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APPLICATION OF GREENPOWER PROJECTS IN DISTINCT EDUCATIONAL SCENARIOS

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The Greenpower Education Trust model has been functioning in the U.K. since 1999, providing evidence on the variety of distinct models available. The proportion of learning and professional development obtained during curricular or extra-curricular activities varies between academic centres that participate in this framework. The students design, manufacture and compete in their own electric cars. Direct participation of teaching staff, family members, specialist technical mentors and industrial partners also varies between different teams. In the Iberia geographical region, the student motivation, and UK Engineering Council defined professional competence development, are key factors which are visible in the schools where the project has been implemented to date. Examples are already available of teams from primary and secondary education publishing their activities, visible on the Kid´s Kitcar - Greenpower Iberia web page, as evidence of their project results for their stakeholders. The transparency of this project promotes these elements of open- and reflective-learning which are key to the students developing their own initiative and ability to "teach themselves". The present work show the Greenpower educational project implementation in the formal education at Gaztelueta high school (Spain), taking advantage of the education by competences and the advantages of the project based learning.

Keywords: *Project Based Learning; Active and collaborative Learning; Experiential Learning; STEAM competences*

APLICACIÓN DE PROYECTOS GREENPOWER EN DIFERENTES ESCENARIOS EDUCATIVOS

El modelo Greenpower Education Trust ha estado funcionando en el Reino Unido desde 1999. La proporción de aprendizaje y desarrollo profesional durante las actividades curriculares o extracurriculares varía entre los centros académicos que participan en este marco. Los estudiantes diseñan, fabrican y compiten en sus propios automóviles eléctricos. La participación directa del personal docente, los miembros de la familia, los mentores técnicos especializados y los socios y patrocinadores también varía según los diferentes equipos. En la región geográfica de la península ibérica, la motivación de los estudiantes, y las competencias profesionales definidas por la Engineering Council, son elementos clave visibles en las escuelas donde se ha implementado el proyecto. Existen varios equipos de educación primaria y secundaria que publican sus actividades, accesibles desde la página web Kid's Kitcar - Greenpower Iberia, mostrando los resultados de sus proyectos. A través de esta difusión se promueve un aprendizaje abierto y reflexivo, que son clave para que los estudiantes desarrollen capacidades de emprendizaje y de autoaprendizaje. El presente trabajo muestra la implementación en la educación formal del proyecto educativo Greenpower en el colegio Gaztelueta (España), con un modelo educativo de educación por competencias y las ventajas del aprendizaje basado en proyectos.

Palabras clave: *Aprendizaje Basado en Proyectos; Aprendizaje activo y colaborativo; Aprendizaje experiencial; Competencias STEAM*

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1. Introduction

In the current social and economic context, there is a consensus that students need a wide range of skills to thrive in an environment marked by a globalized economy and in increasingly diverse societies. Many of these students will work in professions that do not yet exist; and others will need advanced language, intercultural and business skills. Technology will continue to change the world in ways we cannot imagine. Challenges such as climate change will require radical adaptation. In this increasingly complex world, creativity and the ability to continue learning and innovating will be essential qualities that will have greater importance than specific areas of knowledge that run the risk of quickly becoming obsolete. (Kolmos, 2016)

The education system organized in different subjects, based mainly on a rote learning of contents, was created more than 100 years ago. Despite its evolution in certain aspects, it largely maintains its essence. This system is organized in watertight blocks of knowledge, which are usually taught individually, without showing possible connections between the different subjects and without seeking the transversality between the different disciplines. However, in a highly technological world which is constantly changing, this educational system does not correspond to the real educational needs, which should be related to the training needs of a globalized and growing market.

Greenpower is a tool that adapts Kolb's experiential learning cycle to jointly integrate learning by problems and by projects, promoting transversality between different disciplines, and therefore achieving an adequate development of the STEAM competences (Science, Technology, Arts and Mathematics). This model of non-formal education has been established internationally since the 1980s. One of the goals of the Kid's Kitcar - Greenpower Iberia association is to raise awareness about sustainable mobility for society. Another objective of paramount importance is that companies participate to define the skills they need and can identify talent at an early age, so that they can develop a professional career plan for the development of the students.

In this work, the introduction of the Greenpower in the Spanish formal educational system is described. Taking into account the aforementioned disadvantages of the educational system, it is necessary to introduce participative and collaborative dynamics in the classrooms, which allow students to interact in real projects where the student plays a more active role in their learning. Taking into account this objective, the Greenpower project has been introduced at Gaztelueta high school, adapting Kolb's experiential cycle to jointly integrate learning by problems and by projects, being implemented as an interdisciplinary and transversal tool for the development of STEAM competences (Science, Technology, Engineers, Arts and Mathematics). In order to evaluate this innovative project, a satisfaction questionnaire was used. The results show an increase in motivation and an increase in intentionality of future use, in full agreement with experimental theory of the Technology Acceptance Model (TAM).

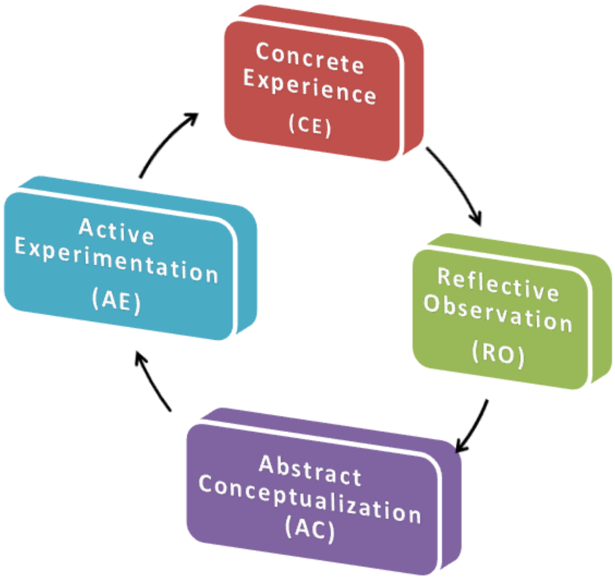
2. Theoretical framework

2.1 Kolb's experiential learning cycle

The Kolb experiential learning cycle is particularly suitable for education, as it is widely documented in the literature (Muscat, Mollicone, 2012). Based on Kolb's theory (Kolb, 1984), there is a combination of theory and performance of experiments applied in the context of the STEAM classroom. The advantage of this systemic instructive framework is that it promotes a balanced learning between general / theoretical principles and innovative influence.

Figure 1 shows Kolb's learning cycle. This consists of 4 phases, specifically the Concrete Experience (CE), the Reflective Observation (RO) phase, the Abstract Conceptualization (AC), and the Active Experimentation (AE). The learning is done through the completion of this cycle, without being any of these phases main actor in it.

Figure 1: Kolb's experiential learning cycle



These phases of the Kolb's cycle have been taken into account for the design of the Greenpower project. The vertical axis in Figure 1 represents the knowledge comprehension dimension. Knowledge can be acquired by Apprehension (Concrete Experience) or Comprehension (Abstract Conceptualization), or by a combination of both. The horizontal axis represents the transformation of knowledge, and can be achieved by Intention (Observation Reflection), or by Extension (Active Experimentation).

2.2 Problem Based Learning and Organized in Projects

Greenpower carries in its DNA the learning based on Problems and organized in Projects. Students are much more involved in their own learning, are motivated, fostering collaboration with other colleagues, which allows to exploit much better the abilities of each student individually creating in the plurality and diversity of students a positive factor for learning and improvement of the whole. On the other hand, working for projects allows the reinforcement of the learning of educational competences, but also allows to integrate in a practical way values such as cooperation, generosity or organization that are not easy to teach in a theoretical way.

Greenpower provides students with a variety of pedagogical approaches, to develop their skills, understanding and competences to address the professional challenges they may face, regardless of whether or not they will devote themselves to a scientific-technical profession.

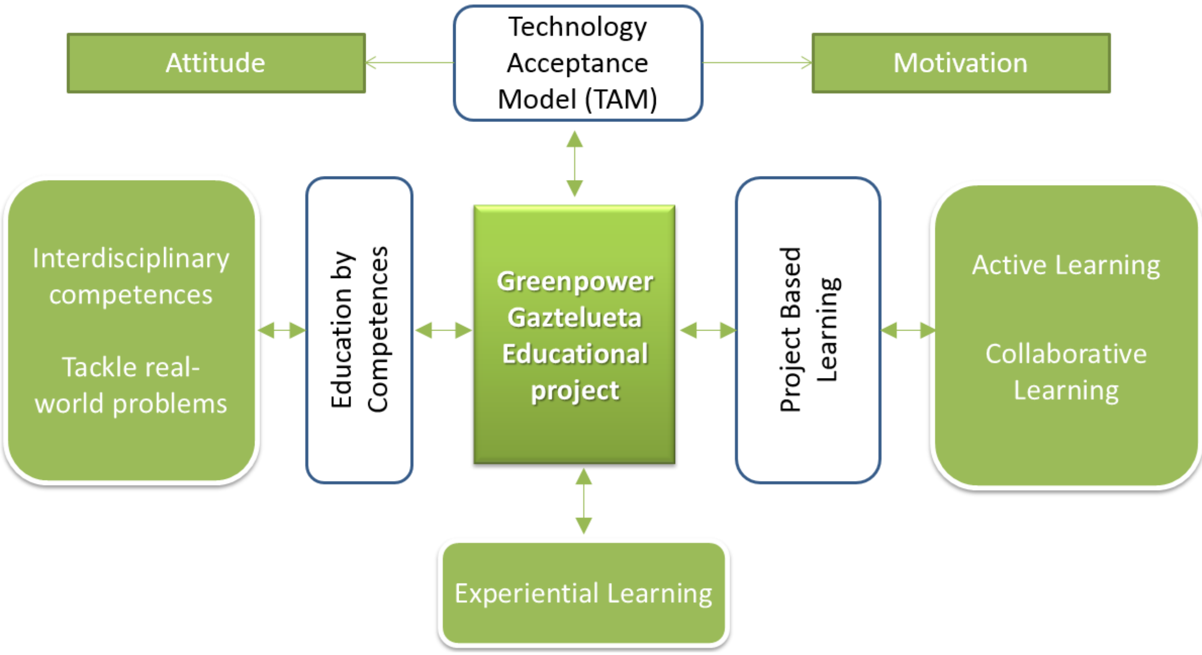
2.3 Technology Acceptance Model (TAM)

The Technology Acceptance Model (TAM) refers to two particular aspects: perceived utility and perceived ease of use, which are the main factors for the acceptance of technology (Davis, 1989). In addition, the perceived usefulness and perceived ease of use affect a person's attitude towards the use of the learning system, and these attitudes towards the use of the learning system determine the intentions regarding the behavior.

3. Greenpower project

Greenpower is based on an experiential Kolb learning cycle, optimal for learning Science and Technology according to multiple experiences gathered in the literature. This proposal, shown in Figure 2, seeks to respond to new problems faced by the student in a global context in which competences are key over theoretical knowledge. For this, a hybrid learning is proposed for problems-projects, in which learning is self-directed by students, and the construction of knowledge is collaborative and supervised by the teacher at certain times. Motivation and attitude are key to the successful implementation of this proposal, which is why the Acceptance of Technology model has been taken into account.

Figura 2: Greenpower framework



The students are divided into teams of 8 students. In order to avoid dominant positions a role is assigned to each student before the completion of the task.

Students are organized into at least three teams, each one with different objectives: The Engineering team, which deals with the construction of the car; The R & D team, which is responsible for applying the new ideas that arise from the reflection amongst the students; and the Marketing team, which is responsible for finding sponsors and public diffusion of the project, amongst others. In this case, the Marketing team also considers the financial aspect. More teams are to be developed in the near future, taking different roles and other types of tasks and objectives, different from the ones already established by the UK Standard for Professional Engineering Competence (UK-SPEC). The teams are created with the purpose of periodic rotation, so that all students develop all the required skills and abilities along the course. This system requires that the teams transmit their advances in their field in the rotation process, so that the incoming team starts at the very same level achieved by the outgoing team.

In the CE phase (Concrete Experience), the Greenpower project provides a kit of a Goblin, F24 or F24 + car - depending on the categories-, and a question or situation is formulated, which is the starting point of the Situation- Problem, for the Engineering team. The same applies to the R & D and Marketing teams that would start from the results obtained previously, if any, and from the resources necessary to carry it out, respectively.

In the RO (Reflection Observation) phase, students should observe the complete car kit, reflecting on which parts should be developed to solve the proposed problem, and the optimal tools to be used for modeling, development and assembly. In the AC (Abstract Conceptualization) phase, students must model the part of the electric car whose design should be enhanced.

Finally, in the AE (Active Experimentation) phase, the students must prove that the developed part fits the car perfectly and that it shows optimum performance. If the developed part does not work correctly, the students will have to redesign it. In this way, the student would move consciously through all phases of the learning cycle. (Shih, Chang, Chen, Chen, & Liang, 2012)

4. Materials and Methods

We have the Goblin and F24 kits and a STEAM classroom specially designed for the experiential learning cycle framed in problem-based learning organized into projects.

4.1 Greenpower kits

The kits have the parts and materials necessary to build the car, except the body. The provided kit includes a guide with illustrations which eases the assembly process. In addition, the kit contains an electric engine and batteries. It is necessary to acquire the tools to assemble the car separately, but a standard toolbox is enough to perform all the assembly and disassembly process. The kits are designed to promote the participation in the initial stages of the project. After this basic learning stage with the kit for students and teachers, all of them are prepared to develop their own car design.

4.2 STEAM Technology Laboratory

The STEAM classroom is an open-office type, wide, diaphanous, and with open spaces for teamwork, for the synthesis and of course for the exhibition and public discussion of ideas. It is a comfortable and acoustically prepared place. The design of the STEAM classroom is shown in Figure 3. The room is divided into several sections with different environments, but without any discontinuity.

The tables and cabinets have wheels to easily change the distribution if the required, and new environments can be created if it is desired by the team members. The laboratory cupboards that are used to store material and to separate spaces are both transparent and small sized in order to favor the vision of the entire classroom without visual obstacles.

There is a zone of mechanical workshop, equipped with textile floor, allowing the students to work comfortably. The area of art and design is connected without any type of obstacle to the other spaces of the classroom. In this area the water taps and sinks are installed. The space is adequate for students to work, build and paint the body, as there are windows and ventilation points nearby. It must be taken into account that students work with materials such as cardboard, plastic, metal plates, fiberglass and carbon fiber, amongst others. In addition, several tables are installed for teamwork, which can be used by up to eight people. Several tables can be joined together if necessary.

Students can find literature on research methods, presentation techniques, and scientific writing on the book shelves of the STEAM classroom. In addition, students have Chromebooks as a tool to share documents, research the Internet or send emails to companies and potential sponsors.

Figure 3: Layout of the Technology Laboratory at Gaztelueta high school

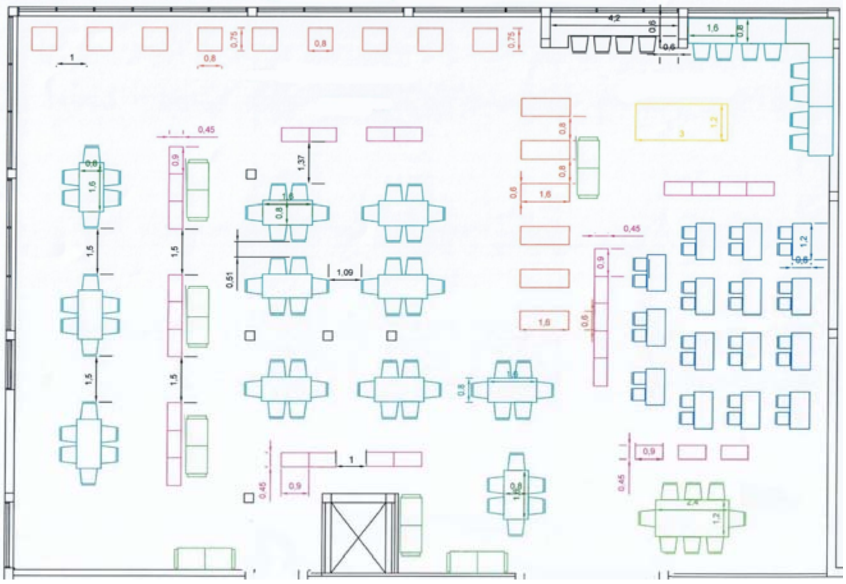


Figure 4: Mechanical workshop zone of the STEAM classroom

The electronics and robotics area is on the other side of the room. It has a zone of welders and several computers. Nearby, there is a space for the 3D printer and a computer with the necessary software installed. In addition, we have the Solid Edge 3D design program in order to create the models.

The workspace offers versatility and adaptability required for the working methods of the 21st century projects, in which experiential learning and generation of collective knowledge are fundamental tools in the scientific-technological field.

The lateral part is configured to give lectures. It is equipped with a projector and a projection screen. In different areas there are some armchairs where students can sit relaxed to express their ideas, reflect or just relax. Finally, there is an area to receive people, such as the sponsoring companies. In Figure 4, the mechanical workshop zone of the STEAM classroom is shown.

4.3 Educational Methodology

Students are organized into teams, which are collectively responsible for the final product, which is the result of the proposed problem. The development of the product must take into account the Ecodesign standards and the results must be exposed in public and must be verified in the official Greenpower races.

The main advantages of this methodology are a more enjoyable learning and the high perception of utility, which together with the organization of competitions result in greater motivation. In addition, the development of transversal disciplinary competences in Sciences, Technology, Arts and Mathematics is encouraged.

The implemented methodology revolves around 5 fundamental axes:

- Education by competences: Competences within the STEAM framework: Science, Mathematics, Engineering, Arts and Mathematics, searching the transversality between all the subjects, so that there are no watertight blocks of contents, and they are intimately connected to each other. Moreover, this type of education promotes the creative scientific thinking (Lawson, 1994) necessary for the technological development of the 21st century. In addition, key core competencies such as the citizen competence and the entrepreneurship will be promoted, together with values such as sustainability and the respect for the environment.
- Experiential learning based on the Kolb cycle: it is widely documented in the literature (Kolb, 1984) that learning within a scientific-technological framework involves different phases and mental processes that are defined within the Kolb cycle, taking into account that experiential learning includes a rationalist phase followed by an empiricist phase that should not be ignored, with the aim of developing scientific thinking.
- Representation of mathematical and physical concepts in order to perform an adequate apprehension of them. That is, prior to the access to symbolic representation, related to the abstract conceptualization of Kolb's experiential learning cycle, the teacher must show the mathematical variables from the most tangible and easy to handle representations, to the most intangible and abstract representations.
- Active learning with the aim of obtaining transferability. Therefore, variables with physical meaning, based on real-world problems will be used.
- Implementation of Ecodesign: all products must take into account the Ecodesign technique, so that every product must be optimal in terms of sustainability even from its conceptual phase, through its manufacture and use, and its recycling process. Therefore, the designed product is efficient and ecological throughout all its design and use cycle, and can be easily recycled.

In this way, the disciplinary competence in Technology is worked together with the transversal disciplinary competences of Mathematics, Arts and Sciences.

On the other hand, thanks to the work based on problems and organized in projects, the entrepreneurship competence is promoted, necessary to give solutions to the proposed problem through real challenges that encourage motivation; the competence for personal initiative, of special importance for the generation of ideas in the field of teamwork; communicative competence, which favours the internal management of problems within a project, and which is necessary for the transmission of results to other colleagues.

In addition, social competence is promoted through the values of social and civic responsibility, through the promotion of the electric car and the Ecodesign methodology, respectful of the environment.

4.4 Electric Car Racing Events

The races allow the team to validate their model and share their knowledge (Open Learning) with the other teams. The experience in competition conditions allows to detect errors or weaknesses in their designs in order to develop feasible improvements. This is the Active Experience phase (AE) of the Kolb's cycle. As they are required to present their developments in public, they all learn from the experience of others, so that the knowledge is produced in collective way.

Figure 5: Boxes of Gaztelueta Greenpower Team in the 1st race of the 2018 season in Bilbao

Figure 6: One of the three F24 electric cars which took part in the race event in Bilbao

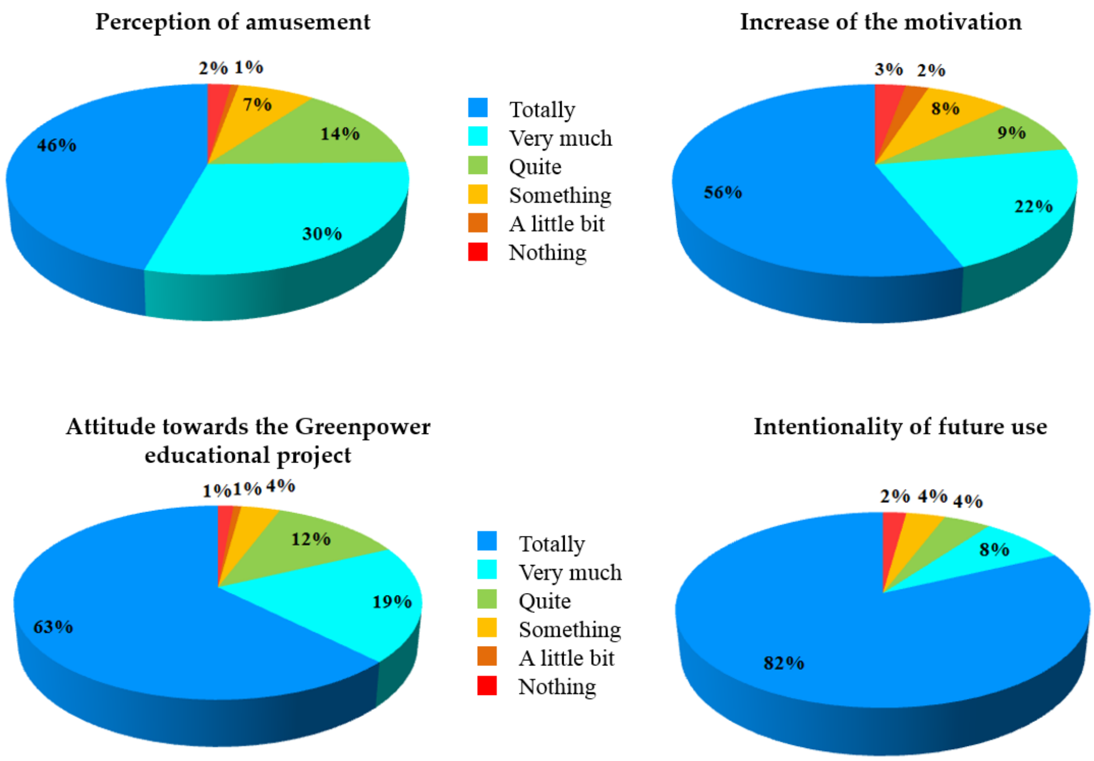
Racing events help to raise awareness among all participants and the general public about sustainable mobility since one of the educational objectives is the promotion of the clean energies and the environmental awareness. In Figures 5 and 6, the racing event in Bilbao (Spain) in 2018 is shown. The students of the Gaztelueta high school raced in competition conditions. The races are organized in public places, racetracks, schools and in industrial fairs, amongst others.

5. Results and discussion

With the aim of evaluating the implementation of the project, a questionnaire was conducted to 139 students of 5th grade of primary school and 1st year of secondary of the Gaztelueta High School, with regard to the Greenpower educational project. The questionnaire was rated on a scale of 1 to 6, with 1 being the lowest and 6 being the highest points of the scale. Through this scale various aspects were evaluated, namely:

- Perception of amusement: More than 76% of the students marked the two highest values of the scale, and only 3% of the students answered that the performed task were not amusing. The general perception is highly positive.
- Increase of the motivation: A 78% of the students marked the two highest marks in the scale, highlighting an increase of the motivation. In contrast, only a 3% of the students thought that their motivation was not increasing.
- Attitude towards the Greenpower project: An 82% of the students marked the two highest values in the scale, whereas only a 2% marked the two lowest values.
- Intentionality of future use: More than 90% of the students would like to continue working in the same way the next academic course, in contrast to the 2% of students who would prefer other options.

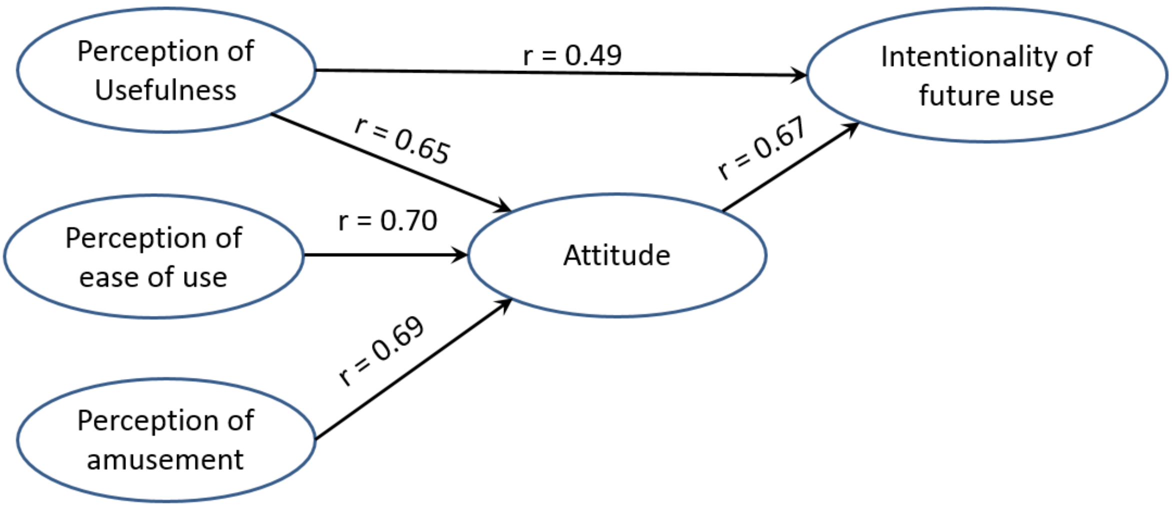
Figure 7: Results of the questionnaire conducted to 139 students of Gaztelueta High School



Moreover, a multivariate analysis has been performed to validate the educational project with the Technology Acceptance model (TAM) by Davis. The results are represented in Figure 8, showing high correlations between the intentionality of future use, the attitude, and the perceptions of usefulness, ease of use, and amusement.

Therefore, the Greenpower educational project shows a clear relationship between what students have done in the classroom, and what is done outside of them. This is reflected in the obtained results, which show an increase both in motivation and in the intentionality of future use.

Figure 8: Multivariate model of the Technology Acceptance Model (TAM)



6. Conclusions

The Greenpower project has been implemented in the formal education at the Gaztelueta High School in Leioa (Spain), during the 2017-18 school year. The advantages of the application of the Greenpower educational framework to the formal education have been clearly demonstrated.

- The Project Based Learning (PBL) system promotes the Education by competences, allowing the student to acquire the abilities and skills necessary to tackle real world problems of the 21st century.
- The perception of usefulness is highly rated by the students. In fact, they are solving real world problems, such as designing an electric car, and taking an active role in the talks with the sponsors.
- The results of the questionnaire show that most of the students are highly involved and motivated to design and develop the electric cars. This fact can be explained through the theory of Davis, which states that the perception of utility, related to real-world problems, is a key factor in the motivation of the students.
- The motivation and the attitude towards the Greenpower educational project is neatly positive. Its statistical correlation with the perception of usefulness and the amusement is demonstrated through a multivariate analysis based on the Davis TAM model.
- The electric car racing events favour the promotion of clean energies in the society. Moreover, key competencies such as the citizen competence and the entrepreneurship are promoted, together with values such as sustainability and the respect for the environment.

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