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From Classroom to Business Ideas: Fostering Eco-innovation through Engineering Entrepreneurship Education

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Abstract

This paper presents an innovative proposal aimed at fostering an entrepreneurial culture among engineering students at the University of Jaén, with the objective of driving eco-innovation in the industrial sector. Through the implementation of a cross-disciplinary training program, we seek to equip students with the essential competencies to identify business opportunities, develop sustainable projects, and lead initiatives that contribute to the transformation of industry towards more efficient and environmentally friendly models [1,2].
The experience focuses on final-year students from various engineering disciplines, taking advantage of their greater academic maturity and proximity to the job market. Through practical and collaborative activities, the project aims to foster creativity, innovation, and critical thinking, as well as the development of entrepreneurial skills such as project management, fundraising, and effective communication. The paper presents the methodology implemented in the classroom to enable the replication of this initiative in other higher education institutions.
The initiative integrates a multidisciplinary team of professors from diverse engineering fields, enriching the program by providing a comprehensive perspective of the challenges and opportunities presented by industrial eco-innovation [3].
The project outcomes significantly exceeded expectations. Notably, 85% of surveyed students reported a substantial increase in their motivation to become entrepreneurs. Through the organization of workshops and the dissemination of results on the project's social media platform. Some social media posts detailing the activities conducted garnered over 2,000 interactions, highlighting widespread interest from the academic community.
It is expected that this initiative will contribute to the training of a new generation of engineers capable of driving the transition towards a circular and sustainable economy, generating a positive impact on both regional and global development.

Keywords: *Eco-innovation, Entrepreneurship, Engineering, Sustainability, Higher education, Training, Industrial transformation.*

1. Introduction

The current scenario demands a profound transformation in the way we produce and consume. The growing concern about sustainability and the environmental impact of industrial activity has accelerated the search for new production and consumption models that are more efficient and environmentally friendly [4]. The transition towards a circular and sustainable economy presents itself as a viable alternative, where waste is transformed into resources and the environmental impact of economic activity is minimized [5]. This change requires the collaboration of all actors in society, including companies, governments, citizens, and higher education institutions.

In this context, eco-innovation has emerged as a key concept, referring to the introduction of new or significantly improved products, services, processes, or organizational models that reduce resource use and environmental impact [6]. Higher education, and universities in particular, play a fundamental role in this process, as they are institutions that generate knowledge and train the future professionals who will lead this transition. In this sense, the integration of classroom activities that work on the transversal competencies of undergraduate and master's degrees is necessary. These transversal competencies, which sometimes do not coincide with the specific topics of the subject, are challenging to address in traditional curricula. In this case, the competence of entrepreneurship and sustainability

in engineering curricula emerges as a critical factor for the successful adoption of eco-innovative practices in the industrial sector [7][8].

In the engineering field, there is a growing need for professionals who not only possess solid technical knowledge but are also capable of identifying business opportunities, developing innovative projects, and leading initiatives that contribute to the transformation of the industry towards more efficient and environmentally friendly models. Consequently, the integration of eco-innovation and entrepreneurship into engineering curricula stands out as a key factor to guarantee the employability and competitiveness of future engineers [9].

Previous work has demonstrated the importance of entrepreneurship education in training professionals capable of generating new businesses and leading innovation processes [8]. Various studies have analyzed the impact of training programs on the development of entrepreneurial competencies, such as initiative, creativity, problem-solving skills, and decision-making. Additionally, the importance of training in transversal competencies, such as teamwork, communication, leadership, and project management, has been highlighted for professional success in an increasingly complex and dynamic work environment [10]. In this context, the integration of sustainability as a transversal element in engineering curricula has become an increasingly relevant trend [11].

Previous scientific studies have demonstrated that universities can play a crucial role in promoting eco-innovation through research and the training of professionals with specific competencies in this field [12]. Some research has analyzed the impact of specific eco-innovation programs on the development of new, more sustainable products and processes, while others have focused on the role of universities as centers for the transfer of technology and knowledge to the business sector [13]. Furthermore, the impact of different factors on the adoption of eco-innovations by companies has been studied, such as environmental regulation, consumer demand, and competitive pressure [14].

Despite the advances made in this field, there are still some knowledge gaps that deserve to be explored. Notably, there is a lack of studies that comprehensively analyze the relationship between entrepreneurial culture, training in sustainability competencies, and the promotion of eco-innovation in the field of engineering. Most studies have focused on analyzing these factors in isolation, without considering the interactions that occur between them. Additionally, there is a need to develop more effective evaluation methodologies to measure the impact of training programs on the development of entrepreneurial and sustainability competencies in engineering students.

The University of Jaén, as an institution committed to regional development and sustainability, is in a privileged position to drive this transformation, through the implementation of training programs that foster an entrepreneurial culture and innovation among its engineering students. In particular, the incorporation of transversal programs that combine technical training with the development of entrepreneurial and sustainability competencies represents a promising approach. This article aims to contribute to this field of knowledge by presenting an innovative proposal to foster an entrepreneurial culture among engineering students at the University of Jaén, with the main objective of promoting eco-innovation in the industrial sector.

The proposed transversal training program is designed to develop competencies will allow the identification of business opportunities, the leadership of sustainable projects, and the promotion of eco-innovation in the industrial sector, contributing to the transition towards more efficient and environmentally friendly models.

Through the implementation of a transversal training program, the objective is to equip students with the necessary competencies to identify business opportunities, develop sustainable projects, and lead initiatives that contribute to the transformation of the industry towards more efficient and environmentally friendly models. Ultimately, it is expected that this initiative will contribute to the training of a new generation of engineers capable of leading the transition towards a circular and sustainable economy, generating a positive impact on regional and global development. The proposal has a transversal nature and seeks to foster the active participation of the student as an agent of change.

2. Description of the Educational Environment and Methodology Used

2.1 Description of the Agents Involved

The teachers involved in the activity have extensive experience in the field of entrepreneurship education [3] [15] [16]. This is a multidisciplinary team composed of professors from the areas of

electrical engineering, electronic and automation engineering, and environmental and materials chemical engineering, along with a young researcher in training. Among them are the two coordinators of the subjects participating in this teaching experience.

To carry out this experience during the first semester of the 2024/2025 academic year, two subjects were selected. The first, "Fundamentals of Solar Photovoltaic Energy," is part of the Master's in Renewable Energies at the UJA, is a mandatory course, and consists of 4 ECTS [17]. Of the 27 students enrolled in this subject, 77.78% participate in the entrepreneurship training activity. The second subject, "Photovoltaic Installations," belongs to the fourth year of the Electrical Engineering degree. It is an optional subject that is assigned 6 ECTS and has 10 enrolled students, all of whom participate fully in the experience [18].

Both subjects are at an advanced stage of training, a period when students usually consider their professional career paths. This facilitates capturing their interest in entrepreneurial activities, even though these are not directly aligned with the specific contents of each subject. However, both subjects include transversal competencies related to entrepreneurship, as detailed in their respective degree programs. Participation in the activity is voluntary and represents 10% of the final grade of each subject.

2.2 Materials and Methodology of the Teaching Experience

The activities proposed to the students are organized both synchronously in the classroom at times compatible with academic activity and asynchronously, using the Facebook social network as a vehicle to facilitate and enhance the different activities. In this sense, it is worth mentioning that the use of social networks in higher education, as commented in [19] [20] [21], is a widely referenced topic, and there is no doubt that the creation and use of work groups have proven to be very effective as a collaborative and engaging tools that helps and motivates students [22]. In [23], a bibliographic review is presented on the use of Facebook as a teaching tool, since it has been habitually used as a social network, analyzing the role of social networks as an educational tool in higher education. The authors of this communication have previously used the Facebook social network as a communication, meeting and debate tool with student groups in different subjects and previous educational projects [24].

The proposed activities are carried out during an entrepreneurship day in which entrepreneurs and the student support service of the University of Jaén collaborate. This event also includes a visit to the science and technology park located in Jaén GEOLIT. To evaluate the influence of these activities, a survey has been designed with two blocks of questions. The first block includes questions related to entrepreneurship and sustainability training and the incorporation of the eco-innovation concept in the designed solutions:

Have you considered about starting your own business? Do you think that starting your own business is a viable professional path for you? Do you know of any technical advisory body offered by the University of Jaén in the field of entrepreneurship? Do you think that sustainability or SDGs are important when starting a business?

These questions are posed on two occasions: initially when the student has not yet received any training or participated in the proposed activities, and again afterwards, once they have completed them. On the other hand, questions are included related to the evaluation of the proposed activities where students will rate the questions from 1 to 5 using a Likert scale in their response.

3. Results

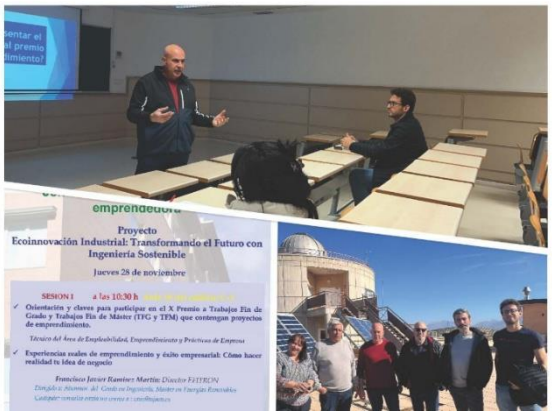
The results of this teaching experience are shown from two perspectives: the engagement achieved on social networks for the activity and the results of the pre- and post-activity student survey.

Firstly, the impact on social networks is assessed. In the private Facebook group, which allows us to stay in contact with professors, students, entrepreneurs, and everyone involved in the educational project, an attractive and participatory work dynamic has been created. When students visit GEOLIT, they learn about what a science and technology park entails and the types of services it offers to professionals who want to start a business, among which the center's director highlighted: the creation of small businesses, entrepreneurial advice and training, and the provision of workshops and courses on business skills development. This center also offers physical spaces to house startups in their early stages. These features have been shared by students in posts that have reached more than 50 people and have had more than 10 interactions. The Erasmus student Gabriele, from the Master's in

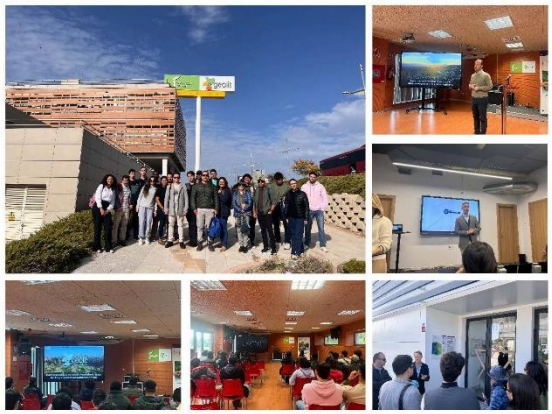
Renewable Energies, emphasized the importance of these types of centers to help future generations, avoiding emigration and promoting work in the province of Jaén. The teaching staff has also published the workshops and their highlights on LinkedIn, achieving the results shown in Table 1.

Table 1 *Metrics summary of published posts: impressions and reach*

[https://www.linkedin.com/posts/catalina-rus-casas-01565447_el-28-de-noviembre-se-celebr%C3%B3-la-jornada-activity-7268714018242973696-Ac6c?utm_source=share&utm_medium=member_desktop]



Entrepreneurship fostering workshop: Keys to participate in the 10th Final Degree Project Award and Efitron, a real experience of entrepreneurship and business success



Visit to the Jaén Science and Technology Park, GEOLIT.

Impressions	327 495	Reached members	168 247	Impressions	957 2462	Reached members	513 1035

With the aim of promoting entrepreneurship and eco-innovation, the project coordinator has published several posts about the activity on LinkedIn. This social network was chosen because students who have completed 50% or more of their degree often create a LinkedIn profile to stay up-to-date on available job offers. Notably, a number of members have engaged with the activity, including students enrolled in the subject and also graduate students who have commented on the usefulness of this activity. The posts have generated over 2,000 impressions at the time of writing this paper, demonstrating its remarkable impact.

Subsequently, the results of the surveys conducted among the 31 students participating in the activity are presented. Of these, 67.8% are students of the Master's in Renewable Energies and the remaining 32.2% are students of the Electrical Engineering degree. The course instructor introduces the activity at the beginning of the semester and outlines the planned activities. At this point, students are encouraged to complete the initial survey. Once the training is completed through the activities, they are asked to complete the final survey. Table 2 shows the results, as well as the improvement after the proposed activities, which make it possible to measure the effectiveness achieved in fostering an entrepreneurial spirit and awareness of eco-innovation among engineering students.

Table 2 *Comparison of percentages of "Yes" responses for the initial and final surveys*

Question	Percentage of "Yes" Responses in the Initial Survey	Percentage of "Yes" Responses in the Final Survey	Observed Improvement (%)
Have you thought about starting your own business?	70,6 %	85%	Increase of 14,4 %
Do you think that starting your own business is a professional outlet for you?	25%	55,3%	Increase of 30,3%
Do you know of any technical advisory body offered by the University of Jaén in the field of entrepreneurship?	15%	70%	Increase of 55%.
Do you think that sustainability or SDGs are	92%	96,6%	Increase of 4,6%

important when starting a business?			
Do you consider that the experience has positively motivated you to follow the course?	*Not available in pre-test*	77,7%	N/A

In the third column of Table 2, the increase in interest and knowledge among the group of participating students after carrying out the activity is highlighted, demonstrating that they now hold a different perception of entrepreneurship and sustainability. Specifically, there is a 14.4% increase in students who consider creating their own company after learning about the initiatives to support entrepreneurship; additionally, 30.3% increase in students' conviction about entrepreneurship as a viable professional outlet. Another noteworthy aspect, which justifies the implementation of projects to foster an entrepreneurial culture in the classroom is the significant 55% increase in knowledge of the UJA's technical advisory bodies in matters of entrepreneurship. On the other hand, it is also noteworthy that the perception of the importance of sustainability in entrepreneurship, which was already high initially, was further consolidated after the experience with a 4.6% increase following the activities.

Another important aspect for the teaching team has been the anonymous recognition by students that this activity significantly fostered their interest in the subjects, as they were able to connect the subject matter with eco-innovative solutions that could potentially become viable business ideas.

4. Conclusions

The need to transform current production and consumption systems, particulary in the context of the environmental crisis, has generated a growing interest in sustainability and eco-innovation. The transition to a circular economy presents a complex but necessary challenge that involves the reconfiguration of production processes, the promotion of reuse and recycling, and the adoption of circular business models. This transformation represents a unique opportunity to build a more sustainable and resilient future and requires the collaboration of all actors in society, including companies, governments, citizens, and higher education institutions. In this context, the University of Jaén, with its projects to foster an entrepreneurial culture, empowers faculty to effectively incorporate this training into the classroom. The results highlight the crucial role of the university in promoting eco-innovation through education and its connection with the business world. Active learning experiences, contact with entrepreneurs, and support for initiatives have proven to be effective strategies for developing an entrepreneurial spirit.

Quantitative results demonstrate a significant impact of the proposed activities. The data indicate a substantial increase in interest in entrepreneurship, knowledge of available resources, and motivation towards the subject. Additionally, the already existing awareness of the importance of sustainability in entrepreneurship have been further reinforced. Overall, the activities succeeded in generating positive and quantifiable changes in students' attitudes and knowledge.

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