three external referees assessed the rocket launches. For the competition, two different aspects were measured.

On one hand, the rockets were launched in a straight line, the flight time was measured, the one that takes the longest to fall was considered to be the highest (neglecting air currents), and the rocket returned to the launch site. Thus, the highest rocket was awarded.

On the other hand, the students compared the launch angle with the distance at which the hydro rocket touches the ground from the launch site, so it was also measured how far the rocket reached the launch site. This depended on four things: the launch angle (less than 90 degrees), which was the independent variable; the acceleration of gravity, which was the same for all launches, so gravity was ignored; the initial velocity, which students did not know; and atmospheric drag, which affected the flight time. The furthest one was also awarded first prize. After the challenge, the questionnaire was again provided to be filled in. The rocket launching competition was uploaded to Youtube [81].

4.1.4. Low-Cost and Hydro Rocket Assessment

The fabrication of the hydro rocket involved investigations of the natural world, and several components were assessed. All students were able to carry out the experience, which included the comprehension of the scientific processes that involve the hydro rocket construction: measurement (water, angles, distance, time...), observation, data collection and management, experimental design, problem solving, scientific content, skills development... Initially, a diagnostic assessment was carried out to determine the prospective teachers' knowledge and understanding of the subject, classroom discussions and informal observations were conducted, and also an emotional pre-test were carried out.

Throughout the whole experience and during all the sessions, students were assessed of a formative way, helping and guiding them day-to-day. Individual and group development were supervised. Teachers who have participated in the experience looked carefully at prospective teachers' work.

After the rocket launch competition, students draw valid conclusions that were delivered in a report and they recognize regularities in nature, including concepts and content scientific knowledge.

The final assessment of the entire experience was carried out by merging three concomitant outputs:

- (a) The most relevant one was the Final Report each team had to upload to the web, so they could be shared by all the students. This document consisted of a preliminary theoretical background (designing the rocket), an experimental sequence (optimizing operational variables) and the final description of the rocket. This Report should include textual documents, mathematical procedures and data process and graphical/audiovisual evidence of the whole experience.
- (b) An observational diary was also carried out in order to periodically assess the students about their performance. Qualitative comments are provided daily, once the number of students was not very high.
- (c) Finally, elements of content (cognitive ones) were included in the regular final exam, which is necessary to pass the subject. Concepts such as Newton's Third Law, Pressure, Potential Energy or Free Fall were part of such evaluation proof.

4.2. Analysis of Emotional Development

Firstly, in this section, an analysis of positive and negative emotions is conducted. Positive emotions, and then negative emotions are shown. Rocket building was an activity that engaged students. When the teachers presented this experience to the prospective teachers, they all reacted quite excited and surprised. Some of their comments aloud were related to the impossibility of achieving it. Their self-efficacy was quite low. They did not feel prepared for rocket fabrication. Nevertheless, the percentage of positive emotions was quite high. The results of the positive emotions pre-test and post-test are shown in Table 1.

Table 1. Percentages of positive emotions selected by students (the percentage of "No" is omitted as it is obvious) pre-test and post-test.

Positive Emotions	Pre-Test	Post-Test
	Yes	Yes
Confidence	68.4	60
Enthusiasm	78.9	90
Fun	94.7	100
Joy	89.5	100
Satisfaction	89.5	80
Surprise	84.2	100

Then, a brief description of what was found in the responses of questionnaire is presented. The following information was extracted from the discourses of prospective teachers and their responses following Bardin's technique [80].

4.2.1. Confidence

When we asked about the degree of confidence they felt, the students who answered "yes" (68.4%), referred to the internal aspects (high expectations of themselves solving the project) and to the external factors which were (a) the teacher and the methodology, (b) the project itself (well structured, fun and new learnings). Students who reported not feeling confident indicated that they did not feel competent, felt insecure and thought that making the rocket would be difficult.

After the implementation, the percentages of students who affirmed they felt confident were lower. The students who responded affirmatively (60%) commented that their confidence increased and improved with the launches and that they were confident that they could perform the activities. On the other hand, students who did not feel confident because they were afraid and did not know how to do it.

4.2.2. Enthusiasm

Despite being a project that includes many enthusiastic dimensions, more than 20% of students stated that they did not feel enthusiasm before the project. The students stated that *“they had to do it as a must”*. The rest of the student mentioned that they were enthusiastic about learning new things, about doing *“an experiment”* that they had never done before, and that they liked it.

After implementation, the enthusiasm increased and they said that they were exciting by the fact of being creating a hydro rocket, and because every single launch was different, and they wanted to see how far it could go.

4.2.3. Fun

At the beginning, 94.7% of students said that they had felt fun because it was a new methodology and an innovative experience to share with their peers. They thought that the experience was attractive, striking and that it would be fun. Some of them stated that they liked the subject, and the experimental methodology to understand how the world around us works.

After the implementation, 100% of students said that they had fun during the process of the rocket fabrication, that it was an interesting project, and they laughed a lot with their classmates.

4.2.4. Joy

In the open responses, when we asked about *“joy”* the prospective teachers talked about being excited about (a) having done new things (different, never done before), (b) having used the PBL methodology (intriguing, innovative, interesting), (c) new learnings, (d) challenging (e) and because *“rockets are cool”*. Only two students responded that they did not feel joy, justifying themselves by saying that:

“I’m bad at chemistry and everything related to it” and “I think it is going to be quite difficult for me”.

After the implementation, 100% of students stated that they felt joy. Their answers focused on the launches, they felt joy when they were testing the rocket, it was a challenge, and a new methodology that has exceeded their expectations.

4.2.5. Satisfaction

Students showed high values (89.5%), all comments were based only on the satisfaction they would feel in completing the task, doing a good job and learning.

After the implementation, satisfaction decreased. Those students who did not feel satisfaction were the ones who did not win any prizes, or for whom the rocket did not launch well. The students who said they felt satisfaction also said that they had given their best and that gave them satisfaction.

4.2.6. Surprise

Finally, regarding surprise, they answered that they were surprised because they did not know what they were going to do, and because of the expectation of destroying and modifying previous knowledge that was not correct.

After the implementation, all students felt surprise during the PBL process. They confessed that at the beginning they felt afraid, but they were surprised by the good organization of the group.

Concerning the negative emotions, the percentages before and after implementation are shown in Table 2.

Table 2. Percentages of negative emotions selected by students (the percentage of “No” is omitted as it is obvious) pre-test and post-test.

Negative Emotion	Pre-Test	Post-Test
	Yes	Yes
Anxiety	57.9	20
Boredom	10.5	20
Fear	63.2	40
Nervousness	63.2	70
Rejection	10.5	0
Worry	47.4	60

4.2.7. Anxiety

Regarding to anxiety, 42.1% of students stated that they felt anxious before the project, with their answers referring to (a) the possible difficulties they thought might arise, (b) being something new and unknown, (c) the limited time they had and (d) there was one student who stated that she always feels anxious during science learning. However, we see that after the rocket fabrication, anxiety decreased by up to 20%.

“I take it slowly because I knew that everything was well organized.”

4.2.8. Boredom

Almost no students answered that the experience made them feel bored; they thought that the project was enjoyable and fun, and that it would help them in their future with their upcoming students. However, after the implementation boredom increased to 20%, and they argued that the repetition of the launches made the experience boring.

4.2.9. Fear

The students who answered yes argued that they felt they would not be able to build the rocket no matter how hard they tried. We did not receive any justification for the students who said they did not feel fear during the rocket fabrication.

After the implementation, the fear decreased to 40%. One student stated that she did not feel fear because *“I knew that no matter what happened, I had tried”*.

4.2.10. Nervousness

The answers were closely related to the aforementioned emotion: fear. More than a half of the students said they were nervous prior to the launch because of the expectation that the project generated, the time limitation, difficulties that might arise, poor results and if the rocket did not work well.

After the implementation, the nervousness increased, and the responses were about competition and the pressure of the launch challenge.

4.2.11. Rejection

The rejection values reported prior to implementation were quite low. Some students justified that they felt rejection because of possible difficulties that could arise. After the implementation, this emotion was not selected by any student.

“Because the project was motivating and because we were working with a different methodology.”

4.2.12. Worry

Finally, in terms of worry, more than half of the students stated that they were worried about the stress of doing well, about some difficulties that might arise or about not doing it

right. After the implementation, worry increased to 60% and prospective teachers affirmed they felt worried about the rocket competition and about not performing the rocket launch.

In terms of the upper-secondary education path, students who had completed a Science, Health, Sciences or Technology course to access university studies felt more positive emotions towards the activity from the beginning, all of them (100%) manifested to feel positive emotions and the negative emotions that they felt are nervousness and worry, emotions classified as exciting (and thus promoting action) [54].

In terms of gender, the explorations that have been made of the data do not generate any relevant results: no generalizations can be made according to gender, there are no evident differences that would allow us to conclude differences in terms of positive or negative emotions by gender.

Regarding the positive emotions, we see that from the beginning, the scores were quite high (all above 60%), but most of them even increased to 100% (such as fun, joy and surprise). However, two positive emotions decreased, such as confidence and satisfaction. In this sense, the assessment the researchers can make is that challenge and competition by itself have generated this decrease. In addition, what we find with regard to the evolution of the negative emotions is that almost all negative emotions were reduced, and some of them, such as rejection, disappear. Anxiety decreased by up to 20%, and the only one that increased is boredom due to the repetition of the launches.

5. Discussion

This experience can be defined as a “hands-on” activity, as described for teaching technology by Sánchez-Martín et al. [62], that is focused on “learning by doing” which means a more meaningful learning, which influences the affective domain of students.

A detailed description of the PBL methodology for Higher Education for Sustainable Development can be found on Youtube [82]. Rocket fabrication involves those skills what are encourage by the Bologna Process, related to problem solving, critical thinking or cooperative learning [83] and that contribute also to Higher Education for Sustainable Development.

Wilhelm et al. [56] demand pedagogical and didactical knowledge from university educators as well as an exhaustive understanding of how to accomplish competence orientation in teaching. Breidenstein’s studies reflect the necessity of a methodological change in school lessons, traditionally lecture-style, because of them being boring [84].

Rocket fabrication supposes an opportunity for students and for teachers to learn and teach by integrating ST²EAM following the scientific method. Prospective teachers become “rocket scientists”, experts enthusiastic and enrolled in such an interesting task. Even though no experience like this has been described previously, NASA recommends the implementation of the rocket fabrication during school [69]. We observed a decrease in anxiety, an emotion that negatively influences on academic performance [85], after rocket fabrication.

Science educators should also provide a cooperative and supportive classroom climate, for those students who remain affected by negative emotions such as anxiety or fear [86]. The emotions that prospective teachers experience towards science contents determine the emotions that they will transfer to their upcoming students [87]. Emotions greatly influence cognition, motivation, interest, and science learning, so it is necessary for teachers to be aware of the potential of emotions and how they influence the development of the classroom. This would help them to carry out their tasks by applying different methods and making decisions to foster positive emotions during the learning of science [88].

More than a few of the PBL practices in higher education have been described and shared by researchers in multiple and different areas such as engineering [89], medicine [90], social sciences, business management, economy [59], geography, architecture and marketing [91]. A Project-Based Learning methodology has also been used with prospective teachers with the aim of teaching sciences with successful results and also including Sustainable Development Goals (SDG) [92]. Brody and Ryu [19] implemented the PBL

methodology and demonstrated the educational impacts on sustainable development. Marcos-Merico, Corbacho-Cuello and Hernández-Barco obtained that prospective teachers need to improve their sustainability consciousness including behavioral changes during their training [34].

Some pedagogical benefits that can be drawn from the research are outlined by Anđelković et al. [27], who analyzed the opinion of 215 higher education students and concluded that fieldwork contributes to improving the didactical-methodical aspects of teaching, highlighting (1) the social relations of students, (2) development of required skills, (3) increased motivation in the learning process, (4) interdisciplinary study of the problem and (5) immediate contact with objects. Other authors report that a PBL experience at higher education provides motivation and prepares students for real practices [90]. Improved students attitudes toward learning and a deeper understanding of the subject content have been also reported [93].

Other active methodologies, such as inquiry-based learning, have been shown to enhance attitudes towards science and decrease teachers in training's anxiety [94]. This methodology also makes prospective teachers realize that almost everything is somehow related to science and stimulates their own curiosity, which indicates that improving the professional and personal attitude of teachers in training is possible throughout the implementation of these affective-centered methodologies.

Jeong et al. [95] have investigated prospective teachers' emotions towards science learning when a Flipped-Classroom setting is used as instructional methodology and they also report more positive and exciting emotions (such as fun and enthusiasm) than negative and paralyzing [60] emotions. The teacher training process should address the emotional dimension in order to improve the emotions they feel by providing them with experiences that provoke changes in them by turning negative emotions into positives ones.

However, it is not just about the affective domain, research analyzing 225 studies reported that students' performance and concept inventories in STEM courses increased more when working under active learning than under traditional lecturing [96].

Controversial studies question whether training schools help teachers to learn [97] and suggest that now more than ever there is a need to improve the quality of teacher training, and this requires teachers with deep subject knowledge and this could be done by teaching for problem solving, invention and application of knowledge.

The following practical considerations can be drawn from the work:

With regard to the implications that the implementation of this methodology has on the Primary Education Degree, Church [11] recognizes how necessary school science is to enhance scientific literacy. Teachers in training will be responsible for the scientific literacy of citizens and that is why we have designed this PBL activity to meet the requirements of school science [11], set out below (a) to draw the student's attention, leading to increasing their motivation, (b) offering them the PBL methodology as a resource for their professional future, (c) providing them with insights into the role of science in the current world and the impact of history, (d) empowering them and helping them to become responsible citizens. The affective domain and attitude towards science teaching are directly related to the behavior and intention to teach science of prospective teachers [94].

The main limitation of the study is that the activity was carried out with a single group with a limited number of subjects. As it was a voluntary survey, although all students filled in the first questionnaire, not all of filled in the second one and therefore it was necessary to express the results as percentages.

Qualitative research is occasionally underestimated because the results are not explicitly obtained through a statistical program. However, qualitative research is necessary, even more so in education research. Jin and Bridges reveal that qualitative PBL research is growing [98]. In our case, our intention is to continue with the implementation of PBL at Higher Education in the Primary Education Degree in order to enhance our constraints; semi-structured interviews can be conducted with prospective teachers to enrich the information obtained from the questionnaires.

6. Conclusions

This work was carried out as a part of research on emotional and cognitive changes in teachers in training programs through different methodologies focused on Higher Education for Sustainable Development. The strength of this research lies in eliciting the emotional performance of a PBL methodology and the exhaustive description of the experience. From the results obtained it can be concluded that, with regard to the first objective, a PBL experience has been described, offering times, materials, teaching and learning activities, and other resources. In accordance with the second objective, the emotional bias toward sciences of teachers in training showed that rocket elaboration is an enthusiastic activity and prospective teachers reported greater positive emotions than negatives ones. After the PBL implementation, an increase in positive emotions (except confidence and satisfaction in those cases where the rocket failed), and a decrease in negative emotions, except boredom is reported. With these results, the authors call for an accurate scientific education for prospective teachers in order to improve the emotional dimension for future transmission by the time learners develop competencies that enable and empower them to reflect on their own actions by considering their present and future environmental, social, economic and cultural impact [99]. The scientific education of prospective teachers should be improved through methodologies that motivate and turn on their emotions that help to produce a meaningful learning [60] and to acquire scientific competencies who enable them to lead healthy, sustainable and fulfilled lives [34]. The results suggest that Project-Based Learning is a resource to enhance the positive emotions and reduce negative ones in the science lessons of prospective teachers and enable learners to contribute towards sustainable development.

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Appendix A. Questionnaire Used in This Research

Code:

Gender:

Age:

Indicate in the following table what emotions you feel when you think about the building of a hydro-rocket and then explain why do you feel this way.

Emotion	Yes/No	Why?
Confidence		
Enthusiasm		
Fun		
Joy		
Satisfaction		
Surprise		
Anxiety		
Boredom		
Fear		
Nervousness		
Rejection		
Worry		

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