mathematics

Article

EXPLORIA, a New Way to Teach Maths at University Level as Part of Everything

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Abstract: The main objective of this article has been to evaluate the effect that the implementation of the EXPLORIA project has had on the Engineering Degree in Industrial Design and Product Development. The EXPLORIA project aims to develop an integrated competence map of the learning process, where the subjects are no longer considered as isolated contents, by elaborating an integrated learning process where the competences and learning outcomes of the subjects are considered as a whole, global and comprehensive learning. The EXPLORIA project connects the competencies of the different STEAM subjects that make up the degree, designing a learning process as a logical, sequential and incremental itinerary. Through concepts on which the foundations of design are based—shape, volume, colour, space and structure—the competencies of the different subjects are defined in incremental learning levels: understanding, applying, experimenting and developing, all taken from Bloom's taxonomy. Mathematics is linked to the rest of learning through active learning methodologies that make learning useful. This new methodology changes the student's affective domain towards mathematics in which positive emotions are transformed into positive attitudes that will improve the learning result and therefore, the students' academic results. To validate it, at the end of the paper, the academic results compared with previous years are shown, as well as an ad hoc survey of the students' assessment of the new teaching methodology.

Keywords: EXPLORIA; STEAM; active methodologies; university level; afective domain

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1. Introduction

Mathematics is described by the National Council of Teachers of Mathematics (NCTM) as "Maths for Life" ([1], p. 4). This means that mathematics is essential for life as it helps in decision-making, planning, mathematical thinking and problem solving, which are necessary in different professional areas and daily life [2,3]. In [4] they add that mathematics is related to other sciences, not only numerical such as engineering or statistics, but also to arts, drawing, commerce, medicine, and so forth.

1.1. Affective Domain

The affective domain is defined as a set of feelings, moods and states of mind, understood as something other than pure cognition, and among which three specific elements stand out: attitudes, beliefs and emotions [5,6]. In [5,6] it is explained that these factors interact in a cyclical way, in the way we perceive mathematics, as we can see in Figure 1.

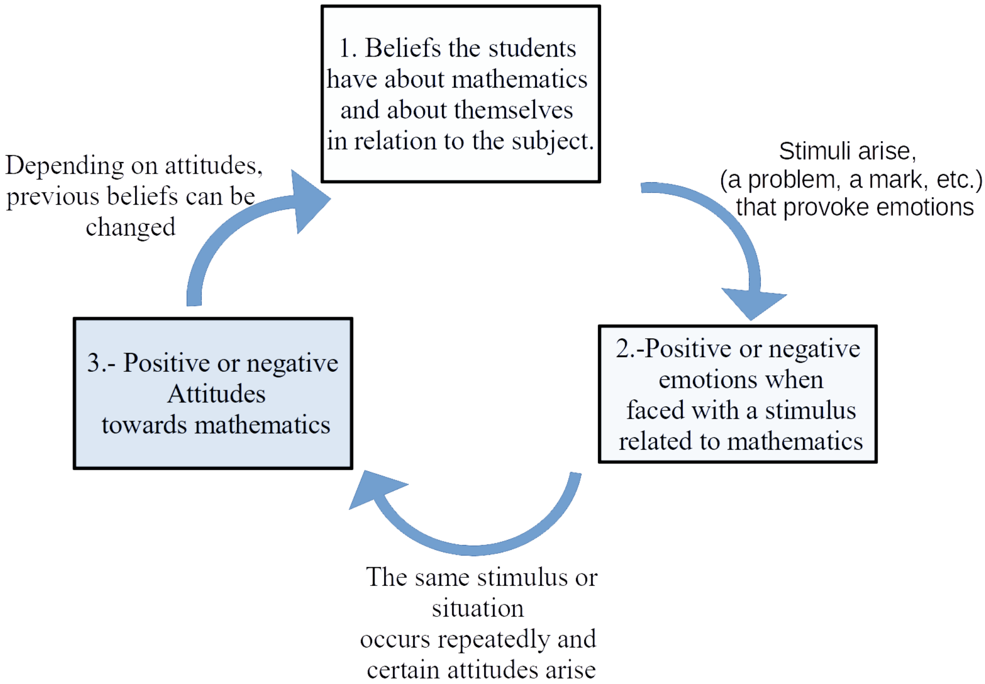

Figure 1. Attitudes and beliefs in mathematics.

Beliefs can be understood as a knowledge or feeling of certainty acquired and determined by past situations, which gives meaning to its own world, and which generates typical reactions without being fully aware of it [7].

Emotions are affective and automatic responses that arise from a significant event for the individual, and which result from complex learning, social influence and interpretation itself [8].

Regarding attitude, there is no unified definition in the literature, however, most authors agree in defining attitude as a disposition or predisposition towards mathematics, as for example in [8].

Attitudes are considered as one of the variables that most explains performance in mathematics [9–13]. In [10] it is estimated that attitudes constitute 30% of the explanatory factors of performance, concluding that students who display a more positive attitude towards mathematics will obtain higher mathematical performance.

1.2. Rejection towards Mathematics

In [12], an in-depth study is carried out on the rejection and negative attitudes towards mathematics. In this study, the number of participating students was 3187, belonging to all education cycles, primary, secondary, high school and the first year of university. The study was carried out in Spain in 10 different autonomous communities. The first item analysed was the taste for Mathematics at the different educational levels. The results show a high taste for mathematics in the initial levels at 87%; however, the taste for mathematics decreases as students go up in level, with 57% when they reach the first year of university. In [12], other subjects were also analysed but this decrease in the negative perception of Mathematics was not detected. In [12] the students' self-perception of mathematics skills is also analysed when answering the question, do I consider myself good at mathematics? In this case, the decrease is higher, going from 80% in primary education to 24% at university level. Finally, in [12] the level of the teacher's responsibility is analysed. In this case, the responsibility is about 15% at primary school level, reaching its maximum in the first year of university with about 60%.

The results obtained in [12] were later corroborated in [14], which showed that 67% of the students dislike mathematics and stated that they did not fully understand it. On the contrary, only 38 % showed an interest and liking for this discipline.

Recently, in [2] a study has been carried out on attitudes towards mathematics in university students. In the study, 1293 students (830 women and 453 men) of different degrees, Agri-food Engineering, Biology, Food Science and Technology, Pre-school and Primary Education, IT and Tourism were analysed. As a result, the average percentage in attitude obtained was 54% which shows that, in general, men have a more positive attitude towards mathematics, agreeing with other existing studies in this regard, such as in [15,16]. In [2] it was also found that students taking engineering degrees showed a better attitude towards mathematics than the rest, agreeing with other studies such as [17]. These degrees tend to have a greater number of men than women.

1.3. Trends in Learning: STEM, STEAM, STREAM

STEM (Science, Technology, Engineering and Mathematics) is a curriculum based on the idea of educating students in four specific disciplines: science, technology, engineering and mathematics, in an interdisciplinary and applied approach. Rather than teaching the four disciplines as separate and discrete subjects, STEM integrates them into a cohesive learning paradigm based on real-world applications.

The implementation of STEM learning generated an in-depth debate on how the four disciplines should be integrated. Two different approaches were established: the traditionalist approach, in which the four disciplines are developed independently, and the integrative approach, in which the four disciplines are developed together [18]. Of the two approaches, the integrative approach is currently the most widely accepted where the four disciplines constitute a single teaching-learning practice [19]. Still, there are researchers who believe that a fair interaction is the right thing to do [20] and others place one discipline above the other [21]. In [19] they observed that, although the disciplines were treated jointly, there was no true connection among them and [22] considered that educational institutions did not agree on how to establish and connect the four disciplines. To solve this problem, in [18] it is proposed to include Art as a new discipline in the STEM context, which was renamed STEAM. In STEAM learning, Art, in addition to promoting interdisciplinarity, facilitates communication and understanding of reality and provides creative strategies and solutions [23]. The concept of Art proposed by [18], is a very broad concept that encompasses, in addition to the so-called fine arts, other fields such as language and social sciences. The combination of scientific and artistic disciplines, apparently opposed, provides “the variety and diversity necessary for innovative product design” [24] and they complement each other because “science provides a methodological tool in art and art provides a creative model in the development of science ” [25]. The European Parliament [26] considers the inclusion of art essential as it leads to the acquisition of key competences. They consider that art in STEAM is primarily concerned with creativity and creativity includes divergent thinking [27] which leads to multiple solutions to a single problem.

STREAM incorporates another component to STEM and STEAM by integrating R (Reflective learning) into the equation [28].

The study developed in [29] revealed that the Greek elementary school curriculum in science and mathematics was lacking a connection to the real-life problems that the students have encounter outside of school. This disconnection with the real-life make STEAM projects of little value if they are not connected to the real problems and do not promote critically thinking citizens. Lessons that address issues of equity, gender, cultural diversity and in general, SDG(Suatainable Development Goals) are the key of R in the STREAM projects introduced in [28].

Whichever form of STEM education we are speaking of, STEAM, STREAM or other, it is a definite “plus” with respect to traditional education. The key principle is “integration”: subjects and real society problems are not taught separately but form part of an integrated curriculum [30].

1.4. Active Methodologies

STEAM projects in general promote the use of so-called active methodologies, encouraging the active participation of the student, who becomes the protagonist of the teaching-learning process and develops his/her own knowledge. Active methodologies place students at the centre of this process and make them protagonists of the discovery, rather than passive recipients of information [31].There are different teaching strategies for creating an active learning environment and engaging students in it. The most common ones are project-based learning, problem-based learning, collaborative learning, and so forth [31].

Active methodologies, such as challenge-based learning, project-based learning, problem-based learning, collaborative learning or flipped classroom, are revealed as effective tools to generate meaningful learning and train critical and creative people who will be prepared to face current and future challenges and will be able to work in a team, communicate, discuss, evaluate.

One of these active methodologies is challenge-based learning, which, based on an initial and global question or challenge, sets out the objective of guiding the students' learning to focus them on an achievable and upcoming challenge, which allows them to get personally involved in the search for effective and plausible solutions. Learning is based on a complete process of research, ideation, documentation and communication, also enhancing personal skills such as teamwork, consensus, negotiation and leadership, as key elements of emotional intelligence. Challenge-based learning allows the process to be approached in a creative and innovative way, so that the process allows the detection of other challenges or problems to be solved. It therefore implies a broader vision than project-based learning.

Project-based learning starts from an initial question or challenge and raises the objective of generating a final product, generating learning through the tasks that are carried out to develop it. If any of these tasks, in addition to being part of the project, pose a new challenge or problem to solve, we will need to overcome these with techniques from another methodology, the problem-based learning. Both methodologies, project-based learning and problem-based learning, use the large methodological umbrella of cooperative learning and therefore for their implementation we need a new organizational structure of the classroom, a different way of managing times and evaluation systems as well as changing the role of teachers and their training.

These methodologies allow the development of practical knowledge, critical thinking, through formal analysis, creative thinking, through empirical analysis and complete active learning.

This type of learning emerges from university education and is, in turn, an active methodology that focuses on the student and generates a good dose of meaningful learning. Both methodologies, project-based learning and challenge-based learning, use the great methodological umbrella of cooperative learning and they need a new organizational structure of the classroom for its implementation, a different way of managing time and evaluation systems and changing the role of teachers and their training.

1.5. Previous Works. STEAM Projects in Educational Systems

The main limitation for the use of STEAM projects in compulsory education is their absence in the national curricula. For that reason, these type of projects are usually part of extracurricular activities and are not integrated into the normal functioning of the classroom. In our previous works [32–34], the curricula of 4th, 5th and 6th grade of Primary Education in Spain, in particular in the Valencian Community were analyzed to determine the areas of opportunity for STEAM learning projects. From the 11 detected opportunity areas, the opportunity area "Sustainability" was selected in [34], for the development of the STEAM project called "Sustainable City". The board in Figure 2 reproduces the block of a city that must be organized so that when the robot travels around its perimeter street, the different elements that make it a sustainable city are activated.

The central core of the platform is composed of nine tiles, six of which are robotic tiles that pose six sustainability and robotics challenges: (1) wind power, (2) sustainable roof, (3) photo-voltaic field, (4) mobility control, (5) selective collection, and (6) urban lighting. Students must work the tiles alternating cooperative and individual work. Subsequently, they begin the assembly and programming of the complete board.

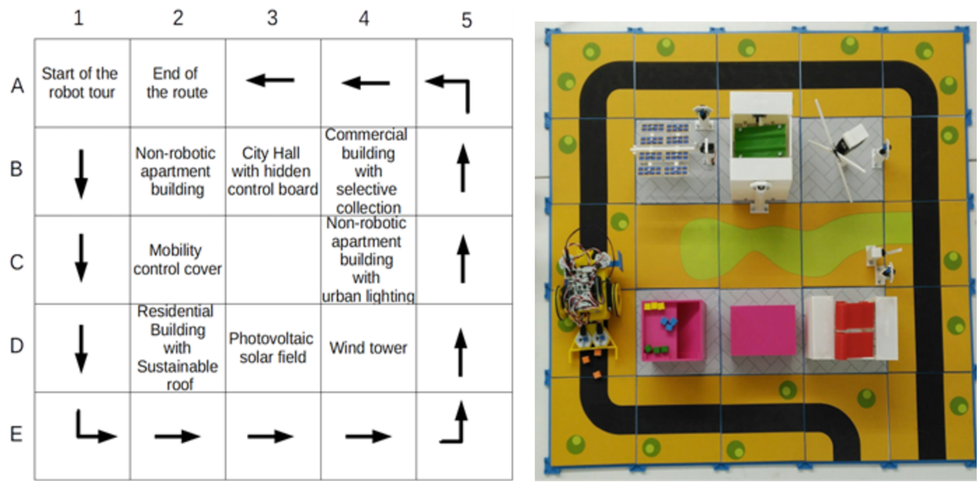

Figure 2. "Sustainable City" STEAM project developed in [33].

The "Sustainable City" STEAM project was tested in [34] in a real classroom. The participants were 30 students (aged 10-11) from 5th year of Primary Education and the project consisted of 14 sessions in which different active methodologies such as project-based learning, collaborative learning and the flipped classroom were carried out. The project included a comprehensive and complete evaluation system with eight questionnaires covering three flipped classroom sessions, two group and two individual self-evaluations, an explanation to the base team, the presentation of the final product and a final test. The average rating of the questionnaires was satisfactory, obtaining an average of 7.23. Throughout all the sessions, a very high degree of motivation and interest has been observed in all the students who have felt highly identified with the project, have discussed among their peers,have solved problems in a collaborative way and have shared objectives. Maths are involved in the project as a part of everything, as a part of STEAM project, but with the stimulus of the "sustainable city" project, seeing the applicability of maths in the real world.

2. EXPLORIA Project. A New Way of Conceiving the University

The EXPLORIA project was born from the need to update university learning methodologies to the new trends, such us active methodologies and STEAM project based learning, among others.

In this sense, the CEU Universities (CEU San Pablo, CEU Cardenal Herrera and CEU Abat Oliva), are developing different pilot projects in degrees such as Advertising, Political Science, Business Administration, Journalism, and so forth, rethinking the processes of university student learning. A group of teachers was formed for each degree to rethink how to do it and which of all new trends in learning methodologies are better for each one. Among the pilot degrees, there is the degree of Engineering in Industrial Design and Product Development, a degree that integrates subjects that coincide with the STEAM classification. That is why STEAM learning process was selected as a way to improve the learning process in this degree.

Project EXPLORIA in the Degree of Engineering in Industrial Design and Product Development

In our previous works [32–34], it was shown that it is possible to transform national curricula into STEAM projects and to improve the learning process, where maths is learned through a project that show its value in real life, in a "sustainable city". In this context, STEAM projects applied to the university environment can be the way to generate positive emotions in the students that change their perception of mathematics and improve their academic performance. There are no STEAM experiences in the literature, based on the authors' knowledge, integrated into the curriculum at university level to improve the understanding and perception of mathematics.

The EXPLORIA pilot project in the Industrial Design and Product Development degree aims to develop STEAM learning process an integrated competence map based on National curricula, in which the subjects are no longer considered as isolated contents, by elaborating an integrated learning process where the competences and learning outcomes of the subjects are considered as a whole, global and comprehensive learning.

In this way, active learning allows students to make the necessary connections to address the resolution of various challenges and problems that require the integration of knowledge from various disciplines. Active learning also enhances motivation, the need to discover, and the autonomy of learning, placing the students at the centre of their development. It transforms the passive attitude, from receiving knowledge and instructions, to an active attitude, in which searching, inquiring, creativity and innovation are present throughout the process.

The pilot project makes use of integrated learning, of temporal sequences focused on different learning objectives linked to Bloom's taxonomy: understanding, applying, experimenting and developing. In this way, through active methodologies, the student addresses all levels of learning, learning by doing. Students develop critical and creative thinking, through formal and empirical analysis, they develop creativity and innovation, and the capacity for global and multidisciplinary analysis, essential in the current context.

The teacher assumes the role of a learning guide, a teacher who accompanies students in their personal and professional development process. The teacher abandons the role of instructor, encouraging students to discover, the motivation to learn and the awareness of the need to learn from each challenge, stage or new situation that may arise. In this way the student is prepared to respond to complex problems, in changing, unstable and equally complex contexts.

3. Research Objectives

As shown in the previous section, the perception and predisposition of students towards mathematics is low when entering university, mainly motivated by the beliefs that the students have about mathematics, which come from previous training cycles. The stimuli that the students receive and their emotions can worsen their results even more, generating negative attitudes that increase the failure of students in this subject, see Figure 1.

The objective of our research is to develop an EXPLORIA pilot project in the Industrial Design and Product Development degree using STEAM learning based on the competences of the Spanish law. The EXPLORIA project connects the competencies of the different STEAM subjects, designing a learning process as a logical, sequential and incremental itinerary. Through concepts on which the foundations of design are based: shape, volume, colour, space and structure, the competencies of the different subjects are defined in incremental learning levels: understanding, applying, experimenting and developing, all taken from Bloom's taxonomy.Each of the learning periods of the fundamentals of design ends with a Milestone based on the Challenge-Based Learning methodology, where students actively and autonomously, and working in teams, integrate the skills acquired, using the learning to propose their solutions.

The goal of the present paper is to analyze the effect of the EXPLORIA pilot project has in Maths in the Industrial Design and Product Development degree. Mathematics is linked to the rest of learning through active learning methodologies that make learning useful, generating positive stimulation and emotions, which lead to positive attitudes of the students and improve their academic performance in all subjects, but especially in mathematics.

4. Materials and Methods

4.1. Research Design and Data Analysis

An experimental design was carried out, following the experts in this field [35]. A qualitative, quantitative and mixed analysis was also carried out, following the experts in this field [36].

The students were classified into two different groups in order to be assessed. On the one hand, the control groups followed the traditional methodology. On the other hand, an experimental group followed the EXPLORIA pilot learning as a methodology. The methodology was defined as an independent variable. Both groups share course, content and teachers, so it is established that there is no prior significant difference between the control and experimental groups.

R was selected as the data analysis language. Descriptive statistics on graphics, mean and standard deviation were used for this analysis. The effect size measure was obtained using Kruskal-Wallis, where a $p < 0.05$ is established as a statistically significant difference. Cronbach's alpha test is also used to see if multiple-question Likert scale surveys are reliable. In that test, the reliability is achieved if $p > 0.7$.

4.2. Participants

The participants in the study were the students of the degree in product design engineering from the courses 2018–2019, 2019–2020, 2020–2021, where the course 2020–2021 is the experimental group in which STEAM learning was applied and the other two courses are the control courses that followed the traditional methodology. The number of students in each sample group was 23, 27 and 31 respectively.

4.3. Scope of Application

STEAM learning has been planned and applied to the first four-month period of academic year 2020–21 in which the following subjects are included, see Table 1.

Table 1. First year subjects.

Subject	ECTS
Maths	6
Physics	6
Art	6
Basic design	6
Art History	6

Where the syllabus of the mathematics subject is as follows, see Table 2.

Table 2. Syllabus of the mathematics course.

Item	Content
1	Vectors
2	Matrices and applications
3	Isometries. Compositions of isometries. Ratio
4	Functions
5	Differential calculus
6	Introduction to integral calculus
7	Basic and advanced trigonometry
8	Linear Algebra

4.4. Instrument

Data collection was obtained through an ad hoc questionnaire. The design of this tool was carried out following other validated methods found in the scientific literature, such as [37]. There are 9 items in the questionnaire. A type of scale is followed depending on the question, some of the questions had the option of YES, NO, others allowed to enter comments in an open format and the rest followed a Likert-type format with a range of five points (from 1 = Strongly disagree to 5 = Strongly agree).

The final grades obtained by the students in each of the courses were also used. In the case of the control courses, 2018/2019 and 2019/2020, they were carried out with a final standard exam while in the experimental group, course 2020/2021, an evaluation by projects and acquisition of skills was carried out. The ways of evaluating, although different in each of the groups, seek to measure the level of acquisition of competences by students.

5. Design and Implementation of EXPLORIA Pilot Project

The EXPLORIA project was born from the need to update university methodologies to new trends and market needs. In this sense, the University CEU has started different pilot projects in degrees such as marketing, law, political science in order to rethink the way of teaching at university. Among the pilot qualifications, there is the degree in design engineering in which the formative character of the subjects coincides with the STEAM classification.

The EXPLORIA project connects the competencies of the different STEAM subjects, see Table 3, where the standard subjects disappear, designing a learning process as a logical, sequential and incremental itinerary. In this learning process, teachers do not have a fixed weekly schedule but rather their schedule is based on the designed itinerary.

Table 3. First-year subjects of design engineering degree.

Cuatrimestral Term 1	STEAM Classification	Cuatrimestral Term 2	STEAM Classification
Physics	S,T,M	Physics Extension	S,T,M
Maths	M	Maths Extension	M
Art History	A	Anthropology	S
Basic design	A,S,T	Design Extension	A,S,T
Shape representation	A	Descriptive geometry	A,S,T

The EXPLORIA project has been designed based on the specification and synthesis of the specific and general competencies of each subject included in the study plan of the Degree in Industrial Design and Product Development, it was estimated that, aiming at obtaining a significant and integrated learning result, it was appropriate to group these skills according to a learning process based on Bloom's Taxonomy relating to the verbs understand, apply, experiment and develop.

On the other hand, and according to the learning objective established by the degree for the student who completes the 1st year of the Degree in Industrial Design and Product Development, we decided to include five concepts that will articulate the itinerary of this course, making them coincide with the basic fundamentals of design: shape, volume, colour, space and structure. In order to adjust to the academic calendar that divides the course into two semesters, we divided the learning itinerary of design fundamentals into two modules. These in turn are divided into three acts as shown:

MODULE I

- Act I: Shape
- Act II: Volume
- Act III: Colour

MODULE II

- Act IV: Space
- Act V: Structure
- Act VI: Project

In addition, to strengthen the objective of each of the fundamentals worked on and obtain a global vision of the related competences, we decided to introduce a milestone at the end of each Act. This milestone is a challenge-based methodology in which students, actively and autonomously, and based on a general topic raised by teachers, respond to their own concerns through a challenge. This challenge is formalized and sustained through the application in a project of the skills and learning acquired by the student during the weeks that have made up each act. In this activity, the role of the teacher is to accompany and guide the student according to the needs required by each phase of the project, being flexible when intervening and adapting to the requirements of the teams depending on their specialization. Since one of the pillars that sustains the EXPLORIA program is the creation and consolidation of the learning community, it is therefore appropriate to develop the milestone within a team. It is in this way that transversal competences such as decision-making, communication, critical thinking, and so forth, are integrated. In addition, the group is changed for each Act, which allows the students to vary their role depending on the idiosyncrasy of the team and obtain different experiences. The project developed based on the challenge is exposed by each team to the community (other teams and teachers) and evaluated on the one hand by the teaching staff, who will determine the cohesion of the acquired competencies and the learning results established for the Act through a rubric designed for this activity. The other teams, using the Post Motorola tool, will qualitatively evaluate what items worked or not, what can be improved and what we have learned, determining a quantitative score based on the responses. Finally, the team itself, and based on an attitudinal and aptitude rubric, carries out a self-evaluation and co-evaluation. The weighting of all these results will be the final grade of each student.

5.1. Mathematics in EXPLORIA

Mathematics, as a basic subject in a first year of Engineering, is part of this project, which has required analysing the role of the subject and how to connect it with the students' learning. Mathematics is a core element not only in the necessary knowledge for the learning of other subjects, but also necessary for thought processes that allow solutions to problems of various kinds to be achieved. In the specific case of the EXPLORIA project, mathematics is essential for understanding physical principles, understanding concepts such as proportion, harmony, present in nature, the objects that surround us and art. The mathematical calculation has a "utility" that can be perceived by students when integrating it and needing it to tackle other type of learning.

Mathematics sessions have a general structure that covers 1 h of theoretical concepts (lectures) and 1 h of practice (seminars). The contents taught are distributed according to the theme of the act in which the subjects take part in a systematic way that determines which curricular concepts should be emphasized. The Milestone makes it possible to evaluate the acquired mathematics competencies, applied to real problems in relation to other competences developed in the other subjects.

5.1.1. Description of Sessions and Timing

We detail the sessions and subjects involved in Table 4 in which you can see a summary of the sessions:

Session 1

1. In the theoretical session of mathematics the concepts of proportionality are explained. Golden ratio.
2. In physics, a practical exercise to measure the proportions of the body is carried out.
3. The authors who use the golden number in art are studied and analysed.
4. In representation of shapes the concept of proportion is used to establish the proportionality of the shape.

Session 2

1. In mathematics we develop the concepts of vector and matrix as set of coordinates of an object. The isometries.

2. In Basic Design, the matrices associated with the shape are applied and also to modular structures.

Session 3

1. In the maths session we study how to build tessellations using isometries. The concept of homothecy is explained.
2. In the basic design subject, tessellations are developed. Exercises using homothecy: gradation and similarity are also performed.

Session 4

1. In the theoretical session of mathematics, the concept of function is developed, seen from two approaches: approximation and the matrix that represents a function.
2. The concept of composition of functions is studied making reference to the composition of isometries.
3. In physics the concept of function is used to approximate the CLO.
4. In basic design, the concept of function and composition of functions is used to develop tessellations with a higher level of complexity than in session 3.

Session 5: MILESTONE I. Sport: Students develop a design project related to sport in groups where they must apply the knowledge acquired in sessions 1,2,3,4. This activity lasts one week and concludes with a defence of the project before a panel of teachers. During the presentation, the students must explain how they have applied the knowledge acquired in the project.

Session 6

1. In mathematics, there is a session in which derivatives are explained and optimization problems are carried out.
2. The concepts are applied to basic design with problems related to space. In physics with problems related to electricity.

Session 7

1. In the theoretical part of mathematics, the concepts of integral are explained as a problem of approximation of areas.
2. In basic design the integral is applied to calculate an approximation to the volume of an object using the serial planes (cross-sectional area).

Session 8

1. In mathematics, Pappus Guldin's theorem is explained.
2. In another basic design session, students analyse shapes of revolution.
3. In the Physics session they calculate the volume and surface area of the shapes of revolution seen in basic design.

Session 9: MILESTONE II. Light: Students develop a design project related to light in groups in which they must apply the knowledge acquired in sessions 5,6,7,8. This activity lasts one week and concludes with a defence of the project before a panel of teachers. During the presentation, the students must explain how they have applied the knowledge acquired in the project.

Session 10

1. Mathematics: The concepts related to Venn diagrams are explained. Logical operations. RGB diagrams are studied.
2. With the logical operations they study the primary, secondary additive and subtractive colours used with Photosop in basic design.
3. Representing shapes are used to make additive and subtractive mixtures.

Session 11

1. Mathematics: Basic trigonometry is explained. HSV/HSL models in which saturation and hue are explained as polar coordinates.
2. In basic design they use different colour gradations and modify them using saturation and hue and making the changes indicated in the maths part.

Session 12

1. Mathematics: they study the colour wheel and establish its polar coordinates. Converting to Cartesian coordinates. The law of sines and cosines is used to establish the distance on the colour wheel.
2. The distance on the colour wheel is used in basic design to find visual harmonies.

Session 13

1. Maths session: vector spaces are explained. RGB is used as a generator space to explain the different combinations of a given value and generate the colour range in RGB. The concept of base and the change of base are studied, in particular, the opponent colour space.
2. In physics the concept of linear combination seen in mathematics is used to measure colours of objects by using an app. This session looks at how to describe them according to their RGB ratios.
3. In representation of shapes, the opponent space is related to 'discomfort' and negative emotions.

Session 14: MILESTONE III. Well-being: Students develop a design project related to well-being in groups where they must apply the knowledge acquired in sessions 10,11,12,13. This activity lasts one week and concludes with a defence of the project before a panel of teachers. During the presentation, the students must explain how they have applied the knowledge acquired in the project.

Table 4. Sessions, timing and subjects involved.

Week	Content	Subjects
	Act I.—Shape	
S1	Proportion, Vectors	Physics, Art, Basic Design
S2	Flat isometries. Matrices connected to isometries. Inverse matrix	Basic Design
S3	Tessellations (DB) Homothecy (gradation)	Basic design
S4	Composition of isometries. Functions.	Basic Design, Physics
S5	Milestone I.—port	
	Act II.—Volume	
S6	Differential Calculus	Physics, Basic Design
S7	Integral Calculus: Approximation of areas and volumes	Physics, Basic Design
S8	Shapes of revolution. Calculation of areas and volumes. Pappus-Gouldinus theorems.	Physics, Basic Design
S9	Milestone II.—Light	
	Act III.—Colour	
S10	Venn Diagrams. Primary, secondary colours Additive and subtractive colours. RGB System	Basic Design, Physics Shape Representation
S11	Flat trigonometry. HSV/HSL Models Polar coordinates. Change from RGB to HSV/HSL	Physics, Basic Design
S12	Laws of sines and cosines. Polar distance. Chromatic harmonies. Colour Wheel	Basic Design, Physics Shape Representation
S13	Vector spaces, Generator system: RGB space. Combination of colours Bases of a vector space. RGB space. Change of coordinates. Opponent space.	Basic Design, Physics Shape Representation
S14	Milestone III—Well-being	

5.1.2. Assessment Methodology

The assessment methodology is one of the most relevant factors introduced in the EXPLORIA project because the traditional exam is replaced by the activities developed in each session as well as the marks obtained in each milestone.

Each session has a theoretical part and a practical part where the student must apply the maths in an exercise related with other subjects (Physics, Basic Design, etc.). The exercises must be done in class. The most important part is that the exercises for each student must be original and different between them. Therefore, the students needs to learn maths to solve their own exercise.

Milestone projects are developed in groups and the mark obtained by the group is the same for each other. However, the teachers check in class the implication of each student in the activity. At the end of the semester, 14 exercises and 3 Milestone projects are used to evaluate the students. The final mark is obtained by 75% exercise sessions and 25% Milestone projects.

5.1.3. Some Milestone Project Examples

Appendix A shows some project examples presented by the Students in Milestone II and III. The projects are:

1. VITALIA: This project is for the Milestone III. Well-being. The students developed a bottle of water that it is able to measure the quantity of water that you drink in a day and alerts you when you should drink because to be hydrated is important for the well-being, see Figure A1.
2. Youmood: This project is for the Milestone III. Well-being. The students develop a product with a bottle of water where each box or bottle has a color and each color is related with art and emotions, see Figure A2.

In these projects, mathematical concepts are applied in different parts of the project. For instance Pappus-Guldin is used to compute the volume and the surface area of the prototype. Both are important for the prototype design. The first one to know the material required if you want to develop the prototype with Polispan. The second one is necessary if you want to develop your prototype with a 3D printer. Students compute both and choose the way to develop their prototype. Color are selected using cosine law and doing linear combinations in order to represent it. In Figures A1 and A2.

6. Results

6.1. Student Perception Survey

To carry out an evaluation of the new teaching methodology, a Microsoft Forms form has been made, in this form the student indicated whether the previous year they had taken the mathematics subject or not. They were also asked what their perception of mathematics was before starting the course and whether that perception had improved after or not. Finally, there were more specific questions about this experience, such as the degree of satisfaction with the activity carried out, perception of learning and appreciations about the educational model. Finally, there is an open question for the student to comment on the experience. The questions asked in the form are shown below in Table 5.

Table 5. Questions asked in the questionnaire for the students.

ID	Question
1	In the previous year, did you study mathematics?
2	What was your perception of mathematics before the course?
3	Have you improved your perception of mathematics after the course?
4	It has been more motivating to solve math problems with the EXPLORIA methodology than with the traditional method.

Table 5. *Cont.*

ID	Question
5	I feel more involved in this type of learning.
6	My perception of learning has improved.
7	Would you propose to keep on using the new learning model next year?
8	In the connection of mathematics with the rest of the subjects, what connection has helped you the most to understand it?
9	What do you think of the application of this new teaching experience?

Table 6 shows the results of question 1, YES/NO answers. Table 7 shows the answers to the question about prior perception of mathematics. Table 8 shows the answers to the Liker-type questions. Finally, Table 9 shows us which of the links with the rest of the subjects have been more useful in understanding mathematics. Cronbach's alpha tests of the multiple-question was performed to assess internal reliability of the questionnaire about perception of mathematics ($p = 0.7791$).

Table 6. Answers to YES/NO questions of the questionnaire.

Question	Yes	No
1	18	1

Table 7. Student questionnaire responses related to the previous perception of mathematics.

Question	Very bad	Bad	Neutral	Good	Very good
2	1	3	7	6	2

Table 8. Student questionnaire responses, Liker-type questions.

Question	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
3	0	0	3	9	7
4	0	1	0	11	7
5	0	0	1	10	8
6	0	1	0	11	7
7	0	0	1	5	13

Table 9. Answers to the question about which link was the best.

Question	Physics	Basic Design	Art	Shape Representation
8	11	7	1	0

If we focus on the answers given by the students of the 2020–2021 course, regarding the evaluation of the EXPLORIA educational model, the survey was answered by 60% of the enrolled students.

The data show that practically all the students have studied mathematics in the previous year. Regarding the perception of mathematics before starting university, 60% show a neutral or negative perception of mathematics, but 85% acknowledge that their perception has improved thanks to the EXPLORIA project.

In the question about if this way of working was more fun than the traditional way, 95% of the students who took the questionnaire completely agreed or agreed with it. In the same way, practically all the students believed that their perception of learning had improved significantly with this new methodology.

Finally, practically all the students expressed the opinion that they would like it to continue in later courses.

Finally, 57% indicate that the connection that has helped them the most to understand mathematics has been with physics, while 36% indicate that the most useful connection has been with basic design. This result is indicative that the applicability of mathematics is key to understanding.

These are some of the answers given to the open question:

- "By coordinating and intertwining subjects, it is easier to relate concepts among them"
- "I think it improves learning, due to its method based mainly on experimentation."
- "In my opinion this new method due to being more practical is more focused on the world of work and what we will do in the future."
- "It is a new method that allows you to see the application of all the theory given in subjects such as mathematics and physics"
- "It is another way of acquiring knowledge in a more practical way in which it becomes more enjoyable and dynamic every day than doing it in an exam"
- "This new methodology in my opinion is much better, since in all subjects there are things that have to do with each other, this means that you can see how the knowledge that is given can be applied in different fields"
- "I think this new methodology makes us more involved in the learning process"
- "It is very effective, because you really learn the meaning and use of mathematics in the professional field"

As a final result, the vast majority of the students have improved the student's belief about mathematics, specifically, 86% of the students, corroborating what is shown in Figure 1 and in the research by [5,6], a positive stimulus or emotion generates positive attitudes that allow the student's beliefs about mathematics to be changed.

6.2. Comparison of Academic Results in the Last Three Years

Table 10 shows the academic results obtained in the last 3 years.

Table 10. Results of Ordinary Exam Call.

	Course 2020–2021	Course 2019–2020	Course 2018–2019
Students attending	93.6%	85.2%	91.3%
Pass	94%	70%	74%
Fail	0%	30%	26%
Average pass mark	7.85	6.55	6.49

In order to determine whether there are significant differences in the average marks obtained, we have used the Kruskal-Wallis test giving a p-value of 0.02168, which allows us to conclude that there are significant differences among the average final grades in the different courses and therefore the methodology introduced in EXPLORIA for learning mathematics has had a positive impact. Figure 3 shows the distribution of grades in the different courses.

As we can see, the distribution pattern of grades, as well as the percentages in the control groups, years 2018–2019 and 2019–2020, are similar, 17% vs. 15% of fail grades, 30% vs. 26% of pass grades 31% vs. 37% of B grades. However, the pattern changes significantly in the experimental group, in the academic year 2020–2021, we can see that the percentage of A grades has increased significantly, reaching 29%, and there is a 3% of grades with honours and finally, the percentage of fail grades has disappeared, reaching 0%.

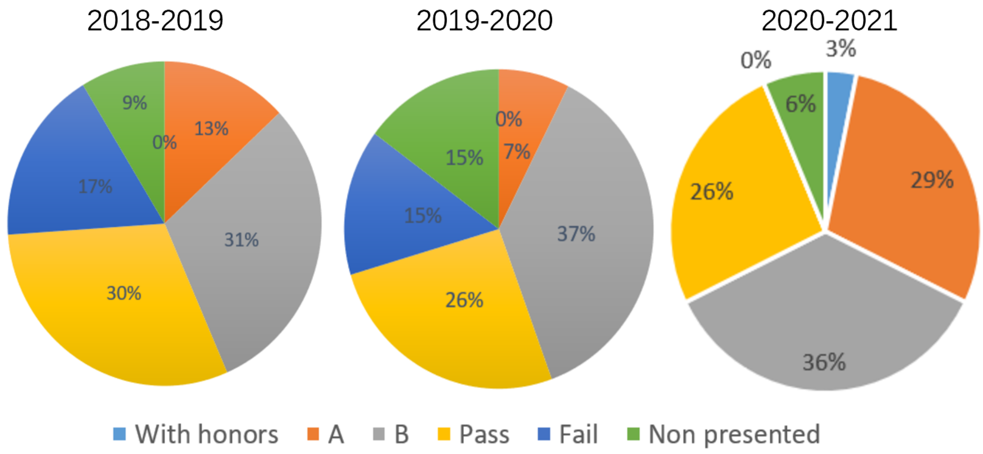

Figure 3. Distribution of grades.

7. Discussion

The EXPLORIA project implemented in the degree of Engineering in Industrial Design and Product Development produce a great impact in the learning process. The vast majority of the students have improved the student's belief about mathematics as well as to understand why it is necessary to learn maths. The present study scores in control and experimental groups and, although it is true that the assessment methods are different because in the control group there are no exams, in the experimental group, the teacher has 14 activities developed in class where the most important part when the teachers design these exercises is that the exercises for each student must be original and different between them. Therefore, the students needs to learn maths to solve their own exercise and then the teacher could evaluate if the student understand the concepts. this is as if an examination exercise of the classical methodology were done in each session of the new methodology. Moreover, the exercise levels are higher than in a traditional exam because the teacher is focused in one concept.

The main limitation for the use of STEAM projects in compulsory education is their absence in the national curricula. For that reason, these type of projects are usually part of extracurricular activities and are not integrated into the normal functioning of the classroom. The first STEAM project developed taking into account national curricula was developed in our previous works [32–34] and in the same way, developed for university level in the present study. Therefore, it is not possible to compare with similar experiences in other universities.

One of the important limitation of the present methodology is that the teachers' schedule is not fixed and it is determined by the learning sequence. If some students fail one part, it is not easy to recover a single part because all the learning process is intertwined between subjects. This could generate organizational problems for the university.

The construction of the learning process could also be a problem for the university because requires a deep effort for the teachers. If an effective learning process is to be achieved, the teachers of the different subjects must act as a single teacher and must know what the other teachers want to achieve from their students.

8. Conclusions and Further Developments

This article shows the design and evaluation of the EXPLORIA project, based on STEAM learning in the degree of product design engineering. The development of an integrated competence map of the learning process, where the subjects are no longer considered as isolated contents, by elaborating an integrated learning process in which the competences and learning outcomes of the subjects are considered as a whole, a complete and global learning, this has allowed a change in students' perception of mathematics, increasing their motivation and their commitment to discovering. The results obtained by the students have improved substantially, both due to the almost absolute decrease in the drop-out rate of the subject, as well as the very low rate of students who failed, as well as the average grades that have increased substantially. In addition to the results, the most significant aspect of the implementation of this project is the change in students' perception of mathematics, which has resulted in a change in attitude and, therefore, in an improvement in academic results. Generating positive emotions through active methodologies in which the students can see the application of mathematics, improves their taste for mathematics and their understanding.

In future works, we intend to implement the EXPLORIA methodology in other degrees related to STEAM learning, such as Architecture. In addition, we are going to transform our STEAM projects into STREAM projects, including Critical reflective learning, mainly focused in the SDG (Sustainable Development Goals).

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Appendix A

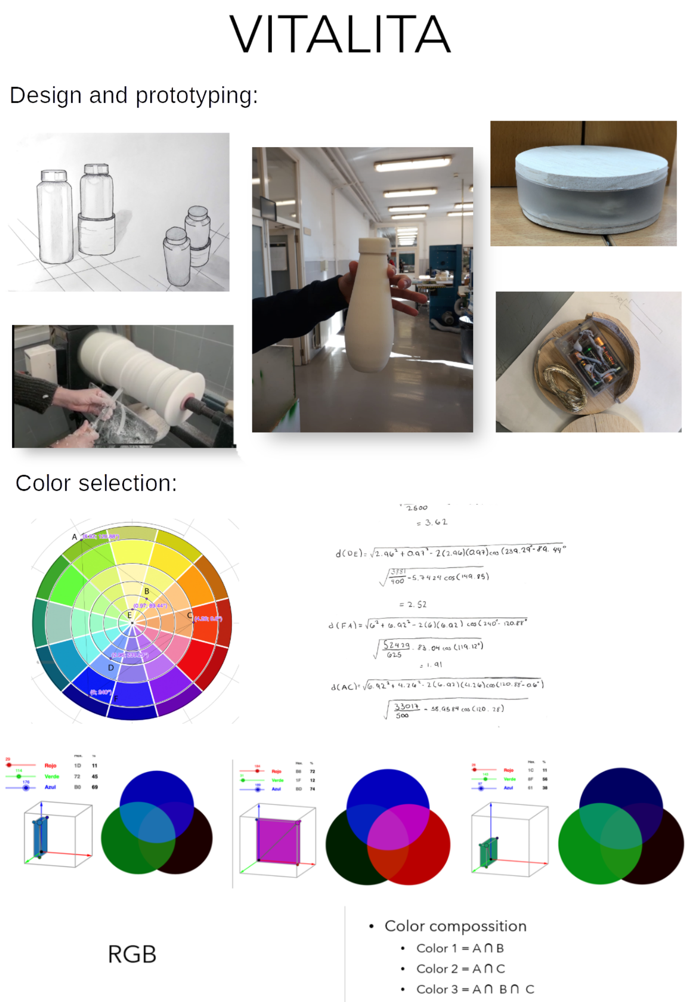

Figure A1. VITALIA. A bottle of water that it is able to measure the quantity of water that you drink in a day and alerts you when you should drink.

Figure A2. YOUMOOD. A product with a bottle of water where each box or bottle has a color related with art and emotions.

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