Sustainable Development Goals in Computer Engineering: A Curriculum Integration

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Abstract: This contribution delves into the incorporation of Sustainable Development Goals (SDGs) into the Computer Engineering curriculum. The study addresses challenges associated with integrating SDGs as cross-cutting content in higher education. Employing a Problem-Based Learning approach, semester projects are aligned with SDGs, and their impact is systematically assessed. Key research questions guide the study, evaluating students' knowledge, perceptions, and the alignment of projects with SDGs.
The methodology integrates SDG-focused learning units within the existing Problem-Based Learning structure. New activities, including initial training, initial assessment, impact assessment, and SDG learning assessment, guide and evaluate students' integration of SDGs. Results demonstrate successful implementation across three years of the Computer Engineering degree. The study involves a significant number of subjects, students, and teams, ensuring a comprehensive evaluation. A rubric assesses SDG impact, emphasizing justification and direct positive contributions to SDG objectives.

1 INTRODUCTION

The Sustainable Development Goals (SDGs) are 17 globally agreed goals adopted by the United Nations General Assembly in 2015 as part of the 2030 Agenda for Sustainable Development[1]. The SDGs represent a global consensus on the priorities for sustainable development. They were developed through extensive consultations and negotiations, reflecting the collective aspirations and commitments of UN member states (Hák et al., 2016).

The goals comprehensively address the three spheres of sustainable development: environmental, social and economic. They also cover critical areas such as poverty, inequality, social inclusion, sustainable energy, climate change, quality education and technological innovation. To address the 17 goals, 169 specific targets and 232 indicators were specified for evaluation[1]. This comprehensive framework helps align policies and actions across different sectors and regions (Hák et al., 2016).

The university has developed different initiatives at institutional level to make its contribution to the development of the SDGs[2]. However, the involvement at the curriculum level was carried out at the beginning of the 2021-2022 academic year, when the Royal Decree 822/2021 was published, which establishes the organization of university education and the procedure for assuring its quality[3]. A relevant feature of this decree is the inclusion of the Sustainable Development Goals among the guiding principles for the design of curricula in official higher education. This means that higher education institutions must incorporate a sustainable and responsible approach in their curricula, enabling students to understand and address global sustainable development challenges. According to Royal Decree 822/2021, the SDGs must be incorporated into curricula as cross-cutting content or competencies[3]. The way in which these values and objectives will be incorporated will be decided by the center or university, always taking into account their academic nature and the objectives of each degree.

The incorporation of the SDGs in the curricula is a new challenge for higher education. In this context, this paper presents the methodology followed to inte-

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grate the learning of the SDGs in the Computer Engineering curriculum, placing the focus on raising students' awareness of the development goals. To guide the work and to perform the measurement of the experience, the following research questions have been answered:

- RQ1: What is the students' level of knowledge about the SDGs before and after the experience?
- RQ2: Do students think it is important to analyze the impact of their projects on the SDGs?
- RQ3: Was it easy for students to align the SDGs with their projects?
- RQ4: What have been the academic results obtained from the evaluation of the SDGs?
- RQ5: Which SDGs have students worked on the most?

The rest of the article first presents a review of the most relevant related works. Next, the case study presented is introduced, detailing the characteristics of the faculty and the adaptations made to the project-based work methodology to incorporate the SDGs. Next, the results of applying the methodology are presented and analyzed. Finally, conclusions and pending challenges are presented.

2 RELATED WORK

In recent years, universities have been incorporating the SDGs into their courses. There are different examples that show how they have integrated them. For example, the University of the Basque Country (UPV/EHU) and the University of La Rioja (UR) have carried out a joint experience introducing the SDGs in the Project Management subject of the Computer Engineering degree, involving so far more than 300 students (Blanco et al., 2024). During the course, students have had to carry out 3 different 3-week projects. The first consisted of producing a video related to the SDGs and uploading it to an online platform. In the second project, students had to produce a video channel aimed at raising awareness of the SDGs. Finally, the students had to implement an accessible website aimed at motivating people to take action on the SDGs. Oliva-Maza et al. (Oliva-Maza et al., 2019) proposed to the students a real-world problem to address and promote engineering vocations through the Internet of Things (IoT) and SDGs. This project already implied certain SDGs and the students had to learn their meaning and the project's implication on them. On the other hand, Brunell and Leslie (Brunell, 2019), implemented a study whose idea was to demonstrate how the use of SDGs would increase sustainability awareness in civil engineering students. To that end, students were asked to select a number of SDGs to work with in their Final Degree Project. A group of professional mentors advised the students in this process. The final results showed that working closely with professional mentors required students to communicate effectively and become socially aware of the global impact of their designs.

Among the different ways of integrating the SDGs in the university, other authors have also opted for introducing them through PBL. Perez-Sanchez et al. (Pérez-Sánchez et al., 2020), have introduced PBL methodology in 6 degrees for the last courses (3rd and 4th year) involving 64 different subjects and more than 60 teachers. Before starting, they defined that PBL allowed students' independence in the decision-making process on what actions were taken to improve the SDGs and allowed them to explicitly present to others and promote awareness of the SDGs. The PBA models were very different in nature, but almost all of them dealt directly or partially with some aspects related to the SDGs. The difference with our proposal is that the students did not reflect on the impact of their projects on the SDGs, but the SDGs were given to them. Marco Braga et al. (Braga et al., 2022) developed a short-term project experience (PBL) with a focus on SDGs in cities at the Federal Center for Engineering Education in Rio, Brazil. For 48 hours, students were confronted with SDG problems in urban communities and challenged to create low-cost solutions. At the end, they had to present an argument for experts from NGOs, governments and corporations. This case shares with our work that students must reflect on the impact of projects on the SDGs, and differs in that their project is shorter in time than the one presented in this paper. Pucha and Dumbar (Pucha and Dunbar, 2022) conducted a PBL experience with first-year engineering students. In their work, they sought through SDG-focused projects to have students explore connections between sociocultural resources and engineering design practices. The continuous assessment plan considered three factors measured through a survey: (i) the level of students' knowledge of aspects and perceptions of the SDGs, (ii) the level of post-activity reflection, and (iii) the level of quality of work products for both individual and team projects. Unlike our work, students are not required to reflect on the impact of their projects on the SDGs. Podgórska and Zdonek (Podgórska and Zdonek, 2024) investigated how PBL innovations at a Polish university contribute to achieving SDGs. The authors conducted a qualitative and quantitative analysis of 108 projects from 2018 to 2021, involving 324

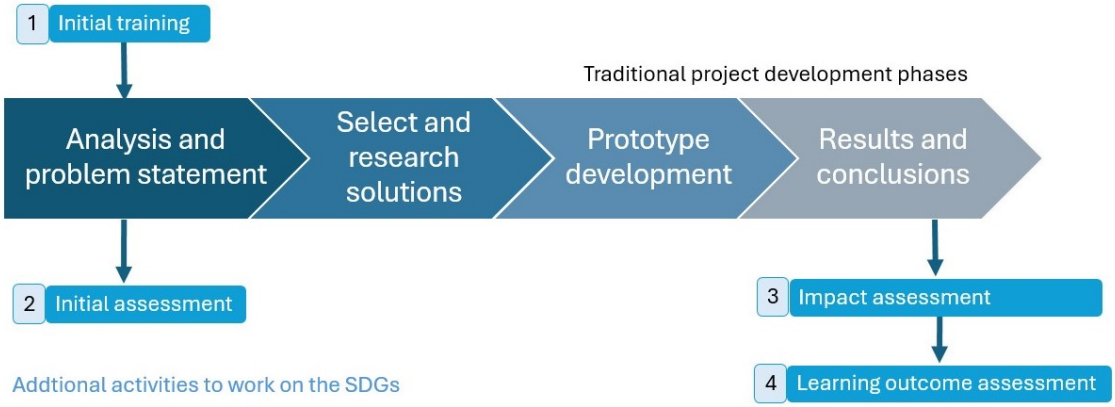

Figure 1: New activities for the development of SDG learning incorporated in the ABP methodology.

researchers, 607 students, and 233 business experts. They detect that interdisciplinarity between research areas was common, highlighting the role of PBL in promoting SDGs at universities.

3 CASE STUDY

This paper presents the methodology used to integrate the systematic study of the SDGs in the semester projects of the Computer Engineering degree.

In the first three years of the degree, each semester is divided into two phases: (i) the teaching period and (ii) the semester project. During the teaching period, all the training and evaluation activities of the subjects are carried out, including the exams corresponding to this period. At the end of the academic period, the semester project is carried out, which consists of a group work that integrates all the subjects of the semester (except electives). The duration of the project is 4 weeks in the first course, 6 weeks in the second course and 8 weeks in the third course. It should be noted that during the semester project, students are exclusively dedicated to it.

The evaluation of the subjects is based on the activities of both the class period and the semester project. Taking into account that the weight of the project varies according to the course, the weight in the evaluation is proportional to the extension of the project in the semester calendar. This means an impact of 20% in the final grade for the first course, while in the second and third courses it means 30% and 40% respectively.

The project is developed following the principles of the PBL (Pérez-Sánchez et al., 2020). Specifically, the PBL methodology is adopted in which the project is oriented to problem-solving (PBL). Guided by this methodology, the student teams, composed of 4 to 6 members, undertake the project in 4 phases: (i) analysis and problem statement, (ii) identification and selection of solutions, (iii) development of the prototype and (iv) analysis of the results and drawing of conclusions. The professors of the semester's subjects are in charge of monitoring and tutoring the projects, and weekly or biweekly meetings are held for their coordination.

In the context of the project, in addition to the development of technical competencies associated with the subjects, cross-cutting competencies such as effective communication and teamwork for problem-solving are also developed. The integration of the study of the SDGs has been carried out within the framework of the problem-solving teamwork competency. Specifically, a new learning unit has been incorporated from which students identify and evaluate the impact that the developed project has on the SDGs. This learning unit has been partially inspired by the SUS Project-Based Learning methodology[4]. To guide the implementation in the faculty and student groups, new activities have been incorporated in the project methodology, as presented in figure 1. In the case of the teaching staff, the contents of the new unit as well as the evaluation system have been presented in the coordination meetings of the different semesters.

The first activity incorporated *initial training* (additional activity N°1 in figure 1) is given with the start of the semester project and consists of a basic training to introduce the history and evolution of the SDGs as well as the proposed working methodology for the study of the SDGs in the project (including the evaluation rubric). During the training, resources and examples are provided to inspire the teams in the problem analysis and approach phase. Once the first phase of

[4]https://sustainabledevelopment.un.org/content/documents/260351525_06_Derek_HESI_Presentation.pdf

Table 1: Rubric for evaluating the impact of the project on the SDGs.

Deliverable	**Weight**	**<5**	**5-6**	**7-8**	**9-10**
Initial evaluation	10%	The initial assessment of the impact of the project on the SDGs is not carried out.	A basic identification of the SDGs that the project impacts is carried out.	An identification and justification of the SDGs on which the project impacts is carried out.	
Assessment of impact	90%	The project's impact on the SDGs is not measured (or poorly measured)	A basic measurement of the project's impact on the SDGs is made, but a superficial justification is made.	A measurement of the project's impact on the SDGs is carried out, and a detailed justification is provided using the targets.	A measurement of the project's impact on the SDGs is carried out, and a detailed justification is provided using the targets. The project has a direct positive impact on (at least) two objectives.

Table 2: Number of students and project teams involved per semester and course.

Year	Semester	Number of Subjects		Number of Students	Number of Teams
		Mandatory	Projects		
1	1	5	2	72	13
	2	5	4		10
2	1	5	5	38	6
	2	5	5		6
3	1	5	5	39	8
	2	5	5		8

the PBA methodology has been developed, the teams have the problem identified, delimited and analyzed. The validation of the selected problem is an activity that has been carried out at the level of technical subjects to ensure that the learning objectives of each subject can be developed in the context of the selected problem.

The second added activity *initial assessment* (additional activity Nº2 in figure 1) complements the validation for the SDG scope and consists of an initial assessment of the impact the teams estimate the project will have on the goals. The outcome of this activity is a deliverable that describes for each project the context of the problem and its alignment with the SDGs. This deliverable ensures that the problem selected by the teams is aligned with the SDGs. Teachers review the deliverables, evaluate them following the rubric (described at the end of this section) and provide the corresponding feedback to the student teams. Teachers provided targeted feedback to help students improve their work. Lecturers recognised teams for clearly defining their project goals and aligning them with relevant SDGs. However, they pointed out areas where the problem scope could be clarified to ensure it was manageable within the project aim. Feedback objective was to highlight creative and innovative ideas, encouraging students to explore these further. At the same time, teachers suggested that some solutions needed more thorough research to improve feasibility and alignment with the objectives.

After completing the next three phases of the PBL methodology to propose a solution, develop the prototype and draw the conclusions, two new additional activities are carried out in relation to the SDGs. In the third embedded activity *impact assessment* (additional activity Nº3 in figure 1 each student team assesses the impact the project has on the SDGs using the self-diagnostic tool *SDG Impact Assessment Tool*[5]. This tool is developed by the Gothenburg Center for Sustainable Development in collaboration with Chalmers University of Technology and Gothenburg University of Technology (Chalmers, 2019) and is published under the *Creative Commons Attribution-NonCommercial 4.0* license. The tool allows for a simple and systematic recording of the analysis performed to later generate a report and visual summary of the impact. In this activity, students are asked to include a summary of the impact in the conclusions section of the project report, and to attach the report generated with the tool as an annex.

Lastly, in the *SDG learning assessment* the teaching team completes the assessment of the work based on the rubric. The assessment of the SDG learning unit consists of two deliverables: (i) initial assessment and (ii) impact assessment, with the weight of each deliverable being 10% and 90% of the unit grade respectively. The three levels of the rubric for the *initial assessment*, the objective of which (described in the first phase of this section) is to ensure that student teams select a project problem that is aligned with the SDGs, are provided in the table 1. In the deliverable section, the rubric provides a four-level scale that rewards work with the greatest impact on the SDGs and the greatest rigor in justification.

The methodology proposed in this work has been implemented for the first three years of the Computer Engineering degree. The table 2 presents the data on the number of subjects and students involved in this study. The table details for each course and semester the number of required subjects in the curriculum

[5]https://sdgimpactassessmenttool.org/

Table 3: Questionnaire results (Strongly disagree, SD; Disagree, D; Neither agree nor disagree, N; Agree, A; Strongly agree, SA).

Questions	Frequencies					Descriptive statistics	
	SD	D	N	A	SA	Median	Mode
Q1: I was aware of the SDGs before the project.	26	6	22	30	25	A	A
Q2: I know the SDG number.	10	13	21	36	29	A	A
Q3: Could you briefly explain what the SDGs consist of?.	5	6	28	48	22	A	A
Q4: I find it interesting to participate in this type of activities (development of SDGs in general).	28	19	31	27	4	N	N
Q5: I consider the introduction of this type of activities in PBL to be positive.	30	16	31	23	9	N	N
Q6: Engaging in the practice of the SDGs can promote a more sustainable vision of knowledge application.	12	20	42	28	7	N	N
Q7: Knowing the existing problems and the established objectives helps me and raises awareness to propose solutions to solve them.	14	19	34	34	8	N	N
Q8: I consider it more appropriate to work on the SDGs in the project period than in the school period.	19	13	37	26	14	N	N
Q9: Aligning the impact of the project with some of the objectives has been easy for me.	18	19	31	32	9	N	A
Q10: Aligning the impact of the project with the specific goals directly in the objectives has been easy for me.	19	19	34	28	9	N	N

(third column of the table) contrasted with the number of subjects involved in the semester project (fourth column of the table). The last two columns detail the number of students per course, as well as the number of teams that carried out the semester project. Note that in the first course, not all subjects of the semester participate in the semester project. In the 2nd and 3rd years, the number of subjects participating in the project is 5, leaving out the elective subjects. In addition, it should be noted that there are students in the first course who for various reasons (they leave their studies, or did not reach the required level during the academic period) did not participate in the second semester project. Finally, repeating students with 12 or fewer credits do not participate in the projects.

4 RESULTS

This section presents the results obtained during the experience, in which a total of 149 students from the first 3 years of the Computer Engineering degree have participated. The number of groups during the first semester was 27 and 24 in the second semester. It should be noted that a total of 26 subjects (6 in the first course, 10 in the second and 10 in the third) and 34 teachers have been involved in this experience.

For the evaluation of this research work, we present the data collected in 2 tables and 2 figures. The table 3 summarizes the results of the questionnaire completed by 109 students, the 73.15% of the total. The survey was accomplished in a Google forms questionnaire, and it was provided to students at the end of the course. Students did not know their final grades when the questionnaire was answered, in order to avoid any bias. To develop the questionnaire, we have relied on the works (Chofré et al., 2021; Seva-Larrosa et al., 2023). The table 4 presents the summary of the scores resulting from assessing the SDG learning unit. Figure 2 present the summary of the impact that the students' projects have had on the SDG. In order to compile the faculty's assessments and evaluations, a new section analyzing the implementation of the SDGs has been added to the semester-end report.

4.1 RQ1: What Is the Students' Level of Knowledge About the SDGs Before and after the Experience?

The first 3 questions in the table 3 answer the students' level of knowledge about the SDGs. The first question shows that a significant number of students were unaware of the SDGs. Despite this, the majority of students were aware of them. After carrying out the project, the vast majority of students know the exact number of SDGs as well as being able to explain what each of them consists of.

It can be concluded that although most of the students knew about the SDGs before the project, after the project was completed, more students know the number of SDGs and are able to briefly explain what each of them consists of. Therefore, the inclusion of the SDGs in the PBA has served to broaden their knowledge of the SDGs.

4.2 RQ2: Do Students Think It Is Important to Analyze the Impact of Their Projects on the SDGs?

Questions 4, 5, 6, 7, and 8 in Table 3 answer this research question. For all of these questions, both the mean and median are N, i.e., students neither agree nor disagree.

For questions 4 and 5, the number of students who strongly disagree is high. These students do not find it interesting or positive to carry out the analysis of the impact of the SDGs on their projects. In general, for these 2 questions, more people disagreed than agreed with them, and they were the worst rated of the entire questionnaire.

For questions 6, 7 and 8, the number of students agreeing and disagreeing is practically the same. In the case of questions 6 and 7, students believe that the inclusion of the SDGs in their projects promotes a more sustainable vision and helps them to become aware of them when looking for solutions. These two aspects are very important and one of the objectives when including the analysis of the SDGs in the students' projects. Regarding question 8, the students have homogeneously valued the fact of working with the SDGs both in the teaching period and in the PBA period.

4.3 RQ3: Was It Easy for Students to Align the SDGs with Their Projects?

Questions 9 and 10 in Table 3 answer this research question. In both questions, the number of students who agree or strongly agree is the same as the number of students who disagree or strongly disagree. This tells us that it has been neither easy nor difficult for students to align the impact of their SDGs with their projects.

4.4 RQ4: What Have Been the Academic Results Obtained from the Evaluation of the SDGs?

The table 4 shows the number of groups per course and semester and the average grade obtained by each of them. First, the 3rd and 5th columns show the average final grade for each of the groups in each course and semester. The objective was that students could adequately identify how their projects have been aligned with at least one SDG goal. In these results, we can see how the average grade obtained in courses 1 and 3 has decreased in the second semester compared to the first. On the contrary, in the second year, the average grade obtained in the second semester was higher.

The results obtained by the third year students are better than those obtained by the first and second year students. This is due to the fact that these students are able to reflect better and analyze in a more mature way how their projects are aligned with the SDGs.

Table 4: Results of the evaluation of the SDGs.

	Semester 1		Semester 2	
Academic Year	#Teams	Mark	#Teams	Mark
1	13	5,53	10	4,38
2	6	4,41	6	5,73
3	8	7,15	8	6,21

4.5 RQ5: Which SDGs Have Students Worked on the Most?

The students have been asked to use the self-diagnostic tool *SDG Impact Assessment Tool* to detail the analysis of the project's impact on the SDGs. The tool allows identifying whether the project developed has a positive or negative impact on each of the goals. It also specifies whether the project's impact on each goal is *direct* or *indirect*. The data shows that most of the impacts analyzed by the students are indirect positive (62%), i.e., they improve the SDGs indirectly with the contribution of their project. It should be noted that the impact analysis carried out by the students has focused (with few exceptions) on the positive impact of the project on the SDGs.

Figure 2 shows the distribution of impacts that the students' projects have had on each of the SDGs. Eighteen percent of the impacts of the works were oriented to the improvement of sustainable cities and communities. The high number of impacts is directly related to the fact that the theme of the project in the second semester of the first year is aimed at developing an autonomous vehicle that the student teams have oriented towards assisting people with reduced mobility, delivering medicines or optimizing travel routes. The second objective with the highest number of impacts (16%) was the SDG-4 (quality education) for quality education. Teams of students from all three courses have oriented their projects to games focused on raising awareness of various SDGs. The third objective with the highest number of impacts (14%) is SDG-13 (climate action) for the adoption of measures to combat climate change and its effects. A significant number of studies have opted for solutions that indirectly have a positive impact on the fight against climate change by optimizing resources to re-

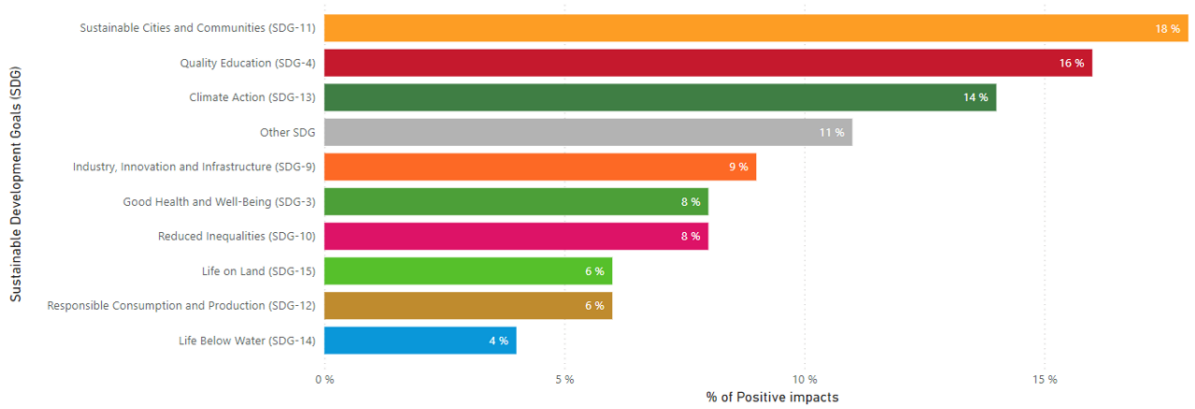

Figure 2: Distribution of positive impacts of projects on the SDGs.

duce consumption and emissions. It is worth highlighting the impact (8%) on the SDG-10 (reduced inequality) to reduce inequalities with striking projects such as a bidirectional sign language to words converter or home automation platforms and systems to support the elderly.

5 CONCLUSIONS AND FUTURE WORK

This paper presents the implementation carried out to integrate the systematic study of the SDGs in the semester projects of the Computer Engineering degree as a new learning unit. To this end, 4 new activities have been incorporated in the methodology of the semester project. In addition, the necessary materials for the learning of the new unit have been developed, as well as the evaluation rubric. The implementation has been carried out and evaluated in the first three courses of the Computer Engineering degree. The initiative has involved 149 students and 34 teachers. Fifty-one projects have been carried out involving 26 subjects. The evaluation of this work has been guided by five research questions and for its analysis data has been collected from the learning unit grades, student surveys, the study of the impact of the projects on the SDGs and the faculty's perception of the implementation.

The results obtained allow us to affirm that all the projects developed by the students have been aligned with the SDGs. Most of the semester projects have an open theme, and sometimes it is difficult for the student teams to define the problem. Narrowing the problems to areas that allow developing solutions for the SDGs has facilitated in some cases the project definition phase.

The development of this learning unit has improved the students' knowledge of the SDGs. In addition, the student teams have conducted a systematic analysis of the impact of the project on the SDGs. This knowledge has provided them with a new dimension to take into account when solving engineering problems.

According to the results obtained, the students consider that incorporating the analysis of the SDGs in the semester project is more appropriate than doing it in the teaching period and also promotes awareness. However, they do not find it attractive to carry out the impact assessment, although it was easy for them to do so. Our hypothesis is that students show little interest in working on SDGs because they focus mostly on technical knowledge. In addition, they may consider that a small-scale project would not have a significant impact on such ambitious goals.

With respect to the subject matter of the projects, the teachers have detected that in previous courses most of the projects were related to leisure or systems automation, while now the students carry out approaches for the improvement of environmental, social and economic problems. This perception of the faculty is corroborated by the results obtained when analyzing the impact of the projects on the SDGs. It can be concluded that, on the one hand, the leisure theme has evolved into a new concept of gamification for awareness.

It has been detected that lecturers do not feel comfortable tutoring and evaluating the SDG section, so training is needed to help them become familiar with the SDGs and to motivate students to become aware of them.

In the future, we want to modify the rubric presented in order to make a more appropriate assessment of student effort and learning. The changes we want to introduce are intended to solve three opportunities for improvement that we have identified: (i) to carry out a gradual work and evaluation of the SDGs in the different courses, (ii) to modify the weights to

concentrate the grade on the final activity and (iii) to avoid the over-alienation of objectives with the project.

For the first point, a tiered rubric has been designed so that in each course, students will have to acquire new knowledge regarding the SDGs and improve impact assessment in their projects. The new rubric will have 4 dimensions of assessment: *methodology, SDG goals, SDG targets and justification*. With the new rubric, first year students will work on the first two dimensions of *methodology* and *SDG targets*, in the second year the dimension of "SDG targets" will be added and in the third year it will be completed with the dimension of *justification*. We intend to accompany the new rubric with revised student SDG training, so that it puts the focus of the training on the dimensions of work that correspond to the course.

In the second point, the design of the new rubric proposes to modify the weights, specifically it is proposed to eliminate the weight of 10% corresponding to the *Initial assessment* with the objective of concentrating the grade (of 100%) in the activity *Assessment of learning SDG*. However, qualitative *feedback* will be retained in the *initial assessment* activity so that student teams can improve the impact analysis in the final activity.

The current rubric rewards (at the top level) direct positive impact on at least two objectives, and we have detected that some students force the justification of alignment to ensure maximum assessment. For this reason, a modification to the rubric has been proposed to avoid this over-alignment of objectives.

In addition to the modification of the rubric, the aim is to train teachers in the SDGs. It has been complex for teachers to be able to evaluate adequately. For this reason, specific training for teachers will be proposed for the following year.

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