Research Article

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STEMbach Experiences at Higher Education

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Abstract: The aim of this work is to describe several experiences of STEMbach in different areas: engineering, economics, materials, etc. The STEMbach is a program carried out by high school students during their two years of study to obtain their High School Diploma (equivalent to A-levels), designed for both the Humanities and Sciences modalities, and created alongside the Galician strategy for digital education. It encourages the vocation of the scholars towards scientific and technological research and allows a connection directly with the college education. The STEM works explained in this work were developed between the University of A Coruña and several high schools located in the region of Galicia (North-West of Spain). Results were very constructive for promoting STEM careers.

Keywords: economics, STEAM, engineering, high school, STEM

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1 Introduction

Today's society is talking more and more about STEM degrees. This term began to be heard at the beginning of this century in the North American educational system and since then numerous allusions and investigations have been made. This acronym includes the terms from Science, Technology, Engineering, and Mathematics. Some later variations include the term Art (STEAM) because of the demonstrated need for creativity in work skills related to this field, as well as innovation and research (STEAMi) because of its relationship with all the previous fields.

The STEM group is characterized by its relationship with the natural sciences, the formal science and the scientific method, and mathematics as a common thread, as well as its practical application (technology). As digitalization makes its way into society, technological development is needed to a greater extent with a previous scientific development and with a conceptual framework that allows these ideas to be used, therefore all branches of STEM degrees are necessary (Gonzalez & Kuenzi, 2012)

According to a 2020 Randstad recruitment firm article (Ranstad, 2020) "more than 25% of large companies will have difficulty finding tech profiles." There are numerous studies in which it is seen that young Spaniards discard science and technology studies (El mundo journal, 2022; Ernst & Young Consultora, 2019).

For all this, the Galician Government started a program in 2018 in order to promote the studies in STEAM areas among high school students. For this purpose, the students of the last two academic years (called baccalaureate students in Spain) had to do a research project in one of the STEAM fields. During this process, some

high school teachers involved expressed the interest that many students had in economic-business topics and entrepreneurship. For this reason, this program was finally extended to Social Sciences.

The objective of the present work is to explain various experiences of STEMbach in different fields of science: engineering, economics, materials, etc. (UDC, 2022). The STEMbach program can be developed by high school students during their two years of study to obtain their High School Diploma (equivalent to A-levels). It is a subject of the "Bachillerato de Excelencia" (UDC, 2022) in Science and Technology, designed for both the Humanities and Sciences modalities and created alongside the Galician strategy for digital education. It promotes the vocation of the students towards scientific and technological research and allows a connection directly with the university education. All these STEM works have been carried out between the University of A Coruña and different high schools located in the region of Galicia (North-West of Spain) (Dou et al., 2019).

2 Methodology and Case Study

The objective of this work is to describe different methodologies that were applied in the STEMbach carried out in the Galician region, which is located in the North-West of the Iberian Peninsula.

The STEMbach is called "Bachillerato de Excelencia" in Science and Technology and it is designed for both the Humanities and Sciences modalities. It was created alongside the Galician strategy for digital education. It intends to promote the vocation of the students towards scientific and technological research and allows a connection directly with the university education.

In this program, one or several students of High School carry out a project, which is directed, at the same time, by the directors of High School and the directors of the University of A Coruña (UDC). Not all the projects had the same methodology to be developed because each of them was tutored by different professors at the university.

During 2019/2020 and 2020/2021 courses, there were a total of 118 STEM projects developed at the University of A Coruña in High Schools of different locations (Table 1), being 52 projects carried out in 2019/2020 and 66 projects developed in 2020/2021.

Particularly, a group of professors of the UDC carried out the STEM projects during the last two years (details are given in Table 2). As shown, there are a lot of varieties in the projects developed during these years because the professors belong to different areas of experience (naval construction, nautical sciences and marine engineering, finance economics and accounting, etc.).

Table 1: Number of STEM projects at UDC considering the location of the High School

Location	Number of STEM projects
A Coruña	24
Betanzos	9
Cambre	5
Culleredo	3
Ferrol	36
Monforte de Lemos	1
Oleiros	30
Santiago de Compostela	10
TOTAL	**118**

Each of these projects have taken into account different methodologies in order to introduce different science areas at High Schools. In this context, Table 3 shows the different methods that have been considered in each STEM project.

The report created by the students had the following specifications:

- Maximum 10,000 characters (1 student) or 20,000 (more than 1 student)
- Structure (similar to a scientific paper):

- Cover page
- Introduction
- Contextualization
- Materials and methods
- Results and conclusion
- Continuity proposal

In addition, all the projects have been evaluated by a public jury composed of three assessors, representing the High School and the University. All the projects took into account a common rubric facilitated by the STEMbach program, which evaluates considering 40% for the process, 30% for the report of project developed by the students, and 30% for the oral presentation of the project.

3 Results

Project Number 1 is titled "***Offshore wind energy in Galicia.***" In this project, the students analyzed the different types of offshore wind platforms, the meteorological data of wind resource, the initial investment of the

Table 2: Example of the STEM projects developed at UDC

Number	Name of the project	Number of projects	Number of students	Area of the professor at the UDC
1	Offshore wind energy in Galicia	3	5	Naval Construction
2	Wave energy in Galicia	1	1	Naval Construction
3	Mechanical behavior of steel at low temperatures. The example of the Titanic	1	1	Materials science and metallurgical engineering
4	In search of the unknown alloy	1	2	Materials science and metallurgical engineering
5	Business plan development and analysis of the financial viability	1	1	Finance, economics, and accounting
6	Initiation to economic and financial activity: financial viability of a business	1	1	Financial economics and accounting
7	Evolution of the Spanish economy during the XXI century	2	4	Financial economics and accounting
8	Analysis of the performance of a two-stroke engine	1	1	Nautical sciences and marine engineering

project, the main components of the offshore farm, and the selection of the best location in order to install the offshore wind farm. The students acquired competences in Information technologies (IT) because they carried out all the work using a spreadsheet, such as Excel®.

First, the students analyzed the differences between floating offshore wind (spar, semisubmersible, and Tensioned leg platforms (Jonkman & Matha, 2010)) and fixed offshore wind platforms (monopiles, tripiles, gravity based foundations, jackets, etc. (Bagbanci et al., 2012)). Second, considering these different types of platforms they had to select the best area where to install each type of platform. For this purpose, they needed to look for different restrictions for the installation of the farm: navigation areas, environmental protected areas, seismic fault lines, etc., and they also need to know the main characteristics of the offshore wind resource. In this sense, they studied the main SIMAR points of the Galician buoys (Puertos del Estado, 2015), where they could see the shape and scale offshore wind parameters for each buoy. The students calculated the energy produced by the farm using the Weibull distribution.

Finally, with the energy produced and the data of the initial investment of the farm (conception, manufacturing, installation, and maintenance of the farm (Castro-Santos & Diaz-Casas, 2014; Castro-Santos et al., 2016)) for each of its components (platforms, wind turbines, moorings and anchoring, and electric system), the students calculated the net present value (NPV) and the internal rate of return (IRR) of the project (Castro-Santos et al., 2018; Short et al., 1995). Therefore, they obtained their conclusion about the economic feasibility of the offshore wind farm.

In this context, the project was composed by two spreadsheets: one containing the calculation of the energy produced (Figure 1) and another containing the economic calculations (Figure 2). The professor gave the students the template of the spreadsheets that guided them in following the project.

Project Number 2 is titled "***Wave energy in Galicia***" and the method was very similar to Project Number 1, but considering other type of offshore renewable energy.

Project Number 3 is titled "***Mechanical behavior of steel at low temperatures. The example of the Titanic.***" It seeks to make the students aware of how external factors can modify the behavior of materials. An analysis of the impact resistance of various steels as a function of ambient temperature was made. For this, Charpy tests were carried out on three different steels at room temperature and at −40°C. In this way, the student was able to verify how the steels become more brittle when the temperature drops, and understand some of the

Table 3: Example of the methods carried out in several STEM projects developed at UDC

Number	Name of the project	Methodology
1	Offshore wind energy in Galicia	Practices using Information technologies (IT)
2	Wave energy in Galicia	Practices using IT
3	Mechanical behavior of steel at low temperatures. The example of the Titanic	Laboratory tests and data analysis
4	In search of the unknown alloy	Laboratory tests and data analysis
5	Business plan development and analysis of the financial viability	Project development with Microsoft Excel using financial formulas (IT)
6	Initiation to economic and financial activity: financial viability of a business	Project development with Microsoft Excel using financial formulas (IT)
7	Evolution of the Spanish economy during the XXI century	Search of economic information and analysis of this information using IT (mainly, Excel spreadsheet)
8	Analysis of the performance of a two-stroke engine	CAD software and mechanical tools

causes that ended with the Titanic at the bottom of the sea.

Project Number 4 is called "***In search of the unknown alloy,***" where the students had to analyze a series of alloys in order to deduce the composition of one of them that was initially unknown. To do this, they had to experimentally determine the cooling curve of each of the alloys, analyze it, and extract the necessary data to calculate the Tamman triangle and the phase diagram of the alloy system. Once these tools were defined, they were able to determine the composition of the unknown alloy. The objective of the project was for the students to discover that by combining two metals, alloys with very different behaviors can be obtained.

Speed (m/s)	exp()	Weibull	
		Weibull MANUAL	Weibull EXCEL
		$F(v)=C\cdot\frac{v^{c-1}}{A^c}\cdot\exp\left(-\left(\frac{v-B}{A}\right)^c\right)$	DISTR.WEIBULL(...)
0			-
0,2			0,002360
0,4	0,0000	0,005237	0,005232
0,6	0,0004	0,008345	0,008329
0,8	0,0013	0,011607	0,011572
1	0,0029	0,014980	0,014918
1,2	0,0051	0,018433	0,018336
1,4	0,0079	0,021946	0,021804
1,6	0,0115	0,025497	0,025301
1,8	0,0158	0,029071	0,028811
2	0,0208	0,032651	0,032319
2,2	0,0265	0,036225	0,035809
2,4	0,0330	0,039777	0,039269
2,6	0,0403	0,043296	0,042686
2,8	0,0484	0,046769	0,046048
3	0,0573	0,050184	0,049343
3,2	0,0669	0,053531	0,052561
3,4	0,0774	0,056799	0,055692
3,6	0,0887	0,059977	0,058726
3,8	0,1008	0,063056	0,061654
4	0,1137	0,066028	0,064467
4,2	0,1275	0,068883	0,067157
4,4	0,1421	0,071613	0,069718

Figure 1: Example of Weibull distribution in the spreadsheet.

I. Características del parque/*Characteristics of the farm*			
Características GENERADOR/*Characteristics of the GENERATOR*			
Tipo energía/*Type of energy*	**Energía viento/*Wind energy***		
Denominación generador/*Name of the generator*	**WindFloat**		
Potencia unitaria/*Power per unit*		kW	
Rto. Disponibilidad/*Availability performance*			
Rto. pérdidas eléct. Transmisión/*Electrical losses performance*			
Número de generadores (NG)/*Number of generators*		aerogeneradores/*wind turbines*	
Energía producida por 1 aerogenerador (E1G)/*Energy produced by 1 wind turbine*		kWh/año	
Características UBICACIÓN/*Characteristics of location*			
Punto de ubicación/*Location*	Costa de Ferrol/Ferrol Coast		
II. Inversión/*Investment*			
INVERSIÓN INICIAL/*INITIAL INVESTMENT*	Valor/Value	Valor Residual/*Residual value*	
Diseño y desarrollo/*Design and Development*			
Fabricación/*Manufacturing*			
Instalación/*Installation*			
Amortización activos fijos/*Amortization of fixed assets*		años/*years*	
Vida del proyecto/*Life-cycle of the project*		años/*years*	
Plazo de construcción/*Time of construction*		año/*year*	
Necesidades de Tesorería (LA DE 2 MESES) = 2*Gastos explotación/12 /*Cash equivalents (2 months)*		€/año /€/*year*	
Cuenta Clientes Media (LA DE 1,5 MESES) = 1,5*Ingresos explotación/12/*Trade receivables (1,5 months)*		€/año /€/*year*	
III. Operación/*Operation*			
Gastos explotación/*Operating Costs*		€/año /€/*year*	
Energía producida por 1 aerogenerador (E1G)/*Energy produced by 1 wind turbine*		kWh/año /kWh/*year*	
Potencia media/*Mean power*		kW	
F. Capacidad /*Capacity factor*			
Energía vendida por el parque = E = NG*E1G*rendimientos /*Energy sold by the farm*		kWh/año /kWh/*year*	
Ingresos de explotación = I = PkWh*E /*Operating incomes*		€/año /€/*year*	
IV. Entorno/*Environment*			
Impuesto sobre Sociedades (IS)/*Earnings tax*			
Coste del capital/*Capital cost*			
Tarifa eléctrica (PkWh)/*Electric tariff*		€/kWh	
V. Financiación/*Financing*			
% Capital financiado /*%Financing capital*			
Tipo de interés/*Interest rate*			
Período del préstamo/*Period of the financing*		años/*years*	
Corretaje/*Notary fee*			
Comisión/*Bank fee*			

RESULTADOS/*RESULTS*	
Concepto/*Concept*	Proyecto Financiado (PF)/*Financed Project*
VAN (€) /*NPV (€)*	
TIR /*IRR(€)*	
Período de Recuperación (años)/*Payback-Period (years)*	
LCOE (€/MWh)	

Figure 2: Example of the spreadsheet of the economic parameters.

Project Number 5 is entitled "***Business plan development and analysis of the financial viability.***" It analyzes the viability of a business idea by developing a business plan. The development of a business plan is crucial to help the students know the operation of a company from different points of view. Additionally, the project can be a first approximation to the steps to follow in case the student wants to start a business in the future.

The project is focused on interior design and the objective of the business will be to offer a quality and personalized service to the customers. In the business plan several aspects are described such as service description, target market, marketing of the product, human capital, SWOT analysis, and other formal aspects of the project.

But the main part of the project is the investment and financial plan, where the student estimated the cash-flows of the business plan, studied the viability of the project with the NPV and the IRR, indicating the financial sources as well as their cost, and, finally, complementing the report with a sensitivity analysis.

Project Number 6 is called "***Initiation to economic and financial activity: financial viability of a business.***" The student who did this assignment had a very clear idea of a business he would like to start and wanted to make a study of its financial and economic viability. To do this, he followed the structure of a business plan, which is an orderly, comprehensive, and structured way of studying a business.

The business linked the hobby of the world of skateboarding with the world of fashion. First, the student had to describe in detail the company's activity. Next he made a complete study of the market, competition, customers

Figure 3: Students who participated in the Stephen Hawking competition (La Voz de Galicia, 2022).

and suppliers. In the third phase, he calculated receipts and payments to make a future projection of the cash flows. Finally, he studied how the business could be financed.

This work, although it is not strictly a research project, gave the student a deep knowledge and, what is very important, a training linked to reality and to his own interests. He learned all the aspects that must be taken into consideration in entrepreneurship and that carrying a study of these characteristics is fundamental to increase the probability of success of the business.

Project Number 7 is entitled "***Evolution of the Spanish economy during the XXI century.***" In this project, students made an analysis of the evolution of the Spanish economy from 2000 to 2019. The students analyzed several macroeconomic variables in detail (such as GDP, GDP per capita, unemployment rate, Gini coefficient, national debt, or risk premium) in order to show an overview of what had happened in the country since the beginning of the new century.

The project involved numerous challenges for the students, such as searching for information in different data sources, obtaining data on the chosen variables, designing tables and graphs, analyzing the information critically, writing a report, and learning to cite references following the APA format.

To achieve the proposed objectives, a seminar on the basis of the Excel spreadsheet was given to the students and online tutorials (on the platform Teams) were scheduled every 3 weeks. There was also constant coordination and collaboration between the University tutors and the high school tutor.

The major difficulties that the students had to overcome were: (1) learning to interpret the data and draw conclusions, (2) creating their own graphs and tables with the data available, (3) being able to write clearly and rigorously, and (4) properly citing the documents consulted.

Project Number 8 is titled "***Analysis of the performance of a two-stroke engine.***" This work dealt with an analysis of the performance of a two-stroke engine. The aim was to disassemble and analyze the engine piece by piece. After that, the different pieces were measured and modeled using a 3D CAD software.

The work was realized by one student from the IES Arcebispo Xelmírez II (Santiago de Compostela). Initially, the work was proposed as semi-presential mode but the sanitary recommendations due to the pandemic led to a 100% telematics mode. The student chose an engine from a chainsaw. He disassembled it, measured the pieces and modeled its performance using the software FreeCAD. A video was realized to show the movement of the engine during its operation.

The student obtained the maximum score for this work. After that, the work was sent to the competition Stephen Hawking, organized by the IES Rosalía de Castro, and obtained the second award (Figure 3).

4 Conclusion

The aim of this work was to describe various experiences of STEMbach in different fields of science: engineering,

economics, materials, etc. The STEMbach program is carried out by high school students during their two years of study to obtain their diploma. It aims at promoting the vocation of the students toward scientific and technological research and allows a connection directly with the university education. The program allowed the students to clarify their future degree studies and to know things that in other circumstances they would not learn (use of spreadsheet, use of CFD, teamwork, communication skills, etc.). On the other hand, the professors have learnt how to simplify their explanations so as to be understood by the high school students, which can also help them to teach at the university. In addition, the students gave the professors other fresh view-points which will be very helpful in the future for teaching activity at the university. In fact, the number of the STEM projects developed at the University of A Coruña has been increasing since the program started, which indicates that it is liked by the students.

The STEM works analyzed have been carried out between the University of A Coruña and different high schools located in the region of Galicia (North-West of Spain). In this context, the projects developed were in different areas of science: naval construction, materials science and metallurgical engineering, finance, economics, and accounting, and nautical sciences and marine engineering.

In addition, these projects were carried out considering different methodologies such as practices using IT, laboratory tests, and data analysis, etc., which indicates that STEM projects can be developed in different ways to promote science and stem careers between students. Results were very positive and gratifying, both for the professors and students, in order to promote the STEM careers in this region.

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