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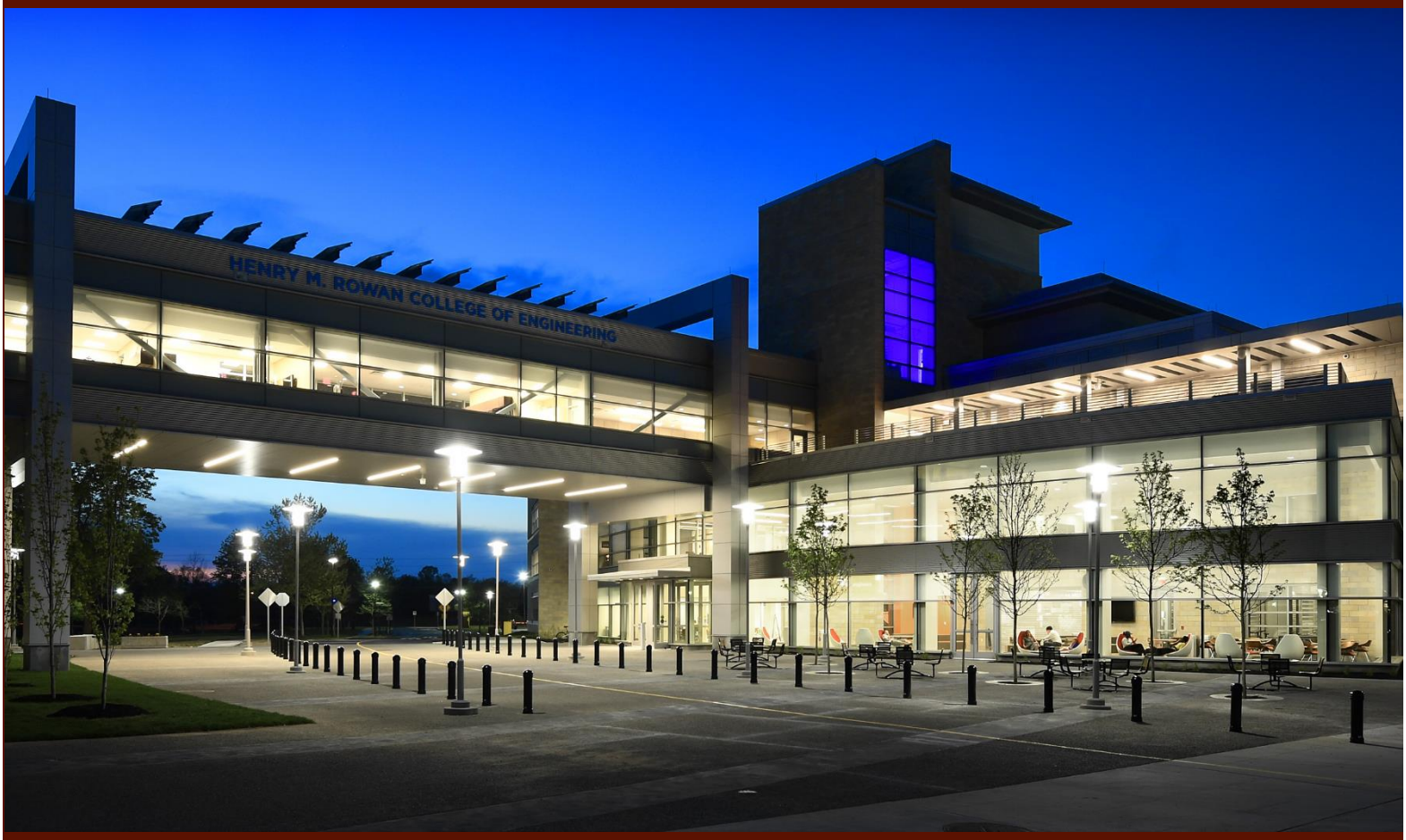

CREATING THE HOLISTIC ENGINEER

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Session 6B: Developing a Sustainable Mindset

The EDINSOST project. Training sustainability change agents in Spanish and Catalan Engineering Education.

J. Segalas[1], F. Sánchez Carracedo[2], A. Hernandez[1], P. Busquets[1], G. Tejedor[1], R. Horta[3]

[1]Research Institute for Sustainability Science and Technology. UPC-Barcelona Tech, Catalonia.

jordi.segalas@upc.edu

[2]Computer Architecture Department. UPC-BarcelonaTech, Catalonia.

[3]Electrical Engineering Department. UPC-Barcelona Tech, Catalonia.

Abstract

EDINSOST is a Spanish R&D+I funded project. The objective of the EDINSOST project is to facilitate the training of graduates capable of leading the resolution of challenges in our society through the integration of sustainability training in the Spanish University System. The project focuses in engineering degrees, given their great impact of engineering graduates on the short-term, and education degrees, in view of its multiplier and long-term effect, because graduates from these courses will be the future teachers of new generations of citizens. The project is organized around four specific objectives:

1) To define the Sustainability Competency Map of each of the participating degrees and establish a framework for incorporating the map into the degree in a holistic way;
2) To validate different didactic strategies for addressing sustainability from a constructivist and community pedagogical approach;
3) To diagnose the status of the sustainability training needs of the teachers of each degree, as well as to develop and test training proposals and
4) To diagnose the sustainability competency level of current university students and to develop and test training proposals.

The EDINSOST project involves fifty-five researchers from ten Spanish and Catalan Universities. This paper presents the results of the project in the field of engineering education. In relation to the first objective it has been defined a sustainability competency map. Based on this map, the most appropriate didactic strategies for sustainability training are been analyzed and tested, the state of the sustainability training requirements in teachers and students are diagnosed, and finally, proposals will be made for training both groups. In this paper, the objectives of the EDINSOST project are presented, as well as early results: the sustainability competence map for engineering degrees, faculty capability and training needs to teach students according to the competence map.

10 Introduction

Sustainability issues are widely recognized as wicked problems (Yearworth, 2016), which should not be regarded as problems to be solved, but rather as conditions to be managed. A general agreement exists about the need to reform the scientific expertise required to deal with sustainability challenges by developing new ways of knowledge production and decision-making. In that sense, Stephen Sterling (2005) maintains that the nature of sustainability requires a fundamental change in epistemology, and therefore in education. As regards technological education, the experience here presented aims at graduating engineers with the

competences stated by the Barcelona Declaration (2004), approved during the Engineering Education for Sustainable Development Conference in 2004.

11 The EDINSOST project

EDINSOST is the acronym for the project "Education and social innovation for sustainability. The training in Spanish Universities of professionals as agents of change to face the challenges of society". The project is funded by the "*Spanish Program for Research Facing the Challenges of Society*" over the period September 2016 to August 2019.

Fifteen degree courses in the fields of education and engineering are involved in the project. These degrees are taught in ten Spanish Universities (Universidad Autónoma de Madrid, Universidad de Cádiz, Universidad Camilo José Cela, Universidad de Cordoba, Universitat de Girona, Universitat Internacional de Catalunya, Universitat Politècnica de Catalunya, Universidad Politécnica de Madrid, Universidad de Sevilla and Universidad de Salamanca). Fifty-five researchers belonging to the research team and the work team are engaged in the project. The ten universities work on sustainability within the framework of the Sustainability Commission on Sustainability (SCS) of the Conference of Presidents of Spanish Universities.

The EDINSOST research methodology adopts an interpretive approach employing both quantitative and qualitative techniques. The work is carried out in different degree courses at three levels of incidence:

- Six Bachelor engineering degrees and one Bachelor Degree with significant implication in short-term social challenges: the Bachelor degrees in Mechanical Engineering, Design Engineering, Electrical Engineering, Informatics Engineering, Chemical Engineering and Architecture.
- Three degrees related to the three dimensions of sustainability (environmental, social and economic): the Bachelor degree in Environmental Sciences, the Master degree in Science and Technologies of Sustainability and the Bachelor degree in Administration and Business Management.
- Finally, and in view of their multiplier and long-term effect, the project is working on five education degree courses, given that such graduates will be the future teachers of the new generations of citizens: Bachelor degree in Early Childhood Education, Bachelor degree in Primary Education, Bachelor degree in Pedagogy, Bachelor degree in Social Education, Master degree in Secondary Teacher Training and Inter University Master Degree in Environmental Education.

The EDINSOST project has the following four specific objectives:

- Objective 1 (O1): To define the Sustainability Competency Map of each of the participating degrees and establish a framework for incorporating the map into the degree in a holistic way;
- Objective 2 (O2): To validate different didactic strategies for addressing sustainability from a constructivist and community pedagogical approach;
- Objective 3 (O3): To diagnose the status of the training needs, in terms of sustainability, of the teachers of each degree, as well as to develop and test training proposals;
- Objective 4 (O4): To diagnose the sustainability competency level of current university students and to develop and test training proposals.

The scope of this paper is limited to the results in the engineering education degrees in February 2018: Objective 1: Sustainability competency Map and Objective 3 Diagnose of the statute of engineering faculty in relation to the competency map. The results generated by the project will be transferred to other universities nationally through the SCS, and to other universities internationally through its diffusion and transferability plan. An Education in Sustainability observatory will be established to carry out this dissemination.

12 Sustainability Competency map.

The SCS (CADEP-CRUE, 2012) identified four sustainability-related competencies to be developed for inclusion of the ESD in the curriculum.

- C1: Critical contextualization of knowledge by establishing interrelations with social, economic, environmental, local and/or global problems.
- C2: Sustainable use of resources and prevention of negative impacts on the natural and social environment.
- C3: Participation in community processes that promote sustainability.
- C4: Application of ethical principles related to the values of sustainability in personal and professional behavior.

Around those competences and based on previous experiences in developing sustainability competency maps the Sustainability Competency Map for Engineering Degrees was developed (Table 1). This map shows the definition of learning outcomes at three domain levels for each of the competency units.

The Sustainability Competency Map of engineering Degrees defines the learning outcomes in sustainability for students when graduating. Subjects must set realistic goals to achieve these learning outcomes, and these objectives must be developed in different subjects for the entire map to be covered. One of the greatest challenges to the achievement of this objective is the lack of adequate training for teachers in sustainability. The Sustainability Competency Map helps to correct this problem, since it clearly defines the aspects in which teachers must be trained. Objective O3 of the project is aimed at identifying these teacher-training needs. Furthermore, teachers also need help in using the most appropriate educational strategies to achieve the learning outcomes. The purpose of Objective O2 is to define those strategies. The Objectives O3 and O4 are just focused on developing training proposals for teachers and students, including the corresponding rubrics for competences' assessment. On the EDINSOST project, experts on pedagogy are discussing about the final format of the assessment of the learning outcomes.

With regard to Objective O1, one of the most important results is that the Sustainability Competency Maps developed may easily be adapted to any degree in the university system. This observation may be verified by the fact that the five Engineering degrees involved in the project (Mechanics, Design, Electrical, Informatics and Chemistry), as well as the Bachelor Degrees in Architecture, Environmental Sciences and Administration and Business Management, make up a map based on the one presented in this paper (with very few differences between them, except those related to the specificity of each degree).

Table 5: Sustainability competency map for undergraduate engineering education. (adapted from Fermin et al, 2018)

C	Competency unit	Domain levels (according to simplified Miller Pyramid)		
		1. KNOW	**2. KNOW HOW**	**3. DEMONSTRATED + DO**
C1	Has a historical perspective (state of the art) and understands social, economic and environmental problems, both locally and globally.	Knows the main causes, consequences and solutions proposed in the literature regarding the social, economic and / or environmental problems, both locally and globally.	Analyses the different dimensions of sustainability when solving a specific problem related to the Engineering.	Identifies the main causes and consequences of a problem related to the sustainability that a product or service related to the Engineering can have, and is able to relate them to known problems and solutions previously applied.
	Is creative and innovative. Is able to see the opportunities offered by the Engineering to contribute to the development of more sustainable products and processes.	Has sufficient knowledge of the concepts of creativity and innovation and strategies to be able to develop them.	Reflects on new ways of doing things. Knows how to use techniques that stimulate creativity, the generation of ideas, and manages them in such a way that they become an innovation. Participates actively when used.	Brings new ideas and solutions to a project related to the Engineering to make it more sustainable, to improve the sustainability of products, processes or services.
C2	Takes into account sustainability in his/her work as an engineer.	Knows the concept of cost of use, direct and indirect, of the products and services of the technologies related to the Engineering. Knows the strategic role that the technologies related with the Engineering play in the sustainability of the planet. Knows the concepts of social justice, resource reuse and circular economy. Knows the concept of social economy, the advantages of solidarity, teamwork and cooperation versus competition. Knows the principles of the economy for the common good.	Is capable of assessing the impact (positive and negative) that different products and services related to the Engineering have in society and in the sustainability of the planet. Knows how to assess the economic viability of a project of the Engineering and whether it is compatible with the environmental and social aspects of sustainability.	Is capable of proposing sustainable projects related to the Engineering taking into account, holistically, the environmental, economic and social aspects.
	Takes into account the environmental impact of his/her work as an engineer.	Knows technologies of reuse, reduction, recycling and minimization of the natural resources and residues related to a project of the Engineering. Knows the life cycle of the products related to the Engineering (construction, use and destruction / dismantling) and the concept of ecological footprint. Knows models for ecological footprint calculation. Knows metrics to measure the environmental impact of a project (e.g. pollutant emissions, resource consumption, etc.).	Is aware that products and services related to the Engineering have an environmental impact throughout its life. Is capable of measuring the environmental impact of the use of technologies related to the Engineering using appropriate metrics (e.g. pollutant emissions, resource consumption, etc.).	Takes into account the environmental effects of the products and services related to the Engineering in the projects and technological solutions in which he/she participates. Includes in his/her projects indicators to estimate / measure these effects from the resources used by the project (e.g. energy consumption, pollutant emissions, consumption of resources, etc.). Calculates the ecological footprint of an Engineering project.

	Takes into account the social impact of his/her work as an engineer.	Knows the problems associated with accessibility, ergonomics and safety of products and projects of the Engineering. Knows the problems associated with social justice, equity, diversity and transparency (gender perspective, needs of the most vulnerable groups, strategies against corruption, etc.). Knows the direct and indirect consequences that the products and services related to the Engineering have on the society.	Knows how to assess the degree of accessibility, ergonomic quality, the level of safety and the impact on society of a product or service related to the Engineering. Takes into account the rights of people in their work as an engineer. Understands the need to introduce social justice, equity, diversity, transparency (gender perspective, needs of the most vulnerable groups, anti-corruption, etc.) in projects of the Engineering. Can assess whether an engineering project contributes to improving the common good of society.	Takes into account the aspects of accessibility, ergonomics and security in technological solutions. Takes into account social justice, equity, diversity and transparency (gender perspective, needs of vulnerable groups, combating inequality and corruption, etc.) in his/her projects. Includes in his/her projects indicators to estimate / measure how they improve the common good of society. Is able to maximize the positive impact of his/her professional activity on society. Is capable of designing projects that contribute to improve the common good of society.
	Is capable of successfully carrying out the economic management of a project of the Engineering.	Knows basic concepts about organizations. Knows the fundamental points of a business plan. Knows the process of managing a project. Knows project-planning techniques.	Understands the different economic parts of a project: amortizations, fixed costs, variable costs, etc. Analyses real planning cases and project budgets.	Is able to plan an Engineering project (both short and long term) and to prepare a complete budget based on the material and human resources required. Is able to follow economic development of a project and detect deviations from the initial planning. Is capable of carrying out the economic management of a technological project throughout its useful life.
C3	Identifies when the sustainability of a project can be improved if it is done through community collaborative work. Responsibly performs collaborative work related to sustainability.	Knows the concept of community collaborative work and its implications in the transformation of society. Knows examples of projects that have been successfully implemented with community collaborative work in the field of the Engineering. Knows the tools of collaborative work in the field of the Engineering.	Given a project in the field of the Engineering, that includes a collaborative community work, is able to assess the implications of such work in the sustainability of the project.	Knows how to use collaborative work tools related to Engineering projects.
C4	Behaves according to the deontological principles related to sustainability.	Knows the deontological principles related to sustainability. He is aware that there are laws and regulations related to sustainability in his professional field. Knows the concept of social and corporate responsibility in general and its possibilities and limitations.	Is able to assess the implications of the deontological principles related to sustainability in a project in the field of the Engineering.	Does not make decisions that contradict the deontological principles related to sustainability. Is capable of proposing solutions and strategies to promote projects in the field of the Engineering, consistent with these principles.

13 Training needs of Engineering Faculty.

In order to evaluate the training needs of Engineering faculty a questionnaire has been validated. The questionnaire evaluates three dimensions of the teaching-learning: competences of the faculty in relation to the competency map (21 questions), pedagogical approaches (20 questions), and teaching practice (8 questions). This paper present the results in the competency dimension.

The questionnaire has been applied to the University of Cordova (faculty population: 211; sample: 26; participation: 12%), Universidad Politécnica de Madrid (faculty population: 2919; sample: 182; participation: 6%) and Universitat Politècnica de Catalunya (faculty population: 3056; sample: 322; participation: 11%) with an overall faculty population of 5196, a sample of 530 questionnaires and a participation rate of 9%.

The questionnaire uses a Likert scale of four levels (*Totally disagree*, *Quite disagree*, *Quite agree* and *Totally agree*) to statements related to each of the four competences and competency units and evaluating the three levels of the competency. (See example in figure 1)

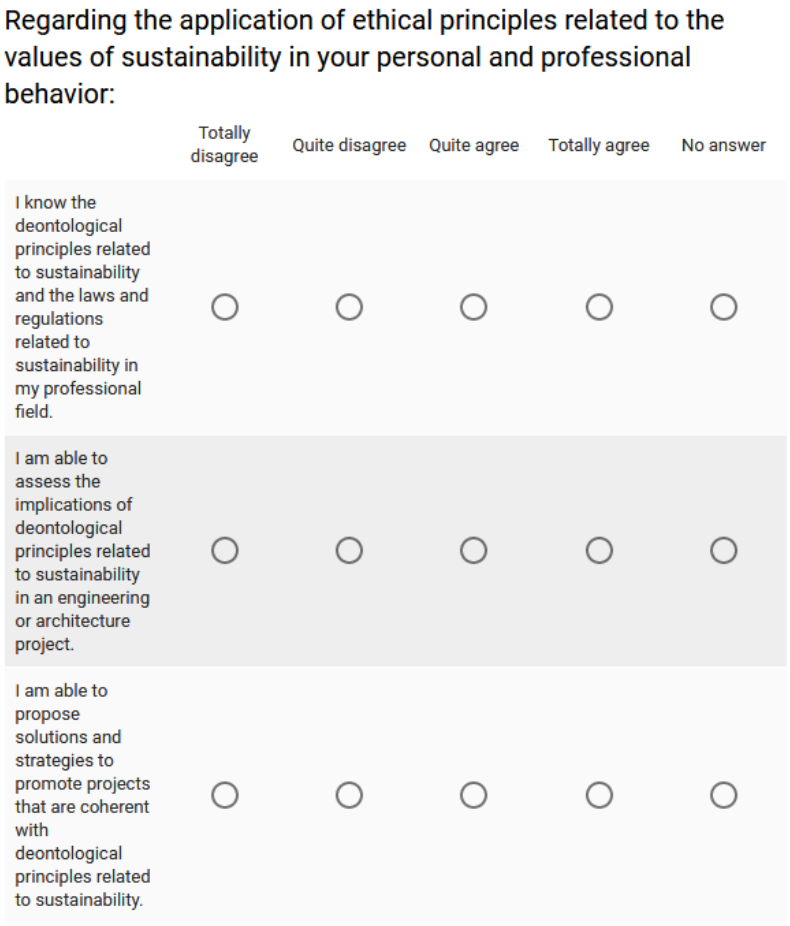

Figure 5: Example of question. Question related to Competence 4 of the competency map.

We are still on the process of analyzing all statistical data. The first results show that most of the surveyed (63%) agree with the statements, therefore they master to a certain extent the competencies, however there is still a 37% of the surveyed that show disagreement with the statements so there is a clear need of training for that sample. The analysis by competences shows (see figure 2) that competence C1 (Critical contextualization of knowledge by establishing interrelations with social, economic, environmental, local and/or global problems) is the most mastered (71% of agreement). The analysis also shows that the competence C2 (Sustainable use of resources and prevention of negative impacts on the natural and social environment), with a 38% of disagreement, is the least mastered.

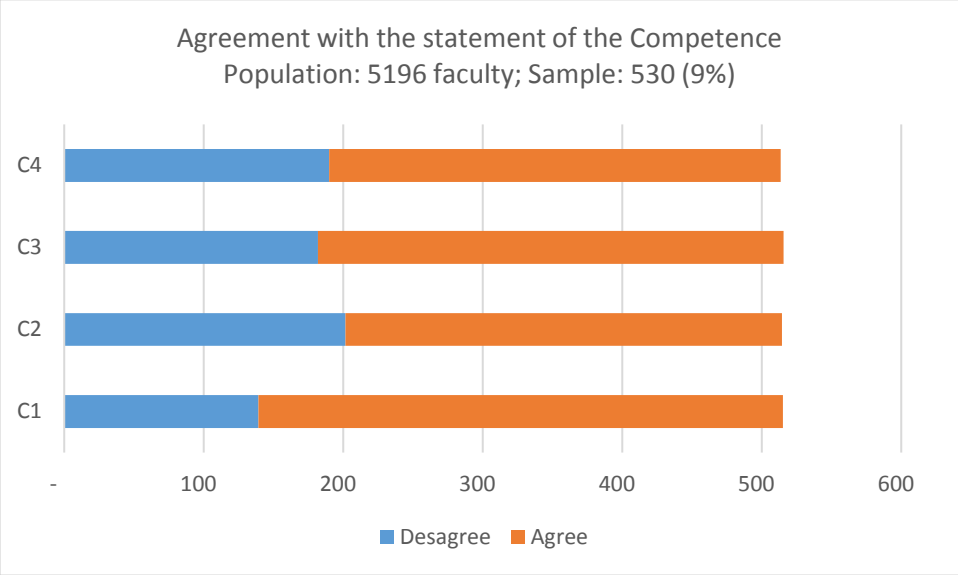

Figure 2: Results of the faculty assessment in relation to the four sustainability competences evaluated.

14 Conclusions

In this paper, the Sustainability Competency Map for engineering degrees, as the initial result of the EDINSOST project, is presented. The map may easily be adapted to any engineering degree.

While a general agreement exists about the importance of sustainability in today's world, and given the need to include it as professional competency for university graduates, sustainability is also one of the most difficult competencies to address in engineering studies, especially if it is holistically approached throughout the curriculum. A tool such as a Sustainability Competency Map, that is easily adaptable to any degree, may prove to be of great help for curriculum designers. The Sustainability Competency Map will enable teacher-training needs, as well as the didactic teaching strategies enabling educators to train their students in sustainability, to be defined, thereby providing them with the competencies defined at the 2004 Education in Sustainable Development Conference.

The analysis of engineering faculty in relation to the competency map shows that there is still around 40 % of the faculty members that need training in relation to the sustainability competences analyzed. However we should take into account that only 9% of the faculty answered the questionnaire which we can assume they are the most concerned about

sustainability education and are going to be easily involved in the training. There is still need to analyze the other 91% of the faculty members and diagnose their concerns and training needs.

Over the next two years, the EDINSOST project will continue working on the O2, O3 and O4 objectives, for which the Sustainability Competency Map obtained in Objective O1and faculty assessment are used as a starting point.

15 Future work

As regards Objective O1, the next step is to compare the curricula of the degrees analyzed in the project with the competency maps introduced herein. From this diagnosis, suggestions for improvements in each degree curriculum will be made to the Spanish accreditation agencies and CSC. The different educational strategies for addressing sustainability, that must therefore be validated in Objective O2, are currently being analyzed by considering each of the competency units of the map and each of the learning outcomes. With regard to Objectives O3 and O4, we are now analyzing the questionnaires of faculty and collecting questionnaires from students. Questionnaires have been designed in accordance to the Sustainability Competency Map. Questionnaires will be surveyed the second semester of 2017 and the first semester of 2018. As a result of the diagnosis, training action plans and educational resources will be developed for both faculty (Objective O3) and students (Objective O4).

Acknowledgments

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