Increasing Engineering Students' Involvement in Circular Economy Practices

Aumentar la participación de estudiantes de ingeniería en prácticas de economía circular

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Resumen. - La Economía Circular se ha convertido en un tema de gran interés para los legisladores, académicos y empresarios, ya que se muestra como un nuevo paradigma para lograr la sostenibilidad de nuestra sociedad. Sin embargo, los principales esfuerzos en la Economía Circular no pueden reducirse a actos de profesionales o de expertos. Consideramos que, si pretendemos satisfacer las necesidades actuales sin comprometer la capacidad de las generaciones futuras para satisfacer sus propias necesidades, tenemos que enseñar a las generaciones actuales los principios para lograr la sostenibilidad económica, social y ambiental a corto, medio y largo plazo. Este artículo destaca el uso de actividades participativas en lugar de cursos tradicionales para enseñar e involucrar a estudiantes de ingeniería con las prácticas de economía circular.

Palabras clave: *Economía circular, estudiantes de ingeniería, caso de estudio exploratorio, sostenibilidad, innovación educativa.*

Summary.- *The circular economy has become a topic of intense interest for policymakers, scholars and business managers because it has proven to be a new paradigm to achieve the sustainability of our society. However, the main efforts made in the circular economy cannot be limited to the actions of professional or experts. We believe that if we intend to meet current needs without compromising the ability of future generations to meet their own needs, we must teach present generations the principles for achieving economic, social and environmental sustainability in the short, medium and long-term. This paper highlights the use of participatory guided activities instead of traditional courses to teach and engage engineering students with circular economy practices.*

Keywords.- *Circular economy, engineering students, exploratory case study, sustainability, educational innovation.*

1.-Introduction.- Current consumption and growth patterns are taking society down a highly unsustainable path, which is increasingly damaging the ecosystem and endangering the provision of resources and ecosystem services [1]. Today's linear industrial model requires an updated model that uses less raw material and is more aligned with the cyclical nature of Earth. A concept that claims to provide such a model is the circular economy (CE), an economic system that aims to

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prevent the depletion of resources, to close energy and materials loops, and to facilitate sustainable development by implementing it at different levels [2], [3]. This concept has the potential to address the sustainability challenge by reducing resource extraction and waste streams and helping businesses moving towards sustainability.

Adopting circular business models that seek to support the planet's resilience present an attractive win-win-win situation for society, the environment and the company itself. In the long run, this transformation could offer an essential competitive advantage, as CE calls for creating more value from resources, helping companies to meet changing market requirements, lowering environmental costs, increasing consumer convenience and securing supplies [4].

Moreover, since Agenda 21 was delivered at the Earth Summit in Rio de Janeiro in 1992, it has been globally accepted that education can promote sustainable development in people's behaviors [5]. Nonetheless, the literature on integrating concepts related to sustainability and the circular economy in higher education and university curricula is still limited. Although this is a topic of interest for millennials in their decision-making process in the market [6], few universities have included it in their curricula. As Preston [4] claims, school and university students are the ones that are going to be the innovators of the next decades, which means that university lecturers have to ensure that they transmit to students the necessary knowledge about sustainability and the circular economy so they will be able to implement the corresponding actions in the near future. An important initiative is being developed by the International Baccalaureate® (IB), a non-profit educational foundation which offers international education programs, which has announced that they are collaborating with the Ellen MacArthur Foundation to embed systems thinking and a circular economy perspective into the IB curriculum [7]. Universities are increasingly offering sustainability and environmental sciences programs. For instance, a survey in the United States identified 840 degree-granting programs at 652 institutions that offer 1,183 interdisciplinary environmental degrees [8].

Moreover, Goel [9] highlighted the fact that engineers' awareness of environmental issues is an appreciated skill in Indian companies; indeed it is valued above other skills such as social skills, specialized engineering proficiency or project management skills. Organizations demand sustainability-related knowledge and environmental training for employees as a way to advance along the path of organizational performance [10], [11]. However, authors like Azapagic et al. [12] have provided evidence that engineering students from 21 universities based in Europe, North and South America, the Far East and Australia, demonstrate low-level knowledge and understanding of environmental and sustainability issues. Furthermore, Mulder et al. [13] observed that engineering educators were not the leaders in improving curricula to teach sustainability topics.
In the case of engineering, several attempts have been made to explore the way to introduce sustainable development issues in the curricula[13 - 15], and the most common practices are the introduction of the concept of sustainable development into regular courses, the design of a new elementary course; and, providing the option to graduate in a sustainable development specialization[14]. Nonetheless, the improvements on curricula require complex academic and bureaucratic processes which limit the response time of teachers who pretend to introduce those topics. However, far too little attention has been paid to out-of-class activities and their impact on the engineers' environmental awareness.

The objective of this research is to provide engineering students with an environmental education that includes the circular economy in the framework of sustainable development. This education will enable students to act as social agents in their professional life, whether their actions will be taken in firms or governmental institutions. Thus, this study aimed to address the following

research question: How do we educate engineers in circular economy in the framework of sustainable development out of class activities? Consequently, this work will contribute to existing knowledge about sustainability learning by providing a detailed case study of engineering students who have learned about the circular economy with real and innovative actions outside the classroom. It was found that these kinds of experiences have a high impact on students' motivation and engagement for all ages [16 – 18].

2. Engaging students in the Circular Economy.- The need for environmental education, starting in grade school and continuing through adulthood, and the integration of environmental issues in education programs has been called for since The Stockholm Declaration [19], where the interdependence between humanity and the environment was recognized [20]. Subsequent declarations, such as the Thessaloniki Declaration, also recognized that sustainability initiatives must be undertaken at all levels of society and linked with other fields of knowledge [20]. Environmental programs should be created in higher education, especially in engineering, as those graduates will be able to contribute to society in a transformative way.

Environmental education should develop in students a strong awareness of the relevance and importance of environmental issues for the individual and the organization, and also foster the necessary competences, skills, and knowledge that will make it possible to take actions related to minimizing the environmental impact of work [11]. A circular economy is an interesting approach for helping students understand those impacts and how to prevent them. Because the CE paradigm looks to protect the environment and prevent pollution while also ensuring economic prosperity [3] , it considers all the steps in the extraction, production, distribution, use, and recovery of any service or product by closing material flows of and minimizing waste in industrial ecosystems and through symbiosis [2].

Some authors claim that is necessary to develop learning programs based on action learning or learning based on real situations to assimilate new concepts and develop problem-solving skills [21], [22]. This type of learning process should be designed by integrating an array of features, such as support from the university, activities with well-defined aims, and final reflections upon the activity. These types of projects should be interesting for the participants, and ideally, the action learning teams should be made up of volunteers who form a diverse team [23]**.**

3. Research Methodology.- This research was carried out by the research group "Sustainable improvement" at the School of Engineering (Tecnun), from the University of Navarra. At Tecnun, some subjects address environmental sustainability, but the faculty believes that it is more effective for the students to acquire the necessary competencies through an activity that can involve the whole campus. As Cardona & García-Lombardía [24] point out, a learning activity is more effective if it is complemented with knowledge transmission, coaching, and training. As real actions are better observed, more people might be made aware of the importance of sustainability.

This study adopted the methodology of the exploratory case study to investigate the effectiveness of Tecnun's program for environmental education in a real-life environment with both quantitative and qualitative analyses of the data [25]. To achieve this objective, the first step was to think of an activity to be included in one of the subjects at Tecnun, although in keeping with the principles of action learning, participation was voluntary. In this way, students were able to acquire the fundamentals of the circular economy, and they could experience how to apply them to different aspects of their education. Then, students design and carry out an activity related to the environment, under the supervision of the subject's faculty. Finally, the participating student volunteers evaluated their degree of satisfaction and their perception of the results of the training program.

To summarize, the training program included the following:

- The researchers of this study gave the students a theoretical introduction to the circular economy.
- The researchers mentioned a list of possible activities that student volunteers could carry out and the students completed the list with other possible activities.
- The student volunteers decided to join each of the different activities and once the groups were made they assigned different roles.
- The students planned the activities, and they executed them during the Green Day.
- The students were asked to complete a questionnaire to evaluate their perception and satisfaction regarding the training program.

4. The learning activity: Green Day. - With the aim to link the activity to an area of knowledge, the activity was done within the Environmental Technology subject for students in the Industrial Management and Industrial Design degree programs. The project, which was voluntary, consisted of organizing a Green Day at Tecnun. This event was one of the more than 30 academic events directly related to the environment and sustainability that took place at 2016 at the University of Navarra (at its four campuses in Pamplona, San Sebastian, Barcelona, and Madrid).

The purpose of Green Day was to make students aware of their impact on the environment and how they would change their behavior towards the achievement of a circular economy. A total of 45 students decided to organize Green Day. These students had one session on the circular economy, so they could better understand the importance of taking care of the environment as consumers and through their professional activities as future engineers; it would help them involve other students in the event. After the session, the students thought about possible activities that could be organized for Green Day. They thought that it was better to focus on just a few activities but do them well. The activities that the student organizers decided to prepare were the following: bicycle paths, communication, sponsors, flea market and workshops.

4.1. Bicycles.- This activity was developed with the aim to encouraging clean urban means of transport. The bicycles group (9 leaders) created three different cycling routes to campus from different parts of the city. Once defined, students created a PowerPoint slide set to facilitate the task of communication.

On the day of the event, the bicycles group divided themselves among the different departure points along the three routes and each subgroup was responsible for being at the meeting place at the defined time to wait for the rest of the people. Although they would have liked more people to participate, progress was made concerning the previous year: a group of 25 people participated in the planned cycling event. Additionally, other people cycled to campus but did not ride with the groups due to scheduling conflicts (Figure I). Along the way, they took photos and videos, and they sent them to the communication team. All participants were given a ticket to a raffle to encourage them to come by bicycle.

Figure I.- Students arriving at the university

4.2. Communication.- The organizers (4 students) were in charge of communicating and disseminating information this event. First, they made several posters that advertised the different activities and events that had been organized for Green Day.

They also talked to the university communication department so that all the information related to Green Day could appear on the university's different digital and social media platforms, such as Twitter, Facebook, and in internal emails. To encourage every student to participate in the experience, they contacted the delegates of each year and each degree program so that they could spread the news through their respective WhatsApp groups. Finally, they took photos of all the activities, which were later published on the Sustainable Improvement Research Group's blog.

4.3. Sponsors. - The objective of this activity was to make students contact organizations that take care the environment, carry out cleaner production process or commercialize green products. The group in charge of getting sponsors (7 students) contacted a total of 19 companies. In exchange for their sponsorship, students gave the corporate sponsors visibility on posters, brochures and in the workshops. The sponsors provided prizes that would be awarded as an incentive to get students to participate in the different activities. The organizers received a positive response from only four companies. The prizes were three bags filled with products from Organic49, an ecological supermarket and with products from Carrefour Express; dinner for two at the restaurant Munto Berri; and ten tickets to the San Sebastian Aquarium. The two first sponsors' products were used as prizes in the different workshops, whereas the dinner and the tickets for the Aquarium were raffled off to the bicycle participants or people that bought tickets at the flea market.

4.4. Flea Market.- The 11 students in this group were in charge of organizing a green market, with the aim of collecting second-hand items and selling them to give them a new use. The purpose of this second-hand market was to educate students about the impact of reducing their consumption and the value of used products which use to be wasted. To this end, throughout the week, they informed the campus community about this activity through posters and images displayed on the university information screens, asking students and employees to collaborate by bringing in objects that they were not using anymore. Two large cardboard boxes were placed at the entrance to the main building, where people could deposit the things they brought in. People could bring anything except clothes, as those would be more difficult to sell to the students and teachers. The objective of the flea market was to raise money for refugees from Syria through an NGO.

In addition to selling objects, the flea market organizers decided to sell raffle tickets (the same tickets that the bicycle participants received) for € 1. On the morning of the Green Day event, several students were in charge of setting up the tables and displaying all the collected objects. A total of four tables were needed to display all the objects. Once the objects were placed, they were priced. They also asked the finance department for € 20 in € 1 notes and € 0.50 coins to have changed on hand. The raffle tickets were very successful, and along with the objects sold, € 223 were collected. The flea market was open all day, until 6 pm, when students finished classes. Both students and employees came to the flea market. The general impression was that women bags were the least successful objects as people didn't buy them. On the other hand, fountain pens had a great level of acceptance as they were in very good condition and were very original.

The flea market allowed students to see that they could give a second life to the objects they had brought in, and at the same time, they were able to buy products that were in very good condition at a very low price. They had the opportunity to understand the second-hand market better, and they also realized that second-hand does not mean low quality.

4.5. Workshops. - Three different awareness raising workshops were held: paper recycling, designing an eco-friendlier campus and designing objects with plastic bottles. Around 30 people in total participated in the workshops.

The paper recycling workshop ran as follows. First, working in teams of 4, participants cut some newspaper into small pieces and put it in a bucket of water. They mixed everything with their hands, and then they made a dough with a hand mixer. After this, they moved the dough to another bucket that contained water and they re-mixed everything with their hands. Each team took a pair of wood frames and placed the one that had no screen on top of the other, leaving the screen in the middle and making a mold. A layer of dough was placed inside the mold, and after the water drained out, participants pressed down on the dough using their hands. Once they had removed most of the water, they lifted off the wood frame without the screen, placed a scrap of t-shirt and then a piece of board on top of the paper. After flipping the whole thing over, they repeated the process on the other side. Before covering one of the sides of the paper with the cloth and board, each team took some tree leaves and put them on the recycled paper to decorate it. Once the paper was decorated, a person sat on top of it for a while to flatten it. In choosing the prize winners, the paper each team made was assessed for consistency and decoration (Figure IIa).

Figure II.- a) Paper recycling activity winners, b) Students designing objects with plastic bottles

The second workshop consisted of thinking about what we would change about the campus to make it eco-friendlier in the future, in 2050. For this activity, participants used a design and creativity technique called the Nominal Group Technique (NGT). This technique is an alternative to brainstorming [26]. Using NGT, students proposed ideas like electric cars, renewable energy use, an organic garden, using ecological materials, more green spaces, natural lighting, and more training related to sustainability.

In the workshop where objects were made from plastic bottles, participants thought of making gift packages and purses/cases with used plastic bottles. To get the materials, they collected bottles on campus, and they designed a poster to get people to leave their used plastic bottles in a cardboard box that was placed at the entrance to the main building (Figure IIb). Participants bought zippers and decorations (bow, tissue paper, stickers), and the glue and scissors were provided by the university. Most people opted to make cases/purses rather than gift boxes. It was amazing how the participants managed to create objects that were so creative, colorful and useful with so few materials.

At the end of the workshops, the three bags of products provided by two of the sponsors, Carrefour Express and Organic49, were awarded to the different workshop winners.

5. Results.- The Green Day activities provided students with environmental knowledge about specific issues related to the circular economy, such as sustainable transportation, sustainable consumption, and material recovery processes.

At the end of the Green Day event, the student organizers were asked to answer a satisfaction

survey in which they were asked to indicate on a scale from 1 to 5 their general impressions of Green Day and the knowledge they acquired in the course. The questionnaire design was based on the work of Jurburg et al. [27], which describes the main elements that tend to motivate people to participate in improvement activities such as training, improvement methodology, self-efficacy, social influence, and satisfaction in general. Forty-one students out of 45 answered the survey. Table I shows the results of the survey (from 1– "Totally disagree, not useful or not appropriate" to 5– "Strongly agree, useful or appropriate").

Fortunately, on average the students had a positive response; they assigned high scores to the question related to the social skills they could develop with their partners and friends (Item 14) and students also responded very positively to the item that asked about feeling comfortable developing and participating in new activities related to environmental awareness (Item 6). On the other hand, students expressed some reservations regarding the improvement of sustainability on campus in the short and long-term (Items 4 and 7).

Item	Question	Score
1.	I believe that the activity I carried out has given me the knowledge and confidence necessary to participate in other activities aimed at sustainability and environmental improvement.	3.41
2.	I believe that the activity I participated in was useful in learning about environmental sustainability issues.	3.41
3.	The approach used for this activity was agile, dynamic and effective.	3.73
4.	I believe that the activity I carried out will make it possible to achieve sustainable (long-term) solutions on campus.	2.83
5.	I believe that the practices, techniques, and tools used in the activity were appropriate.	3.78
6.	After doing this activity, I feel able to develop and participate in other environmental improvement activities.	3.63
7.	Participation in this activity will improve sustainability on campus.	2.93
8.	Participation in this course will allow me to improve my skills.	3.22
9.	Participation in this course will help sensitize students to environmental sustainability.	3.17
10.	Participation in this activity will help me in my professional and personal development.	3.17
11.	I think the organization of the event was clear and easy.	3.63
12.	I think that the activity I carried out will help me to create a positive atmosphere among my classmates.	3.80
13.	I think my colleagues see this activity as something positive.	3.88
14.	It would be positive if more of my classmates were to participate in this activity.	4.17
15.	In general, I am satisfied with this course.	3.71

Table I.- Satisfaction survey results

6. Conclusion.- Regarding the research question, this case study has proven that the "Green day" at Tecnun, it is an opportunity to educate engineers about sustainability and especially about circular economy implementation. All the organized activities were useful and fruitful, as they increased students' environmental awareness on campus and as a professional skill. In addition, the Green Day activities are alternatives to reducing pollution in the environment, and they proved that it is not very complicated to carry them out. Cycling to campus or ride sharing does not require any special effort. Using waste materials to create new products is an activity that can be carried out by everybody in their own homes. Moreover, reselling products, that are no longer used, at the flea market minimized waste and showed students that both parties can benefit from the sale.

Regarding the survey results, the item fourteen (14) had the highest score which prove the importance to increase the students' participation in these activities. If we continue to offer this course and the activities are improved every year, and new ones are added, participation will increase, and the impact will be greater both for students and for the employees of the university. In this case, students increased their environmental awareness through real actions instead of

through traditional courses, and the lecturers had the opportunity to innovate in the way they teach sustainability circular economy**.**

Then, the lowest scores (items 4 and 7), show out that students tended to become negative about both the long- and short-term improvement of sustainable solutions on campus. This pessimistic view of the students must encourage teachers and university staff to develop strategies towards sustainability and involve the whole academic community. An event like the Green Day is key to remind the academic community and future professionals each year that we have to improve our behavior, as our everyday life can affect our environment.

Although the survey presented a low score in the items related to the usefulness of the activity for the students personal and professional skills, the students improved these abilities by involving external organizations such as restaurants, supermarkets and foundations to support and communicate the Green Day activities. Hence, this study demonstrates that university activities may involve different stakeholders, and as in this case, promote the circular economy in society. This rather contradictory result may be due to the pessimistic view of the students, so the next "Green Day" should include activities that empower students as future professionals to make changes in the organizations towards the circular economy.

The current research was limited by the location of the School of Engineering (Tecnun), which is separated from the main Campus of the University of Navarra in Pamplona. Consequently, the activity just analyzes the results of the "Green day" with students of engineering. Nonetheless, it would be interesting to develop this pedagogical experiment with students from different degrees.

Finally, there is abundant room for further progress in determining the effects of this kind of learning activity in the long term with monitoring activities to review the professional performance of the students. Additionally, in future research, it might be possible to use different activities like games or company visits to explore other areas of the circular economy, which may be more interesting for undergraduate students.

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