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Factors affecting the engagement of academics of engineering studies towards sustainable development

Boris Lazzarini

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UNIVERSITAT POLITÈCNICA DE CATALUNYA
PROGRAMA DE DOCTORADO DE SOSTENIBILIDAD

Doctoral Thesis

Factors affecting the engagement of
academics of engineering studies
towards sustainable development

by

BORIS LAZZARINI

Advisor: Agustí Pérez Foguet

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UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
University Research Institute
for Sustainability Science and Technology



ABSTRACT

Higher education institutions (HEIs) play a critical role in societies' transition towards sustainable development (SD), as they educate future professionals and decision makers. Engineering is widely recognised as a critical discipline for addressing global challenges and contributing towards a sustainable future. In the last few decades, numerous technical universities have devoted major efforts to integrating SD into engineering curricula. However, there is still an increasing need to further transform learning and training environments, and to build capacity of educators and trainers, on SD issues. Advances being made in curriculum and educators' practices, at all levels of education, are slow and incremental, and more effort is needed to properly institutionalise education for SD in technical universities. Implementation of SD in the different university functions appears to face various challenges. On the one side, learning processes enabling changes depend to a large extent on the academic professionals and their capability and willingness to support transformative processes. On the other side, scientific literature highlights a number of barriers to change that persist and prevent lasting faculty engagement, including: i) limited institutional commitment, and lack of appropriate policies and incentives to promote sustainability at different university levels; ii) conservative disciplinary structures and resistance to change; iii) lack of awareness or proper professional development of professors; and iv) high work pressure, lack of time, and overcrowded curricula.

This thesis analyses the factors affecting the engagement of academics of engineering studies in SD, addressing the shortcomings cited above. Chapter 1 assesses the role of online training courses in promoting SD in engineering degrees, within continuing professional development (CPD) strategies. In it, two sets of quantitative and qualitative indicators are combined to assess the perceived relevance of training proposals developed in the framework of the present thesis, and the learning acquisition of participants. Chapter 2 analyses the research profile of engineering academics promoting education in SD, by employing a bibliometric research approach to compare and characterise academics with different degrees of expertise and involvement in SD. Chapter 3 complements the previous chapter by providing a characterization of a group of professors participating in a training program, integrating a qualitative approach. Finally, Chapter 4 focusses on the effects of integrating SD into real-world teaching modules in a subject of basic engineering science, employing a research approach that is eminently qualitative.

Overall, the results provide evidence that online learning can be an effective approach for continuing professional development of academics. The findings also suggest that the engagement of specific academic profiles can facilitate a cultural change in engineering education, as well as more holistic transformations of universities towards SD. We suggest that two specific research fields be explored in the near future: i) engagement of accreditation agencies and professional engineering institutions; and ii) solid commitment of HEIs towards the integration of Sustainable Development Goals from the United Nations in their academic functions.

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- Pérez-Foguet, A., **Lazzarini, B.**, Giné, R., Velo, E., Boni, A., Sierra-Castañer, M., Zolezzi, G., Trimingham, R., 2018. Promoting sustainable human development in engineering: Assessment of online courses within continuing professional development strategies. *Journal of Cleaner Production* 172, 4286–4302. doi:https://doi.org/10.1016/j.jclepro.2017.06.244

Book Chapters

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- **Lazzarini, B.**, Pérez-Foguet, A., Boni, A. Sierra-Castañer, M. 2016. Global Dimension in Engineering Education: promoting learning in Spanish Universities, in: III International Congress of Development Studies Proceedings, 29 June -1 July 2016, Zaragoza, Spain, pp. 555-567.
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ACRONYMS AND ABBREVIATIONS

ARWU:	Academic ranking of world universities
CPD:	Continuing professional development
DESD:	United Nations Decade of Education for Sustainable Development
ENG:	Engineering/Technology and computer sciences
ESD:	Education for sustainable development
GD:	Global dimension
GDEE:	Global dimension in engineering education
HEI:	Higher educational institutions
HDR:	Human Development Reports
IDR:	Interdisciplinary research
LIFE:	Life and agriculture sciences
MDG:	Millennium Development Goals (set by the UN)
MED:	Clinical medicine and pharmacy
NGO:	Non-governmental organization
OSE:	Online student engagement scale
SCI:	Natural sciences and mathematics
SD:	Sustainable development
SDG:	Sustainable Development Goals (set by the UN)
SHD:	Sustainable human development
SOC:	Social sciences
UPC:	Polytechnic University of Catalonia (Universitat Politècnica de Catalunya)
VLP:	Virtual learning platform
WoS:	Web of science

INTRODUCTION

In the first part of the introductory chapter, the theoretical framework of the study is presented by describing the context of the research, and specifically, the current situation of the Education for Sustainable Development (ESD) in the international context. The chapter also introduces and describes the main principles and processes of integration of Sustainable Development (SD) in Higher Education Institutions (HEI) and specifically, in technical universities. It finally outlines the factors promoting the engaging of academics towards SD, deepening on professional development strategies. The second part of the introduction provides an outline of the research problem, introducing its aim, objectives and research questions, and describes the structure of the remainder of the thesis.

1. Education for Sustainable Development in the international context

At the beginning of this decade, an increased political will in relation to SD issues has been apparent. The considerable political support for the Millennium Development Goals (MDG) (United Nations, 2000) added political impetus to the argument that there cannot be sustained progress towards the achievement of development goals without active and critically aware citizens. This, along with strategic work by global and development advocates, has led to historical agreements, such as the ‘2030 Agenda for Sustainable Development’ and its 17 Sustainable Development Goals (SDGs) (United Nations, 2015a), and the Paris Convention on Climate Change (UNFCCC, 2015), which strengthen the link between climate and energy policies at both national and international level.

The most widely-recognised definition of SD comes from the United Nations World Commission on Environment and Development in 1987, which stated that “sustainable development is the development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (WCED, 1987, p. 42). The different meanings of this generic definition of SD and its misconceptions have been discussed in academic literature (Filho, 2011, 2000).

Other development approaches, such as those based on Human Development (HD) and Sustainable Human Development (SHD), focus specifically on addressing global inequalities (e.g., extreme poverty, gender equality, and human and civil rights), and the promotion of a more socially just world. HD and SHD approaches define development as a process of expansion of capabilities and real freedoms that people enjoy (Sen, 1999).

The Human Development Reports (HDR) of the United Nations Development Program have institutionalised and operationalized the HD approach, by combining both aspects of development (sustainable and human) and, in the year 2011, by defining SHD as the “the expansion of the substantive freedoms of people today while making reasonable efforts to avoid seriously compromising those of future generations” (UNDP, 2011, p. 18). Theoretical boundaries between the concepts of SD and SHD are neither clear nor precise and thus present diverse possible interpretations (Absell, 2015). In this study, the concept of SHD is specifically used when highlighting the fulfilment of basic needs and the expansion of human capabilities within SD approaches.

In the last two decades, the advances in SD have been unprecedented. Among the main achievements worth highlighting include: the profound decline of extreme poverty and child mortality; the high increase of life expectancy and human health in developing contexts; the rise of literacy rates among youth; and important achievements in environmental sustainability (United Nations, 2015b). Nevertheless, the international development policies promoting SD have not produced adequate or effective solutions to the problems of global inequality. In fact, we still have large gaps between the poorest and the richest, social and gender inequalities, environmental degradation, and climate change, which pose critical challenges for the global community and future generations (United Nations, 2015a). Within this context, major transformations and systemic changes need to be promoted in different societal spheres (Wals, 2014) and the ESD has been recognised to be of crucial importance for its potential to foster pedagogical innovations at all level of education, involving key stakeholders within and beyond the education sector (UNESCO, 2014).

Among the many accepted definitions of the concept of ESD, the one proposed by Waas et al. (2012) (cited in UE4SD, 2015) is particularly inspiring. In it, ESD is defined as: “...a transformative and reflective process that seeks to integrate values and perceptions of sustainability into not only education systems but one’s everyday personal and professional life; a means of empowering people with new knowledge and skills to help resolve common issues that challenge global society’s collective life now and in the future; a holistic approach to achieve economic and social justice and respect for all life; a means to improve the quality of basic education, to reorient existing educational programmes and to raise awareness...” The concept of ESD and its principles have been shaped during the last decades, starting from the publication of the Bruntland report. Figure 1 shows the key milestones in global ESD. Specific information on the evolution of

the concept of ESD and its current issues and trends can be deepened in a recent publication of UNESCO (Leicht et al., 2018).

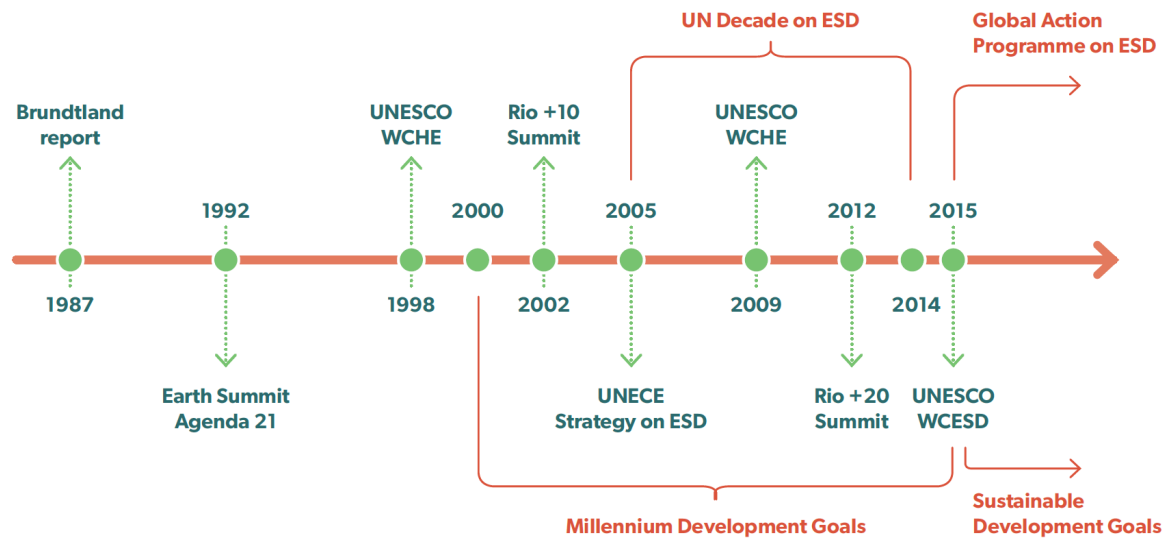


Figure 1 Key milestones of global ESD. Source: UE4SD (2015)

For the purpose of this study, it is worth mentioning the United Nations Decade of Education for Sustainable Development 2005- 2014 (DESD), which set a global vision of ESD and stressed the critical contribution that HEIs can give to global SD (UNESCO, 2014). In the framework of the DESD a number of countries devoted considerable efforts to promote the integration of the principles ESD into all aspects of education, including higher education. With varying degrees of success among countries, it is worth highlighting some encouraging trends, such as: i) the reorientation of education programs, at different levels, to increasingly address and integrate sustainability issues; ii) the convergence of sustainable development agendas and education agendas; and iii) an increase of essential pedagogical innovation, such as whole-institution approaches towards ESD.

The DESD final report, however, also indicates that actual changes in curriculum and educators' practices, at all levels of education, have been slow and characterised by only incremental advances, and that greater efforts are needed in order to properly institutionalize ESD in HEIs. The final report for HEI include, as one of the priority actions, the need to further transform learning and training environments and to build the capacity of educators and trainers for SD (ibidem).

Regarding continuing education, scientific literature reports diverse educational initiatives promoted through a variety of strategies addressed to different profiles of learners (Casey and Asamoah, 2016; de Wit and van der Werf, 1997; Wehrmeyer and Chenoweth, 2006), with the aim to increase the awareness and penetration of SD issues in different segments of the population. The Bonn declaration, in the framework of the DESD, recognises the essential role of continued education to achieve sustainable lifestyles based on principles such as “economic and social justice, food security, ecological integrity, sustainable livelihoods, [...] respect for all life forms, social cohesion, democracy and collective action” (UNESCO, 2009). The rapid obsolescence of knowledge in many fields and professions, the complexity of the debate on SD, and the continuous rise of new societal and environmental issues over time make it essential to address potential training gaps related to daily-life activities and work (Milana et al., 2016; Wehrmeyer and Chenoweth, 2006). As a consequence, continued education/professional development is critical to promote an aware and sustainable citizenship; through specific programs targeted to academics, such continued development can play a critical role in contributing to the integration of SD in universities.

The seventeen SDGs, adopted by the United Nations on September 2015, follow and expand the Millennium Development Goals (MDGs) and respond to new challenges (United Nations, 2015a). The SDGs can be described as “action oriented, global in nature and universally applicable; and constitute a holistic, indivisible set of global priorities for sustainable development” and can be expected to “...integrate economic, social and environmental aspects and recognize their interlinkages in achieving sustainable development in all its dimensions” (Arranz et al., 2017).

The discussions preceding the adoption of the SDGs in 2015 stressed the critical role of education for the achievement of all the SDGs in the next fifteen years and this led to a specific goal, SDG4 ‘Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all’. Target 4.7 is specifically related to ESD and have critical importance for the for the success of the interlinked and mutually reinforcing set of SGDs: “*By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture’s contribution to sustainable development*” (United Nations, 2017)

The recent adoption of SDGs through their incorporation in government agendas represents a unique potential for HEIs to reinforce their commitment to ESD and to advocate for the role of higher education in delivering critical SD impact (The Association of Commonwealth Universities, 2015). Scientific literature highlights the advantages of the integration of SDGs in teaching (Kopnina, 2017) and research (Dlouhá and Pospíšilová, 2018; Leal Filho et al., 2017).

2. Promoting Sustainable Development in technical universities

Higher Education Institutions (HEIs) play a critical role in societies transition towards SD and SHD since they have an incomparable capacity, through their academic function, in educating and preparing the future leaders and decision-makers (Sammalisto et al., 2015) who will face important and complex decisions on environmental, social and political issues (Lozano et al., 2013b).

Recent scientific literature highlighted that the implementation of SD competencies in university functions appears to be challenging, in various ways (Lozano et al., 2015). From one side, learning processes enabling changes depend to a large extent on academics and their capability and willingness to support transformative processes (Barth and Rieckmann, 2012). From the other side, various studies identify a number of barriers to change (see Table 1) that persist and prevent lasting faculty engagement (Lozano, 2006; Velazquez et al., 2006; Verhulst and Lambrechts, 2014).

Table 1 Barriers for the integration of SD in Higher Education (HE). Own elaboration based on data of Verhulst and Lambrechts (2014)

Related to lack of awareness	1. Lack of interest and involvement of the majority of the students and staff members
	2. Lack of support by management and policy makers
	3. Lack of professionalization and training of teachers
	4. Lack of policy making in order to promote sustainability
	5. Lack of standard definitions and concepts of SD in HE
	6. Lack of recognition, change agents for SD are often not taken seriously
	7. SD seen as a threat to academic freedom and credibility
	8. SD is not seen as relevant to a certain course or discipline
Related to the structure of higher education	9. Conservative disciplinary structure of HEI, barely open to new paradigms
	10. Inefficient communication and shared information both top-down and bottom-up
	11. Resistance to change by education and research
	12. Focus on short-term profit as a result of managerial thinking and policy making in HE
	13. Lack of interdisciplinary research as a result of insufficient coordination and cooperation
	14. Overcrowded curriculum
	15. Focus on content-based learning
Related to the lack of resources	16. Lack of money, SD is not seen as a priority for funding
	17. High work pressure and lack of time, the responsible for SD combines this task often with other tasks
	18. Lack of access to information, due to absence of measuring instruments or by unwillingness of staff
	19. Lack of consistent legislation 20. Lack of qualitative and quantitative performance indicators
	21. Technical problems
	22. Lack of physical place

During the last decades, several initiatives and approaches aimed at integrating SD in HEI at different levels have been successfully promoted (Lozano et al., 2015, 2013a; Ramos et al., 2015). Furthermore, scientific paradigms and education theories in HEI have undergone dramatic changes related to the processes of societal transformation towards SD (Dlouhá et al., 2013). Nevertheless, it has been argued that ESD has not fully permeated university culture (Lozano et al., 2013b; Mulder et al., 2012).

The integration of SD in curricular activities can be promoted in different ways. (Lozano and Lozano, 2014) indicate four main approaches that have been used in combination or independently: i) some coverage of some environmental issues and material in an existing module or course; ii) a specific SD course; iii) SD intertwined as a concept in regular disciplinary courses, matching the nature of each specific course; and iv) SD as a possibility of specialization within the framework of each faculty. These options have been differentiated in vertical or horizontal integration (Watson et al., 2013). The former approach calls for including a specific course to the curriculum, namely the option ii, while the latter comprises different range of integration, specifically options i, iii and iv. Vertical integration might not provide students with adequate opportunities to incorporate SD into their professional practice (Lourdell et al., 2005; Rose et al., 2015); instead, intertwining SD as a concept within regular courses has been described as the most favourable approach for integrating SD (Lozano and Lozano, 2014). These different approaches can be combined depending on the university strategy.

Obtaining changes towards a culture of sustainability in universities have been deemed to require a more holistic approach that connects all different functions and university actors (McMillin and Dyball, 2009; Müller-Christ et al., 2014; Sammalisto et al., 2015) as well as universities with external organizations (Boni et al., 2015; Pérez-Foguet, 2008; Yarime et al., 2012) and communities (Dlouhá et al., 2013; Holm et al., 2015; Ramos et al., 2015). Engineering is widely recognised as a critical discipline to address SD challenges and contribute to a sustainable future (Davidson et al., 2010; Karatzoglou, 2013); and the impact of engineering on the achievement of SDGs is beyond question (Clifford and Zaman, 2016). In the same vein, international institutions recognise the impact that engineering has on societies, ethics and ones' individual value-base (UNESCO, 2010). Consequently, abundant literature reflects the increasing need for improving the connections between engineering and SD (Lozano and Lozano, 2014; Mulder et al., 2012; Rose et al., 2015).

The integration of SD into engineering curricula has been conducted according to different approaches, primarily through the implementation of SD individual courses (Boks and Diehl, 2006; Davidson et al., 2010; Kamp, 2006), as well as through whole curriculum reform (Fenner et al., 2005; Lozano and Lozano, 2014; Rose et al., 2015; von Blottnitz et al., 2015). The educational strategy of curriculum reform has been focused either by integrating changes in content (Lozano and Lozano, 2014; Watson et al., 2013), emphasising a new framing of learning outcomes (Biswas, 2012) or focusing on the

articulation of competencies (Wiek et al., 2011). Nonetheless, scholars indicate that curriculum changes have mostly been framed in terms of changes of content with little consideration of desired learning outcomes (Rose et al., 2015). Furthermore, literature includes limited examples of testing assessing changes in learning outcomes as a result of curriculum change. The assessment measurement has been based on different approaches, including: student satisfaction (Biswas, 2012), conceptual maps (Segalàs et al., 2010) and changes in students' attitude (Schneiderman and Freihoefer, 2012). Limited insight in the literature is available to understand these processes of integration of SD in universities' curricula (Desha et al., 2009; Velazquez et al., 2005). However, academic staff have been recognized for being the prime contributor for curriculum reform (Fenner et al., 2005; Holmberg et al., 2008; Lozano, 2006) and a catalyst for curriculum change towards SD (Barth and Rieckmann, 2012).

The barriers preventing SD from being properly integrated into higher education (Lozano, 2006; Velazquez et al., 2006) highlighted earlier, are particularly critical for engineering, a discipline characterised by approaches and methods mainly focused on technical paradigms and strong disciplinarity (Halbe et al., 2015). Consequently, both the promotion of cultural shifts to engineering academic structures and the practical integration of SD principles into curricula are particularly challenging (Mulder et al., 2012). For these reasons, limited responses have been made to the calls of curricula reform in engineering (Fenner et al., 2005; Lozano and Lozano, 2014; von Blottnitz et al., 2015), and much of the effort has been focused on developing individual courses on SD (von Blottnitz et al., 2015). Diverse approaches aimed at embedding SD in a more integrated and holistic way have focused specifically on technical universities through complementary strategies, such as: i) developing specific, integrated curricula that holistically connect engineering with SD (Lozano and Lozano, 2014); ii) promoting unconventional ways of faculty empowerment and engagement (Holmberg et al., 2008; Svanström et al., 2012); and iii) fostering innovative pedagogical approaches (Pérez-Foguet et al., 2018; Segalàs et al., 2010). Furthermore, other efforts have aimed at reinforcing the alignment between engineering and development studies (Boni and Pérez-Foguet, 2008; Pérez-Foguet, 2008; Pérez-Foguet et al., 2005), in line with a SHD theoretical framework, focusing specifically on addressing global inequalities and the promotion of a more socially just world. (Absell, 2015).

Globalization of the higher education arena has also contributed to build momentum in this direction. It is essential to provide future engineers with skills and capabilities to

enable them to exercise their profession in a globalized and changing society, and with appropriate approaches that support global needs (Boni et al., 2015). The effect of globalization on the development and practice of the engineering profession, alongside the increasing challenges of SD, are calling for significant adaptations to the curriculum of engineering studies.

Over the last decade, technical universities and engineering faculties have been involved in embedding SD into their academic systems, improving teaching strategies (Boni and Pérez-Foguet, 2008; Mulder et al., 2015; Pérez-Foguet et al., 2005; Segalàs et al., 2010) and ensuring that the approach is incorporated into professional education (Boni and Pérez-Foguet, 2006; Holmberg et al., 2008; Lozano and Lozano, 2014; von Blottnitz et al., 2015). However, a number of scholars highlight a lack of a proper understanding of the principles of SD among engineering students (Azapagic et al., 2005; Byrne et al., 2013; Segalàs et al., 2009).

2.1 The experience at the Polytechnic University of Catalonia

As described in various scientific publications (Ferrer-Balas, 2004; Ferrer-Balas et al., 2009; Pérez-Foguet and Cruz López, 2011), the Polytechnic University of Catalonia (Universitat Politècnica de Catalunya; UPC) has been particularly proactive in the last decades in promoting SD in its internal functions and in its active collaboration with local communities. Leal Filho et al. (2018), describe the experience of UPC (specifically in the case study 6) as a progressive trend towards SD through many initiatives that it has promoted since 1996, which are aimed at integrating SD principles in university policies and strategies. It is worth mentioning that UPC has implemented different environmental plans (Ferrer-Balas, 2004) as well as a specific corporate strategy, the ‘2015 UPC Sustainability Plan’ (Ferrer-Balas et al., 2009), during the last decades, with the aim of integrating SD in education, research, and campus operations, and thereby progressively integrating a holistic perspective. Figure 2 illustrates the evolution of UPC’s commitment to SD.

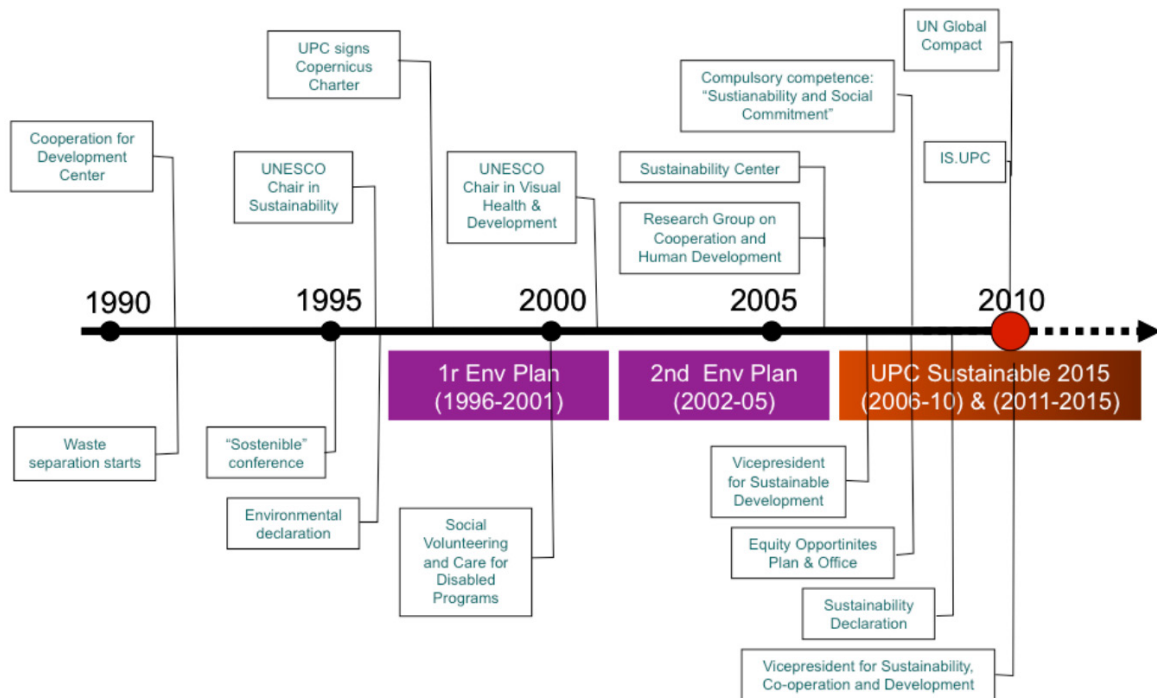


Figure 2 Evolution of UPC's commitment to SD. Source: Pérez-Foguet and Cruz López (2011)

The literature reports different experiences of staff professional development implemented at UPC, specifically aimed at fostering the integration of SD principles into the engineering curricula. Specifically, Boni et al. (2004) and Boni and Pérez Foguet (2006) presented blended-learning initiatives addressed to academics, driven jointly by technical universities and international non-governmental organisations (NGO), such as Engineers Without Borders (EWB) and OXFAM Spain. Furthermore, Pérez-Foguet et al. (2005) proposed the use of field-based case studies as supporting teaching materials aimed at integrating SD in engineering courses.

Contextually, education for SD has been strongly promoted through complementary initiatives focused on engineering students. For instance, the integration of the transversal competency 'Sustainability and Social Commitment' (Caetano et al., 2015; Pérez-Foguet and Cruz López, 2011) is currently mandatory in all bachelor and master degree courses at UPC. Accordingly, Pérez Foguet and Lobera (2008) promoted practical applications materials developed by lecturers in the context of a course addressed to academics focused on the crosscutting integration of competencies specifically related to 'Sustainability and Social Commitment' in technical courses. From a different approach, specific academic programs have been promoted that focus on sustainability, such as the Master of Science and the Doctorate program in Sustainability. Furthermore, SD research at UPC has been

fostered through the creation of a dedicated research unit, the Research Institute for Sustainability Science and Technology (ISST), which currently catalyses the research initiatives of UPC in SD (Pérez-Foguet and Cruz López, 2011).

As noted above, the processes enabling transformation in moving towards sustainability largely depends on the competencies and the engagement of academic staff. In line with this, UPC has been promoting continuing professional development of academics in SD during the last decades, through innovative training initiatives addressed specifically at engineering faculty (Pérez-Foguet et al., 2005). These efforts have recently resulted in a UPC-led European initiative, the Global Dimension in Engineering Education (GDEE), which is presented in this research as case studies. In this initiative, attempts of transformation in learning have focused on integrating SD as a cross-cutting issue in teaching activities by improving the competences of academic staff and through engaging both faculty and students in initiatives related to SD, through the active involvement of NGOs in academic practices (Trimingham et al., 2016).

This transdisciplinary learning approach, extensively described in Pérez-Foguet et al. (2018), highlights the fact that cooperation between NGOs and academia can be a critical factor in reinforcing the presence of SD in formal teaching programs at all levels of engineering education. The results of the GDEE project allowed the promotion of different local initiatives, financed by the Barcelona City Council, that specifically focused on the professional development of academics at Catalan technical universities and faculties. One such initiative is the project ‘Integrating and promoting global issues in scientific and technical studies’ (extensively described in section 4). Despite all of these initiatives, UPC currently has only a small number of university educators and researchers who are actively involved in promoting change towards sustainability in their academic functions (Lazzarini et al., 2018a), highlighting the need for a greater effort to foster more holistic and complex transformations towards sustainability.

3. Engagement of academics towards Sustainable Development

The debate about which practices or processes can enable change at the university level (Ferrer-Balas et al., 2010; Lozano et al., 2015; Pérez-Foguet, 2008; Pérez-Foguet and Cruz López, 2011; Ramos et al., 2015) and, specifically, in engineering education (Davidson et al., 2010; Mulder et al., 2012; von Blottnitz et al., 2015) is still open; nonetheless, the active engagement of academic staff has been indicated as a starting point to drive transformative changes in curriculum innovation toward SD (Barth and Rieckmann,

2012). Increasing the interest of academic staff, and improving their competencies, are indeed vital to engage faculty in the process of SD integration. However, previous studies suggest that the understanding and knowledge of SD remains a major challenge in this regard (Filho, 2011; Jones et al., 2008). The different understandings and the interdisciplinary nature of the terms involved have been described as blocking academics' engagement in ESD (Cebrián et al., 2015; Sammalisto et al., 2015). An unquestioned issue is therefore to increase the awareness and knowledge of SD among university educators.

Professional development programmes addressed to academics play a relevant role in increasing interest and knowledge of the professors. Along with professional development experiences developed at the UPC, described in the previous section, it is worth mentioning other successful initiatives implemented in other technical universities. Lozano García et al. (2008) proposed an 'educate the educators' course, based at the Tecnológico de Monterrey (Mexico). The course was structured combining traditional training activities, such as lectures, readings, class role play activities, etc., with a workshop-format aimed at helping the educators incorporate SD issues within their own courses. Ceulemans and De Prins (2010) developed an 'educate the educators' self-instructional manual, focusing on how to integrate SD into the curriculum of 'commercial engineers', at the Hogeschool-Universiteit Brussels. Barth and Rieckmann (2012) analysed an academic staff development programme implemented at the Universidad Técnica del Norte (Ecuador), set out as a blended-learning course. The approach combined a moodle-based e-learning environment with five face-to-face seminars. A particularly successful approach, applied in Chalmers University of Technology (Holmberg et al., 2012; Svanström et al., 2012), combines individual interaction, such as individual coaching discussions, with specific workshops addressed to different engineering programmes (Holmberg et al., 2008). This approach, as reported by Mulder et al. (2012, p.213) reversed the "teach the teacher approach", specifically because academics are engaged in the learning process by 'proposing contributions to SD' from their own expertise, instead of being trained. More recently, Lozano and Lozano (2014) presented the development of a new Bachelor degree in 'Engineering for Sustainable Development' – based at the Tecnológico de Monterrey – incorporating SD throughout all curricula. Faculty engagement and empowerment was fostered through a professional course designed to educate the educators.

Similar to training initiatives, teaching-support material and dedicated learning resources for educators are commonly lacking; this lack is one of the most common reasons for a

limited integration of SD principles in courses, especially at technical faculties. Teaching-support material can be developed directly together with professors, tailoring the resources by focusing on specific disciplines and needs. Alternatively, and more commonly, more general case studies can be developed, that can be easily adapted to the specific needs of professors. In the engineering field, the work of Boni and Pérez-Foguet (2006) is noteworthy for promoting the use of teaching-support materials with specific pedagogical proposals and with a focus on Spanish technical universities. More recently, specific teaching material based on contextual case studies have been promoted at the European level by the project GDEE (GDEE, 2015a) as well as by the project 'Integrate and promote global issues in STEM education' (2016-2018) promoted at the UPC (EScGD, 2018).

Despite the increasing need to improve the capabilities of academic staff, to support the integration of SD at a curricula level (Ceulemans and De Prins, 2010; Verhulst and Van Doorselaer, 2015), literature shows limited research on staff development programs on SD, particularly in the field of engineering (Holmberg et al., 2008; Lozano and Lozano, 2014; Lozano García et al., 2008; Pérez-Foguet et al., 2005; Svanström et al., 2012).

Human factors, such as the empowerment and commitment of academics, have been recognised to be success factors regarding the integration of SD in university functions (Lozano 2006; Ferrer-Balas et al. 2008). Along with personal interests, institutional factors, such as career opportunities and institutional support to particular fields of research, influence the willingness of engaging. Nonetheless, the scientific reward system is generally based on conservative disciplinary structures. Conventional academic rewarding mechanisms, mostly characterised by a narrow disciplinary focus, represent major impediments to a more socially engaged higher educational system (Ferrer-Balas et al., 2008; Krizek et al., 2012). As a consequence, they can dissuade inter and transdisciplinary collaborations, as well as complex and integrated systems approaches required to address SD challenges (Stephens et al., 2008). In this regard, Hoover and Harder (2014) identify these contradictions and tensions in the HEI organizational structure that can undermine processes of change toward sustainability. These issues, presented in Figure 3, are also influenced by the perception of who has the power to affect change, networks, and institutional structures. These tensions are reinforced by current trends of higher education such as globalization and an increasing corporate managerialism (Morrissette, 2013).

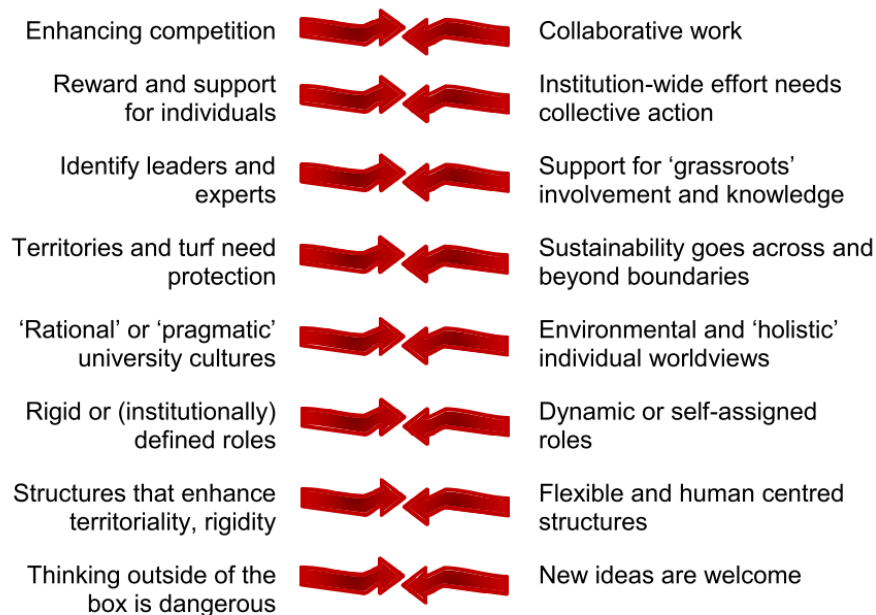


Figure 3 Contradictions/tensions of integration of SD in HEI. Source: Hoover and Harder (2014)

Various recommendations addressing academics have been proposed to trigger cultural change in an environment characterized by dominant structures based on technical paradigms and strong disciplinarity (Egelund Holgaard et al., 2016; Mulder et al., 2012; Sammalisto et al., 2015). Lozano (2006) recommends “detecting, engaging and empowering the individuals who are already convinced with the idea, making them SD champions to help them achieve a multiplier effect throughout the entire organisation”. Nonetheless, it is widely recognised that HEI often do not provide adequate institutional support and incentives for those academics willing to integrate SD into their teaching and research activities (Hoover and Harder, 2014), and the majority of endeavours are primarily made for the personal satisfaction of overcommitted academics, and most go unrewarded (Krizek et al., 2012). In the case of engineering, activities not falling within the disciplinary context of the core technical content are often not fully recognised during the evaluation of teaching and research merits. The literature analysing the education of engineers for SD and its relevant challenges, emphasises the need for complementary approaches to foster changes in engineering curricula (Krogh Hansen et al., 2014; Mulder et al., 2012). Specifically, the scholars point out that top-down institutional support has to be complemented with bottom up initiatives, aimed at further engaging motivated academics. It is vital, thus, to effectively tackle this shortcoming, identifying the drivers to foster the empowerment and the active engagement of academics in sustainability education and research.

(Ferrer-Balas et al., 2008), in a work comparing sustainability transformation across seven scientific-based and technical universities worldwide, discuss barriers as well as internal and external drivers of university transformation towards SD. The research conclusions point out that, on the one hand, among the various factors that affect transformation towards SD, the main barrier to overcome is “the lack of an incentive structure for promoting changes at the individual level”. On the other hand, the authors highlight the main driver affecting transformation as the existence of “connectors” with society. Specifically, connectors are identified with networks of people engaging in interactions between departments or with non-academic societal entities. These connectors can be interdisciplinary research groups as well as professors or groups engaged with societal challenges. Language, practices, approaches and incentives adopted by connectors can influence diverse actors of universities, encouraging the creation of a critical mass of professionals engaged with SD (Ferrer-Balas et al., 2010).

Recent literature reinforces these findings. The promotion of change at the individual level as a starting point to bring about greater change has been emphasised in current research (Barth and Rieckmann, 2012; Cebrián et al., 2015; Hoover and Harder, 2014). However, support and appropriate incentive structures aimed at maximising academic engagement are still lacking (Krizek et al., 2012; Wood et al., 2016). Furthermore, which kind of incentive structures should be offered to academics appears to be still largely undefined, with a risk of oversimplification (such as the increase of research funding, fostering career perspective, etc.). In fact, the literature highlights that the perceived role of academics involved in SD has been changing, above all over the last decade, due to increasing and contradictory pressures of the globalisation of higher education and the competition between universities in global networks (White, 2015). The increased relevance of rankings, benchmarking and the focus on scientific and economic productivity of HEI, has turned academics, according to Morrissey (2013), into “economic units of use” where managing tasks and achieving ‘business’ targets have exceeded traditional goals, such as excellent teaching. Contextually, recent research highlights different “academic identities” among sustainability champions committed to embedding sustainability in curricula and pedagogy (Wood et al., 2016). Accordingly, engaged academics give meaning to their role as educators in their efforts towards the integration of sustainability in their teaching approaches, through personal motivation and different narratives that emphasise a diverse and personal way to engage with and practice SD (ibid.). Therefore, further research is

needed to define incentives and institutional approaches to maximise the long-term organisational impact of SD champions.

The existence of ‘connectors’ with other research groups inside universities and with society at large is undoubtedly an essential driver to promote transformation towards SD. In this sense, it is widely accepted that to address sustainability challenges – namely, complex multi-stakeholder problems of high social and environmental relevance – it is necessary to have approaches that transcend the boundaries of disciplines and the boundaries of universities themselves, including diverse perspectives and knowledge of non-scientific stakeholders in research processes (Gaziulusoy and Boyle, 2013; Lang et al., 2012; Wals, 2014). Nonetheless, the overspecialisation of research and the fragmentation of knowledge through disciplinary boundaries are still common in engineering faculties (Halbe et al., 2015), and ‘connection’ – within university borders and with society as a whole – should be enhanced in order to overcome this shortcoming. In fact, there is a claim of more permanent relations between universities and external non-academic partners (Mulder et al., 2012; Velazquez et al., 2006), and to foster the collaboration with international networks to accelerate SD learning and transformation (Withycombe Keeler et al., 2016).

AIMS AND METHODS

1. Towards a definition of the research problem

Despite the need to better connect engineering studies to the new realities of SD and globalization, only a limited number of engineering faculties have made major updates to their courses and curricula (von Blottnitz et al., 2015). Even though an increasing number of HEIs have engaged in incorporating SD into their systems (Lozano et al., 2015), and in particular by reconsidering university policies (Wals, 2014) as well as the content of their curricula (Lozano and Lozano, 2014; von Blottnitz et al., 2015), the scientific literature stresses the fact that SD is not yet comprehensively integrated into higher education systems (Mulder et al., 2015). Moreover, the pace of change has been quite slow, and the impact of change has been minor (Watson et al., 2013).

The processes enabling transformative changes in universities largely depend on academic staff and their capability and, equally important, their willingness to support such processes (Sammalisto et al., 2015). Therefore, one of the most critical issues fostering the integration of SD in HEIs is the empowerment and the commitment of motivated professors (Verhulst and Lambrechts, 2014). Consequently, identifying and empowering committed academics, who are frequently heralded as “sustainability champions”, is central to promoting a full engagement with SD and to fostering whole-university approaches (Lozano 2006; Ferrer-Balas et al. 2008). Furthermore, it is especially critical to promote the engagement of professors who until that point have had little or no experience in SD.

The process of integrating SD into academic activities requires a large amount of effort and motivation, as changes are necessary not only in content but, above all, in teaching and learning methods (Segalàs et al., 2009), and as approaches go beyond disciplinarity (Barth and Rieckmann, 2012; Cebrián et al., 2015). Far from being motivated and incentivised by HEIs (Lozano et al., 2013b), these efforts rely essentially on the individual commitment of a limited number of academics (Hoover and Harder, 2014; Krizek et al., 2012) and are commonly left unrewarded by traditional disciplinary and rewarding structures.

Scientific literature outlines the ‘understanding and knowledge of sustainability’ as one of the main challenges faced by academics who would like to engage with SD (Cebrián et al.,

2015; Sammalisto et al., 2015). A further challenge comes from revising not only the teaching strategies in the classroom but also the teaching and learning techniques (Segalàs et al., 2009). Therefore, promoting a broad understanding of sustainability issues as well as appropriate teaching and learning techniques is critical for involving academics in incorporating SD into their functions. SD professional development programs addressed to academics are aimed at promoting and developing the competence of professors in favor of changing their teaching practice and integrating SD principles in regular curricular activities. The literature focusing specifically on SD lifelong learning addressed to academic staff, highlighting that professional development facilitates their learning and teaching capabilities, as well as promotes personal reflection on possible implementation of SD principles into teaching (Barth and Rieckmann, 2012; Lozano García et al., 2008). Furthermore, to effectively integrate SD principles into academic activities, specific training processes such as ‘educating the educators’ are reported to be a relevant aspect in fostering a clear understanding of the principles of SD (Lozano, 2006).

To date, however, only a few attempts have been made to focus on academic staff development in engineering as a starting point to bring about change towards SD, and little evidence exists about the impact that actions and existing initiatives aimed at training faculty on SD can have on improving their competences at integrating SD issues into academic functions. Furthermore, only a handful of research studies have specifically focused on the analysis of the academic profile of faculty who are committed to SD. Against this background, the research presented in this thesis is especially aimed at extending the scientific knowledge about the possibilities of engaging academics in the engineering field in SD.

1.1 Main objective

The main objective of the present study is to deepen the scientific knowledge about the aspects and factors that foster an active willingness on the part of academics to become agents of change, by integrating and promoting SD into their academic activities. Here, the specific focus is on engineering studies. Within this particular goal, the ultimate purpose of this research is to provide organizational and policy recommendations, specifically addressed to HEI leaders, that aim to actively contribute to the process of integration of SD into engineering studies.

1.2 Specific objectives

This research was designed to study and improve current scientific knowledge about different specific objectives. In particular, it aims to:

- Analyse national (e.g., in Spain) and international initiatives focused on the promotion of SD in HEIs through continual professional development programs, with the goal of empowering academics of engineering;
- Investigate the effects of current policies and globalisation trends in higher education as well as their impacts on SD integration in universities, with a particular focus on technical universities;
- Explore the implementation, major success factors, and long-term impact of professional development initiatives aimed at training academics in SD, and specifically, in engineering studies.
- Study the academic profile of communities of faculty involved in professional development programs and other academic initiatives related to SD, with the aim of promoting successful experiences in different contexts.

2. Aims of the research

Within the outlined main goals and objectives, the study will specifically examine the following research questions (RQs):

RQ1: In the framework of a continuing professional development initiative for engineering faculty, does participation in online SD training result in academics acquiring relevant and useful knowledge for their teaching activities? This question is examined and responded to in Chapter 1.

RQ2: Do research profiles of academics engaged with SD practices share any common patterns with regards to their scientific productivity? This question is examined and responded to in Chapter 2.

RQ3: Are there any common patterns in the academic profile of academics engaged in SD practices? This question is examined and responded to in Chapter 3.

RQ4: Which are the effects on students and professors of the integration of SD in new teaching modules, implemented in regular courses, in a subject of basic engineering science? This question is examined and responded to in Chapter 4.

3. Brief overview and topics addressed in the research

This research can be divided into three parts. The first part focuses on the role of continuing professional development initiatives addressed to academics as a way to engage with SD. The initial aim is to assess the results of a continuing professional development (CPD) program targeted to engineering academics (Chapter 1). The next step is to identify and analyse the characteristics and common patterns of academics engaged in CPD programs about SD, exploring specifically their scientific productivity (Chapter 2) and their general academic profile (Chapter 3). Finally, the third part explores the effects of integrating SD in new teaching modules that are implemented in regular engineering courses (Chapter 4). It concludes by proposing recommendations and possible further actions (Conclusions and Ways Forward). In more detail:

Chapter 1 *Assessment of professional development strategies on SHD addressed to engineering academics.*

This section assesses the role of online training courses, within CPD strategies, in promoting SHD in engineering degrees. It was built upon the implementation of a European initiative, the GDEE, described in the following section. In terms of methods, the chapter analyses two sets of quantitative and qualitative indicators to assess i) the perceived quality/relevance of the training proposals, and ii) the learning acquisition of participants. Quantitative indicators are complemented by a descriptive analysis of findings from a semi-structured survey. The results provide evidence that online learning can be an effective approach for CPD of academics. The findings also suggest that participants perceived online courses' contents and curricula as relevant and useful for integrating sustainability principles in teaching activities.

Chapter 2 *Research profile of engineering academics engaged with SHD.*

This chapter presents a bibliometric analysis of the scientific production of an academic community involved in a European initiative aimed at capacitating engineering academics for SD. Specifically, two groups of academics with different degrees of expertise and involvement in SD were characterized and compared, revealing common trends and similarities of their research production. A better understanding of the scientific profile of the academics who engage in SD activities can help to develop and promote initiatives for increasing faculty engagement in all academic functions. The results show different implications for future strategies aimed at engaging specific academic profiles in the field

of engineering, highlighting especially health science–related fields linked with engineering as a potential opportunity of promoting the integration of SD in engineering education.

Chapter 3 *Key characteristics of academics promoting Sustainable Human Development within engineering studies.*

This section provides an analysis and a profile of a group of academics, participating in a training program on SHD, granted by a European fund. The methods employed include a semi-structured survey, focusing on the academic activities and social outreach of the participants, complemented by a bibliometric analysis of their scientific production. The findings show: 1) an interdisciplinary profile of the academics, 2) an integration of SD principles in all academic activities and 3) a promotion of those principles outside the university. It is emphasised that the commitment of this type of academics can facilitate a cultural change in engineering education, as well as more holistic transformations of universities towards SD.

Chapter 4 *Transversal integration of sustainable human development in basic engineering sciences courses.*

This chapter explores the extent to which a CPD program, aimed at engaging and empowering faculty, has positive effects on integrating SHD principles into existing courses of engineering. Specifically, the research focuses on the effects of integrating SHD principles into new teaching modules in a subject of basic engineering science, which is used in regular courses of the first year of the degree in engineering. The methodology includes a focus group conducted with the students of the engineering courses involved in the initiative, and in-depth interviews conducted with the academic coordinator of the subject analysed. The relevance of CPD programs addressed to academics is highlighted with regard to the integration of sustainability principles in formal science disciplines.

Chapter 5 *Conclusions and ways forward.*

Chapter 5 presents the main findings of this research study. The final results indicate that CPD strategies based on online training activities can be effective ways to train and engage engineering academics. Furthermore, the results reveal that having specific information on the research and academic characteristics of professors involved in SD

initiatives is critical for fostering appropriate policies aimed at promoting SD integration into engineering universities and faculties. A detailed proposal of how to move forward in the near future is then given.

2. Methods

The methods used in this research can be divided into three general stages, which are briefly outlined below. To ensure clarity, and to allow the reader to follow the design rationality, a detailed description of the different methods used has been integrated into each chapter.

The **first stage** consists in the bibliographical review of existing experiences geared towards the strategies of integration of SD in HEIs, with a particular focus on technical universities. The organizational and institutional features that either facilitate or hamper the engagement of academics are analysed in-depth. Contextually, current research on HEI globalisation trends, and potential impacts on the integration of SD principles in the different university functions, are analysed. These topics are examined especially through the theories of organizational change and transition studies, and specifically focused on sustainability in HEI. The former approach is grounded on the analysis of organizational issues such as governance, culture, structures, hierarchies, and institutional change in universities (Trowler, 2008). The latter refers to dynamic approaches that identify and deal with complex transitions of societal systems, focused on critical strategic level dynamics or reflexive activities that could facilitate and accelerate change processes (Geels, 2002), specifically focused to HEI (Stephens and Graham, 2010).

Grounded in the concepts and topics analysed through the first stage, the second and third stages were developed starting from the analysis of two identified case studies (described in detail in the following section). Both cases are based on experiences of promoting SD in technical universities through training activities addressed to academics, but at either the international level (in the second stage) or at a local level (in the third stage). The case in the second stage comes from the GDEE initiative, an international case study financed by the European Commission and implemented in different European countries. This case is complemented by the case study presented in the third stage, ‘Integrate and promote global issues in STEM education’, which was implemented at a local level in Barcelona and financed by the Barcelona City Council.

In the **second stage**, the characteristics and the implementation of a CPD program addressed to academics of engineering and the impact of its training activities and courses were explored. This training program was developed and implemented as part of this thesis work. Specifically, new training materials and nine different open source online courses were developed within the framework of an international project, funded by the European Union, which was subsequently complemented by a second project implemented at local level (see below). With respect to this stage, the learning process and the learning acquisition of participants of the aforementioned training experience were analysed, using an adaption of the Online Student Engagement Scale proposal (OSE) (Dixson, 2015) and employing different analytical tools, such as: qualitative description of training processes, quantitative analysis of courses results, focus groups, and personal surveys.

The **third stage** analyses and characterises the research and the academic profile of academic communities involved in the analysed initiatives and training activities related to SD. This last stage employs both quantitative and qualitative analytical frameworks. Specifically, bibliometric analysis is performed with the aim of identifying and analysing the research profile of communities engaged with SD. Conventional bibliometric analysis is complemented with bibliometric network analysis and science mapping. The results obtained are enriched with qualitative research tools such as surveys focused on different academic features (e.g., teaching, research, social outreach, and institutional issues), focus groups/group dynamics, and personal interviews.

3. Case studies

3.1 The GDEE initiative

The GDEE initiative is a European network whose aim is to increase the awareness, critical understanding and attitudinal values of undergraduates and postgraduate students in technical universities across Europe in connection with SHD and its relationship with technology. This objective was tackled by integrating SHD as a cross-cutting issue in teaching activities, improving the competences of academics, and through engaging both staff and students in initiatives related to SHD. The initiative started in 2012 as a collaborative project funded by EuropeAid, between a consortium of European Universities (Polytechnic Universities of Catalonia, Madrid and Valencia – Spain; Loughborough University – UK; and University of Trento – Italy) and four international non-governmental organizations (NGOs) (Engineering Without Borders – UK; Practical

Action – UK, ONGAWA – Spain; and the Training Centre for International Cooperation – Italy), and was completed at the end of 2015.

The pedagogical approach, based on the previous works of project partners (Boni and Pérez-Foguet, 2008; Pérez-Foguet et al., 2005), has been extensively described elsewhere (Pérez-Foguet et al., 2018; Trimmingham et al., 2016). For the purpose of this research, it is worth mentioning that the project strategy was based on a continuous professional development approach addressing academics focused on three main areas: competences, connectivity and collaboration:

1. Competences: enhancing the competences of academics and students with regard to their understanding of SHD issues and their capability to mainstream them in the academic curricula;
2. Connectivity: enhancing the capability of academic institutions to connect and share efforts within and across EU Member States as well as share and disseminate results and best practices regarding the integration of MDGs/SDGs into technology studies;
3. Collaboration: enhancing the ability to work with other stakeholders, NGOs and other non-profit organisations in order to advance a more practical dimension to the work carried out at academic levels.

Through activities related to each one of these three areas the project has been promoted by emphasising the integration of a Global Dimension (GD) of engineering education. The focus on the GD encourages students to think of themselves as global citizens and thus promote a sense of global social responsibility. This specific approximation on the incorporation of SD into academic activities, expressly promotes an understanding of different issues related to global development: extreme poverty, human rights, globalisation, equality issues and environmental challenges. This emphasis on the global impact of engineering activities worldwide integrates other agendas related to development contexts, such as: SD, humanitarian engineering and ethics. However, the benefits of including a GD is that it can help students make links with the complexities of the real world, and enable them to think of themselves as actors able to play an active role in poverty reduction, human rights issues, and conflict resolution. The composition of the consortium, comprising universities and NGOs, reflects the approach promoted with this initiative: fostering the cooperation between NGOs and academia as key factors in

reinforcing the presence of SHD in formal teaching programmes at all levels of engineering education (Zolezzi et al., 2013).

According to this strategy, the project included different complementary activities aimed at up-skilling, motivating and engaging academics with development issues, as well as promoting sustainability issues in engineering education. Among the main project outcomes, nine online courses were developed in order to increase the competences and abilities of academic staff of technical or science-based universities to integrate development-related issues into their teaching and research activities. For the implementation of each course, a set of training materials was developed by selected European experts in this field (GDEE, 2014), as well as a set of teaching resources aimed at supporting lecturers at integrating sustainability issues in teaching activities (GDEE, 2015a). All these resources are available online at the project website (<http://gdee.eu/>) distributed as Open Educational Resources.

3.2 Integrate and promote global issues in STEM education

This local initiative, financed by the Barcelona City Council, was developed by starting from the results of the European experience GDEE, in partnership with the Escola de Cultura de Pau (School for a Culture of Peace) at the Universitat Autònoma de Barcelona (Autonomous University of Barcelona - UAB). This two-year academic staff development program, which ended in 2017, was aimed at promoting the integration of SD principles and their global challenges as crosscutting issues specifically in technical faculties and secondary schools within the Barcelona city area, with a specific focus on scientific and technological disciplines. Therefore, the ultimate objective of the action was to contribute to the field of formal education, to improve students' knowledge of structural causes of poverty, inequality, exclusion, and violence.

This objective was intended to be achieved by implementing two complementary lines of work. On the one hand, it aimed to provide professors with theoretical and practical tools to improve their teaching quality, in order to effectively promote the integration of SD issues in their academic functions. On the other hand, the initiative aimed to promote dialogue and networking among teachers of both secondary schools and universities, which should then foster exchanges of resources, experiences, and knowledge.

Based on the premise that professors are key agents for change, the project aimed at fostering the integration of SD, working with two reduced groups of professors (from university technical faculties and secondary schools). The professional development program first intended to develop a basic understanding of SD issues and their global challenges and, subsequently, to apply the knowledge acquired in real-world teaching situations. This research focuses specifically on the training program aimed at empowering university professors, held at the Polytechnic University of Catalonia (Universitat Politècnica de Catalunya, UPC). Different possible training alternatives were proposed to the academics involved, which could be selected according to respective affinity and interests; specifically, these were:

- Teaching initiatives combined with NGO training personnel
- Preparation of case studies *ad hoc* to be used as teaching modules
- Exploring teaching methodologies through online training tools

The development, implementation, and evaluation of these different pilots were developed through different training workshops as well as in individual coaching sessions. The details of the methodological approach driving this initiative are given in Chapter 4.

4. Limitations

With respect to the limitations of this research, it is important to note that the development of the thesis was based mainly on the results of the European project GDEE. As a consequence, the research has undergone continuous adaptations to project deadlines and other organizational/implementation requirements, especially the parts concerning the evaluation of the online training project and, to a lesser extent, related to the characterization of the academic profile of the professors involved.

The conditioning described above introduced certain limitations to the research; nonetheless, the fact that the thesis was based on an EU-funded project represented a unique opportunity to develop a research work within an international context, with the participation of academics affiliated to well-known universities from different European countries, and with the possibility of putting into practice distinct training strategies at national level. Thus, the benefits of this approach are likely to far outweigh the restrictions.

The general limitations for each chapter are described briefly in the following:

Chapter 1: Some limitations are primarily inherent to the methodology employed. First, a mostly quantitative approach was used for course assessment. Complementing this data with more qualitative assessment, such as discussion groups or personal interviews, could have enriched the results and allowed the learning experience of participants (including those who did not complete the course) to be described better; this could have provided important information for improving the replicability of the training initiative. Second, due to the fact that a highly-homogenous target profile was used (e.g., university academics with similar backgrounds in engineering), the results cannot be generalised for more generic lifelong learning approaches for adults.

Chapter 2: The limitations of this study are mainly related to the sample involved in the analysis and the methodology applied, primarily based on bibliometric analysis. First, a reduced sample size can imply lower precision of estimates; and second, the characterization of the community could be more accurate if it included qualitative information, in addition to research production. Another limitation is related to origin of the sample, which comprised almost exclusively of academics with a specific interest in SD. Further analyses that include a broader community of researchers and are made from both origin and SD perspectives would be necessary to reinforce these preliminary results.

Chapter 3: This chapter specifically analyses the academic characteristics of professors promoting SHD within engineering studies and has been principally designed to complement the bibliometric analysis performed in the previous chapter. In particular, it comprises a survey addressed to academics, which includes information about their research, teaching activities, and social outreach activities. The improved understanding of the GDEE community presented with this study did not modify the results described in Chapter 2. However, it helps to improve the definition of further strategies to be taken in the future to promote SD.

Chapter 4: The last study specifically focusses on the effects of the integration of SHD in dedicated teaching modules in a subject of basic engineering science, employing a research approach that is eminently qualitative. The main limitation of this research could be related to the size of the sample, which has been analysed through a focus group and in-depth interviews with the subject coordinator. Nonetheless, it should be noted that this

research was specifically aimed at deepening personal perceptions, visions, and opinions from both the students and the professor. Additionally, this study was explicitly designed to integrate and complement the quantitative approach used in the first two chapters.

CHAPTER 1

ASSESSMENT OF PROFESSIONAL DEVELOPMENT STRATEGIES ON SUSTAINABLE HUMAN DEVELOPMENT ADDRESSED TO ENGINEERING ACADEMICS

Abstract

Higher Education Institutions play a critical role in societies' transition towards sustainable development, educating future professionals and decision makers. In the last few decades, a number of technical universities have devoted major efforts to integrating sustainable development into engineering curricula. There is still, however, an increasing need to further transform learning and training environments and build capacity of educators and trainers on sustainable development issues.

Against this background, this study assesses the role of online training courses, within continuing professional development strategies, in promoting sustainable human development in engineering degrees. It was built upon the implementation of a European initiative, the Global Dimension in Engineering Education, promoted by a transdisciplinary consortium of technical universities and non-governmental organisations. In terms of method, this study analyses two sets of quantitative and qualitative indicators to assess i) the perceived quality/relevance of the training proposals, and ii) the learning acquisition of participants. Quantitative indicators were complemented by a descriptive analysis of findings from a semi-structured survey.

The results provide evidence that online learning can be an effective approach for continuing professional development of academics. The findings also suggest that participants perceived online courses' contents and curricula, developed jointly by academics and practitioners of non-governmental organisations, as relevant and useful for integrating sustainability principles in teaching activities. To conclude, authors recommend the leaders of higher educational institutions to explore the integration of online courses addressed to faculty into university policy and strategies, as a way to promote professional development and the engagement of academics on sustainable development.

Keywords: Sustainable Human Development, Engineering, Global Dimension, Continuing Professional Development.

This chapter is based on:

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- **Lazzarini, B.**, Velo, E., Perez-Foguet, A., 2017. Fostering global learning in engineering education, in: IEEE Global Engineering Education Conference, EDUCON. 25-28 April 2017, Athens, Greece. IEEE, pp. 389–394. doi:10.1109/EDUCON.2017.7942877
- **Lazzarini, B.**, Pérez-Foguet, A., Boni, A. Sierra-Castañer, M. 2016. Global Dimension in Engineering Education: promoting learning in Spanish Universities, in: III International Congress of Development Studies. 29 June -1 July 2016, Zaragoza, Spain, pp. 555-567.
- Pérez-Foguet, A., **Lazzarini, B.** Giné, R., Velo, E., Boni, A. Peris, J., Sierra-Castañer, M., Zolezzi, G., Trombino, G. Zortea, M., Trimmingham, R., Noble, N., Mongera, F. 2015. Promoting global learning in engineering curricula: lessons learnt from the Global Dimension in Engineering Education initiative, in: Global Cleaner Production and Sustainable Consumption Conference Proceedings, 1-4 November 2015, Sitges, Spain.
- Trimmingham, R., **Lazzarini, B.**, Pérez-Foguet, A., Noble, N., Boni, A., Sierra-Castañer, M., Mongera, F., Zolezzi, G., 2016. Global Dimensions in Engineering Education: experiences from a collaborative project, in: Leal, W., Pace, P. (Eds.), *Teaching Education for Sustainable Development at University Level*. Springer, pp. 175–190. DOI 10.1007/978-3-319-32928

1. Introduction

In the last few decades, a number of technical universities have devoted major efforts to integrating SD into engineering curricula. There is still, however, an increasing need to further transform learning and training environments and build capacity of educators and trainers on SD issues.

The advances in technology have been increasingly facilitating the spread of web-based learning approaches (LeNoue et al., 2011; Wang et al., 2014), fostering different initiatives focused specifically on the promotion of SD at university level (Azeiteiro et al., 2014). Due to its flexibility and potential for customisation of the learning approaches of participants (Cornelius et al., 2011), and their potential to actively support constructivist approaches (Barth and Burandt, 2013; Dlouhá and Burandt, 2015), web-based initiatives on SD can have a clear attraction in continuing education and could contribute to maximising the participation to such initiatives. Despite successful examples of online courses addressed to academics on SD (Barth and Rieckmann, 2012; Boni and Pérez-Foguet, 2006; Luppi, 2011), and other scientific fields (Psillos, 2017; Riviou and Sotiriou, 2017) the impact of e-learning approaches on SD addressed to academics remains understudied.

Given the increased interest in the role of web-based learning approaches to enhance the penetration of SD principles among academics and, specifically, the potential of these delivery methods to improve the competencies of engineering faculty in SHD, this study examines the following research question: in the framework of a continuing professional development initiative for engineering faculty, does participation in online SHD training result in academics acquiring relevant and useful knowledge for their teaching activities?

This chapter seeks to answer this question through the analysis of the learning process of a group of academics involved in online training courses implemented in the framework of the European initiative GDEE (GDEE, 2015b). In terms of methods, the study comprised of both quantitative and qualitative indicators including data provided by i) a virtual learning platform (VLP) (enrolments, completion rate, grading, degree of participation and implication of participants), and ii) a survey addressed to courses participants assessing the perceived relevance and usefulness of online courses. The analysis assesses i) the perceived quality/relevance of the training proposals, and ii) the learning acquisition of participants. Quantitative indicators were complemented by a descriptive analysis of findings from a semi-structured survey. The chapter is organized as follows. Section 2

describes the characteristics of adult learning, focusing on the potential of digitally mediated learning environments. Section 3 focuses on the integration of SD into engineering curriculum, describing relevant staff development experiences. Section 4 reports the overall strategy and implementation of the GDEE initiative. Section 5 introduces the research methods. Results are presented in Section 6. Discussion and main conclusions follow in the last sections.

2. Evaluation framework

This chapter focusses on continued professional development for engineering academics; however, lessons can be learned from other adult education literature. Adult education can generally be defined as the practice of teaching and educating adults, usually after compulsory education (Jarvis, 1996). In the last decades, the concept of ‘lifelong learning’ has been increasingly framing policy and practice towards adult education (Crowther and Sutherland, 2007; Grace, 2005). A distinctive feature of lifelong learning, in its initial idea, was related to a strategy shaping educational policies throughout the whole people’s life, integrating a perspective of inclusion and emancipation, aimed at empowering individuals and communities for the promotion of social justice and democratic change (Delors, 1996; Faure et al., 1972; Gelpi, 1979). This humanistic perspective has been recently reasserted by UNESCO (2015). Nonetheless, currently there is no shared agreement on its usage. Critical views highlight that the current orientation of lifelong learning is increasingly focusing on individualist and instrumentalist directions (Blewitt, 2013; Grace, 2005; Grace and Rocco, 2009), following approaches aimed at maximising the function of education for promoting economic growth and competitiveness (Casey and Asamoah, 2016; Holford, 2016). Reporting different interpretation of lifelong learning, Edwards and Usher (2008, p. 59) emphasise a general agreement with the argument that ‘lifelong learning is providing a strategy through which post-school education and training, including the education of adults, and potentially all education, is being and is likely to continue to be reshaped’.

Knowles et al. (2005), in a milestone work on adult learning, highlight specific characteristics that make the learning process of adults distinctively different. First of all adult learning is self-directed, in the sense that adults take responsibility over the personal process of learning, being able to identify and define their learning needs as well specific learning strategies. Secondly, adults have a problem-centred approach to learning, perceiving meaning for issues that are relevant and immediately useful in their personal

lives and/or in the work environment. Thirdly, adult approximation to learning is selective, in the sense that they are not inclined to learn issues that are not interested in. Finally, adult learning is based on previous knowledge and experience, as they draw upon their own resources in the learning process. This implies important considerations that must be taken into account for the effectiveness of adult learning process. The responsibility that adults are willing to take for their learning is strongly related to their learning motivation (Wlodkowski, 2003). Specifically, adults take responsibility on their own learning if they feel they have control over it, having the possibility of selecting what is really significant for them to learn, and possibly being involved in the planning of their own education process (Caffarella and O'Donnell, 1987; Merriam et al., 2007). Furthermore, adults bring into their learning process a wide range of personal resources including; previous experience, an established system of values, beliefs and preconceptions framing their thinking (Jarvis, 2004); as well as “predefined ideas for what they need to learn” (Beavers, 2009).

Given these characteristics, diverse learning strategies, predominantly based on a constructivist approach, especially tailored to adults, have been emphasised as specifically effective (Jarvis, 1996; Rubenson, 2016). Constructivism is based upon the notion that individuals constantly build new understanding as a result of the interaction between previous knowledge and the knowledge acquired through new experiences (Phillips, 2000). A social approach of constructivism has been traditionally promoted in adults' education, emphasizing that individuals' representations and understanding of their self and the external world are influenced by political and social factors, such as the economy, power, religion, etc. (Richardson, 2003). Constructivist pedagogy emphasises the importance of the learning context for optimising learners' approach and motivation (Richardson, 2009). Specifically, knowledge is view as constructed by learners through social interaction with others (Huang, 2002), consequently, pedagogical approaches aim at actively engaging learners in open and interactive learning environments (Phillips, 2000). Among the different learning strategies focused on adult learning, it is worth highlighting the following:

Self-directed Learning: it assumes that adults are responsible for their own learning and take initiative in defining autonomously their learning needs and goals (Brockett and Hiemstra, 1991). Accordingly, the teaching strategy aims at fostering learning processes in which learners develop their own knowledge independently, providing them with the ability to actively make choices on different aspects of their learning process (Caffarella

and O'Donnell, 1987). Self-directed learning, opposed to mere knowledge transfer, dramatically improves the success of the learning experience.

Collaborative Learning: it appreciates that adult learning comprises both an individual and a social dimension. It aims at creating interactive learning environments where learners engage in common tasks allowing them working together to create common understanding, meaning, and solutions as a result of a collaborative learning process (Dillenbourg, 1999). It is specifically effective in adult learning since the possibility of sharing personal experiences and connections contributes in fostering group engagement and promoting a supportive learning environment (Scherling, 2011).

Active Learning: it acknowledges that the learning process improves when learners engage actively, applying their acquired knowledge, rather than absorb it passively (Bonwell and Eison, 1991). Therefore, it aims at providing learners the opportunity to put in practice the notions learnt acting on a specific piece of content, either individually or in groups. Practical application consists of short writing, peer activities, simulations, group discussions, problem solving activities, etc. Specifically, problem-based learning (or problem-oriented learning) is an activity considered especially effective in adult learning (Karge et al., 2011). Learners are provided with complex real-world problems and some guidelines on how to solve them. The group analysis of the different approaches and perspectives applied to solve these authentic situations enrich the learning process of participants.

Transformative Learning: it defends that through relevant learning processes, adults can re-evaluate and reframe previous assumptions, patterns and ideas of self and others, and the society, often uncritically accepted (Kitchenham, 2008; Mezirow, 2000). Accordingly, this strategy aims at fostering learners to critically question their frames of reference and mental habits – including perspectives, forms of reasoning, beliefs etc. – through different activities such as discussion, critical reflection, alternate perspectives, role plays etc. (Cranton and King, 2003).

Experiential Learning: it acknowledges that different styles of learning might be involved in the processes associated with making sense with concrete experiences (Fry and Kolb, 1979). Specifically, Kolb (1984) learning theory sets a four-stage learning/training cycle that ideally applies to all learners, identifying four learning styles associating a specific learning preference: i) assimilators - sound logical theories; ii) convergers - practical

applications of concepts and theories; iii) accommodators - practical experiences; and iv) divergers - observation and collection of information. Corresponding strategies take into account different possible adults' preference in order to maximise their learning experience (Honey and Mumford, 1992).

Education programmes targeted at adults usually combine the highlighted strategies to improve the effectiveness of the learning experience (Lawler and King, 2000). Literature focusing specifically on the professional development of educators emphasise that the combination of these strategies, adapted according to the characteristics of the group of learners, provides a significant learning experience for participants (Beavers, 2009; Gregson and Sturko, 2007; Lawler and King, 2000). Contextually, a reiterated suggestion recommends avoiding traditional approaches based on simple transmission of information, ignoring experience and professional knowledge of participants (Brockett and Hiemstra, 1991; Wlodkowski, 2003). Instead, adult educators should be perceived as facilitators of significant learning experiences, specifically: i) encouraging the active participation in all the process, through learner-centred pedagogies aimed at building learning on personal experiences; ii) creating a climate of mutual respect where experiential and collaborative learning can easily take place; iii) providing learning immediately applicable to professional context; and iv) paying specific attention to internal motivation of learners (Wlodkowski, 2003).

2.1 Digitally Mediated Learning

The spread of new technologies in the world of education has created new opportunities, especially for the professional development of adults. Along with the clear advantages in term of flexibility, giving learners the possibility to participate at their own convenience and according to their own style and pace of learning, new technologies currently offer dynamic learning environments with a great potential to enhance the active engagement of participants in the whole learning process (LeNoue et al., 2011). The current range of distance learning include different typologies of courses, including fully online courses, courses offered through blended learning – combining face-to-face approaches with online delivery – and ‘technology enhanced options’, mainly based on a face-to-face approach while integrating elements of digitally-mediated learning (Palloff and Pratt, 2007). These delivery approaches currently integrate a growing number of technologies (including wikis, virtual worlds, online communities, internet forums, RSS feeds, peer-to-peer media sharing technologies, blogging, gaming, and many more) that, applied to the educational

environment, contribute to a dramatic improvement of the learning customisation and flexibility to “accommodate individual learner characteristics, preferences, motivations and goals” (Bae et al., 2015; Cornelius et al., 2011). Furthermore, constructivism principles can be effectively applied in distance learning applying proper instructional guidelines (Dlouhá and Burandt, 2015; Huang, 2002; Richardson, 2009).

As rightly emphasised by Barth and Burandt (2013), e-learning, compared to the traditional face-to-face learning approaches, does not intrinsically provide better or more efficient learning processes. Nonetheless, it presents a clear potential for a socio-constructivist approach of adult learning, framing the learning process encouraging autonomous and independent learning as well as increasing the opportunities for collaboration and the construction of new knowledge. As an example, open learning environments are learning design frameworks aimed at maximising users’ control over their own learning process, supporting personal sense making of learners providing, through enriched technology tools and resources, concrete experiences involving authentic problems (Hannafin et al., 2004). Such environments, based on authentic learning and promoting divergent thinking and multiple perspective, are especially suitable for competence development of learners and are designed following some of the strategies described above: self-directed learning, collaborative learning and problem-oriented learning (Barth and Burandt, 2013). Accordingly, advanced online technologies along with sound instructional strategies can offer adult learners effective educational approaches maximising constructivist pedagogies (Huang, 2002; Psillos and Paraskevas, 2017).

3. Improved methodology for data collection

3.1. The project strategy

The GDEE university-NGO partnership was aimed at reinforcing the cooperation between civil society and academia, which has been recognized as a key driver to promote SHD in formal teaching programmes at all levels of HE (Pérez-Foguet, 2008; Zolezzi et al., 2013). These partnerships have been typically promoted in the field of international development (Boni et al., 2015), and the majority of them focus on mobility programs for both faculty and students to promote real-life experiences within NGO programmes in developing contexts. These approaches, well-grounded on sound partnerships at the national level, are rarely implemented at a regional - e.g. European – level. The GDEE made a remarkable

effort to overcome this country-based perspective by promoting a European perspective on international development issues.

The methodological approach driving this initiative was founded on relevant experiences of capacity building on SD addressed to engineering faculty cited in the previous section, specifically, following Fenner et al. (2005), Boni and Pérez-Foguet (2006) and Barth and Rieckmann (2012). The initiative, focused on a socio-constructivist approach, specifically aimed at providing academics with appropriate information in order to facilitate a deeper personal reflection and understanding of SD concept and principles, but also to provide learning environments and practical tools aimed at fostering discussion and collaboration among other learners and tutors, and encouraging hands-on applications in their teaching activities.

Within this framework GDEE courses and activities were designed through a transdisciplinary process involving representatives of all institutional partners, comprising academics and practitioners. In addition, a set of case studies were jointly developed by academics and practitioners as a practical resource to provide academics with teaching materials, based on real cooperation projects, to be used with students in the classroom. The courses were structured to enhance the reflection and understanding of essential concepts and interconnected elements of SHD (see the details in Appendix B), as well as to actively involve academics in a collaborative learning context designed to be open and interactive where new knowledge can be generated through discussions and collaboration among the academics involved. The Global Dimension (GD) concept was emphasised to increase awareness among engineering students about global citizenship, thus promoting a sense of global social responsibility (Bourn, 2014). In particular, the courses sought to increase understanding of sustainability, international development and human rights, along with equality issues and environmental challenges. The ultimate aim was to educate engineering students from a global perspective, increasing their awareness about SHD challenges and empowering them to contribute from their professional career to poverty reduction, human rights issues, and conflict resolution. This does not stand alone within engineering education, as linkages with other development-related agendas are remarkable, such as globalisation, sustainability, humanitarian issues and ethics (Trimingham et al., 2016).

The project included different complementary activities aimed at up-skilling, motivating and engaging academics in SD issues. Specifically, this research, focuses on the

professional development of engineering faculty through a series of on-line training courses using specific training materials addressed to academics comprising elaboration of training materials for academics, as open educational resources (OER), which was complemented with the joint elaboration (practitioners and academics) of contextual case studies (teaching materials), as OER.

3.2 Competencies

The list of competencies to be acquired by teaching staff after courses' completion was defined through a collaborative process between all project partners. Specifically, two 'focus group discussions', each of the duration of approximately one hour, were performed at the beginning of the project, with fifteen people participating in each session, representing all project partners. One of the authors adopted a facilitator role. Following Morgan (1997) proposal, sessions were recorded and transcribed verbatim, identifying the contributions of each individual. Then, individual contributions were grouped and classified as either 'university' or 'NGO' contribution. A rough thematic guideline for the sessions was proposed based on previous research on SD competencies (CSCT, 2008; Segalàs et al., 2010; Svanström et al., 2008; Wiek et al., 2011). The results of this transdisciplinary collaborations were broadly reflected in competencies development (see Table 2), which were the reference point for the development of learning outcomes (Appendix B) and courses (Appendix A).

Table 2 GDEE Competencies

Competencies	Description
Systemic Thinking	Ability to recognize and analyse the complexity of development issues across different domains (society, environment, economy, etc.) and across different scales (local to global). Ability to identify locally and globally relevant SHD issues and to connect the local and global aspects. Ability to analyse and explain the role of technology and engineering in a globalized context connecting local and global aspects.
Knowledge Acquisition	Ability to acquire relevant knowledge about SHD challenges and issues. Ability to select educational goals for SHD, taking into account the prior knowledge of students, and the diversity within the group of learners. Ability to find partners outside the school community and to co-operate with organizations that promote SHD.
Ethic and Values	Ability to include and embed in teaching SD Ethic and values, principles and goals. Ability to encourage students to question their beliefs and assumptions on SD values such as justice, solidarity, dignity, participation, etc. in order to clarify their thinking. Ability to work with students on contradictory beliefs, assumptions and values as well as moral dilemmas, specifically about the role of technology and engineering in SD issues.
Action	Ability to introduce SHD as crosscutting issues in teaching (introductory courses). Ability to advice students involved in fieldwork or other extension activities during BSc projects or MSc thesis, typically within a formalized International Cooperation Project (mid-level courses). Ability to design and implement a subject in the field of SHD (advanced courses).
Emotion	Ability to motivate students towards SD issues through Leadership and Empathy. Motivate and facilitate participative problem solving and Teamwork. Build capacity to understand diversity across cultures, social groups, and communities.

3.3 Development of materials

With the aim to support the practical implementation of each course, a set of training materials were been developed by selected European experts in this field. Nine separate publications, one for each course, were published and offered to learners (GDEE, 2014). Each publication corresponds to one course and includes five chapters, one chapter per course session. Alongside training materials, a set of contextual case studies were also

developed as teaching materials (GDEE, 2015a), aimed at providing academic staff with specific materials to be used in the classroom. In total, 28 case studies based on real development projects from NGOs', project partners, and external organizations were selected according to their relevance. Each case study was jointly developed between an academic, who provided the academic background and designed the activities, and NGO practitioners, who provided the context-based information. Almost one hundred academics, from different European universities, and forty experts in the field of development (from NGOs, development training centres, and engineering organizations, among others) closely collaborated in developing training materials and case studies. All these materials were published and disseminated as OER.

3.4 Courses' implementation

In all, nine open source online courses were designed. Courses were divided into three thematic blocks (see Appendix A) to cover a range of potential needs and motivations of academic staff, as well as different degrees of interest in development issues. Courses were conducted either in English – when implemented in Italy and UK – or partially in Spanish and English, in the case of Spain. A set of learning outcomes was defined for each course session (see the details in Appendix B). Finally, assessment tools aimed at evaluating the progress of participants were also developed.

Each course ran for 3 weeks beginning on March 2014, with one week of break between courses, in order to meet the project timeline. In total, courses were designed to take approximately 25 hours to be completed, including readings, quiz assessment and 'academic activities', consisting in developing practical implementations of the notions learnt through the sessions as class activities. Activities were evaluated by course coordinators, and participants were given different levels of feedback, such as commentaries and suggestions aimed at further developing proposed ideas into teaching modules. Each course was divided into five sessions, each of which included one reading lecture and a set of on-line resources (videos, reports, articles). In parallel, online group discussions and forums were promoted through VLP or online collaborative tools, such as 'LinkedIn groups'. To complete a session, 2 hours in the classroom plus 3 hours of personal study were required.

In terms of coordination, every course was overseen by an academic who took the responsibility for the scientific and academic content. Each partner country (Spain, Italy and UK) selected course coordinators with both expertise and knowledge about web-based

teaching and tools. Participants also had the support of technicians of online virtual platforms. Overall, a team of more than 30 people, including academics and professionals, coordinated and supervised the courses. The number of faculty learners - more than 200 people enrolled in the courses - varied consistently among the different courses. As discussed in the following sections, this number mainly depended on participants' interests and also on the dissemination strategy by partner universities. The open source nature of the online materials also allowed interested academics to 'dip in' without completing the courses.

3.5 National implementation strategies

Courses have been separately implemented in the three European partner countries. The rationale behind this approach was to promote participation through more locally-oriented dissemination strategies, as well as to empower the different partners and foster course replication and further diffusion of teaching materials. Dissemination was carried out at both national and European level through different university networks.

The courses were implemented in the three partners' countries through distance learning, but with different implementation strategies, as shown in Table 3.

Table 3 GDEE National implementation strategies

Spain	Italy	UK
- Online approach	- Blended approach	- Online approach
- Registration to single courses	- Registration to a whole Block (3 courses)	- Registration to single courses
- Virtual Learning Platform	- Virtual Learning Platform	- Social networks (google tools, LinkedIN groups)

In Spain, all courses have been offered through on-line learning via a moodle-based learning platform at the Polytechnic University of Catalonia. It is worth highlighting that three of the five universities participating in the GDEE initiative were Spanish, consequently the diffusion of the training activities has been prolific. Academics and staff of the three Spanish universities have closely collaborated in the implementation of the courses. The UK adopted a different strategy. Since partner Engineering Without Borders UK has historically worked in English universities, training engineering students and educators on SHD, it was agreed that it would lead the implementation of UK courses, with the academic support of Loughborough University. Instead of a university-based virtual platform, courses were run using online tools provided by social networks aimed at

managing courses' content, such as google training tools (google groups and google documents) as well as 'LinkedIn groups'. Furthermore, social networks were used for promoting groups' activities. Specifically, discussion groups were set up using LinkedIn groups, in order to enhance the social dimension of training activity, namely the possibility to easily 'invite' external experts to discussions and forums; as well as to 'connect' with courses partners and experts. In Italy courses were run using the virtual platform of the University of Trento. Unlike the other partners' countries, here a blended learning approach was adopted. Specifically, the first sessions of each course were offered face to face or, alternatively, via videoconference with all registered members. The beginning of each course purposely coincided with workshops and other events organized jointly by universities and NGOs, addressed to academics and student in the framework of the GDEE initiative. This aimed at improving the connection and collaboration between academics and NGOs, exploring common fields of work and facilitating networking among academics, practitioners and students. Alongside this approach, courses were promoted for whole thematic blocks, namely were mandatory registering to the three courses comprised in each block.

From an educational point of view, some differences should be highlighted regarding online and blended courses. Literature comparing online versus blended learning environments emphasise significant distinction in terms of greater effectiveness from blended learning, as well as higher satisfaction and emotional engagement of learners (Conrad and Donaldson, 2012; Dixson, 2015). Besides, other initiatives remarks that online learners, compared with blended, report the perception of more workload and less clear courses' instructions (Lim et al., 2007). This suggests important consideration regarding psychological state of learners that has to be taken into account in designing clear online instruction and in handling learners' questions and requests (Pundak et al., 2014); specifically ensuring, as reported by Swan et al. (2001): i) frequent and quality interaction with instructors; ii) dynamic discussions; and iii) a transparent interface and easy navigation. Research available is generally limited to student settings and it is difficult to generalise these findings for faculty learners. No literature has been found regarding differences between learning through university virtual platforms and online tools provided by Google and social networks. The main difference can be analysed in terms of preference to traditional learning environments, such as virtual platforms, versus new tools integrating social media.

4. Methods

This study was designed to assess the role of online training courses addressed to academics, implemented throughout the GDEE initiative, with specific focus on the acquired capacities and skills by the academic staff. The Online Student Engagement Scale (OSE), proposed by Dixson (2015, 2010) was taken as reference point to measure adult learners' engagement. The OSE combines objective behavioural validation, assessed through online information available from the course management system, with learners' self-perception of their engagement, assessed through a survey. The OSE measurement comprises four factors:

- Skills (staying up on readings, listening/reading carefully);
- Emotional (applying course material to their lives, desiring to learn the material);
- Participation/interaction (participating actively in discussion forums);
- Performance (getting a good grade, doing well on tests/quizzes).

Adapting Dixson (2015) methodological proposal, the methods employed in the analysis of the learning process of participants in GDEE online training courses included two complementary set of indicators, aimed at assessing the effectiveness of online courses, as shown in Table 4 and described in detail below.

Table 4 Indicators.

Indicator	Data	Source
Perceived relevance and quality of the training proposal		
Interest in the training proposals	Number of enrollments	VLP, Courses Coordin.
Propensity to complete training programmes	Completion rates	Virtual Learning Platform
Learning acquisition of participants		
Engagement in training activities	% of extra activities completed	Virtual Learning Platform
Grading of participants that completed one or more courses	Grading	Virtual Learning Platform
Students perception of the knowledge acquired	Survey	Survey

a. Perceived relevance and quality of the training proposal

The GDEE courses, as the majority of free online courses, had no requirement of completion, nor any kind of obligations for the academics registered. Therefore, it can be argued that the willingness of faculty to participate and to complete the courses relied mainly on their perceived relevance and quality of curricula and activities proposed. The assessment of the perceived relevance and quality of GDEE courses has been measured through two indicators:

- Interest in the training proposals: this quantitative indicator will be assessed through the number of enrolments in the different national training proposals.
- Propensity to complete training programmes: this quantitative indicator will be assessed through courses completions rates.

The most successful strategy, namely the one that maximised the number of enrolments and completions, will be analysed through the following indicators.

b. Learning acquisition of participants

The Individual learning of participants on SHD-related issues was assessed through two complementary indicators:

- Engagement in training activities: this quantitative indicator will be assessed through the percentage of extra activities completed, namely activities potentially not required to formally complete a course.
- Grading of participants that completed one or more courses: this quantitative indicator will be assessed through the grading values of participants.
- Perception of the knowledge acquired: this quantitative and qualitative indicator was assessed through a survey addressed to participants at the end of each course.

Data collection has been performed using two main sources: i) data extracted from VLP (and provided from courses coordinators in the case of courses run in UK), and ii) a survey addressed to participants at the end of each course.

4.1 Completion, assessment and grading of GDEE courses

The number of enrolments, completion rates, grading and the assessment of activities' have been gathered from the virtual platforms used to impart online courses or directly provided by English partners who ran courses through social media. The completion rate

is defined as the “percentage of enrolled participants who satisfied the courses criteria in order to earn a certificate”. The evaluation criteria is presented in Table 5 and consisted of: i) five multiple-choice quizzes, at the end of each session, aimed at assessing the degree of understanding of SHD theoretical concepts and issues presented through courses ‘materials; ii) two ‘academic activities’, namely practical implementations of the notions learnt through the sessions as class activities; and iii) a final multiple-choice assessment.

To complete a course, a minimum of 70 points was required; therefore, participants could complete each course completing assessment quizzes (one for each session) and the final multiple-choice quiz. ‘Academic activities’ were the most demanding assignments and were conducted according to time availability and interests of trainees. Participation and contribution in the discussion forum were not graded individually. However, students were strongly encouraged to participate to discussions and course coordinators assessed the quality of discussions and group performance.

Table 5 GDEE grading scheme.

Assessment	Grading
5 Quizzes (10 points maximum each)	Max. 50 points
2 Academic Activities (10 points maximum each)	Max. 20 points
1 Final multiple choice quiz (30 points maximum)	Max. 30 points

4.2. Survey

At the end of each course, participants were asked to answer a semi-structured survey aimed at deepening their perception of the usefulness of the training activity as well as the quality of the materials. Following the design and validation process for questionnaires reported by Larrán Jorge et al. (2013, p. 37), the data collection tool was designed and validated through a number of different steps. Firstly, an extensive literature review, specifically related to training and competence assessment (Segalàs et al., 2010, 2009; Wiek et al., 2011) and on learners’ assessment and engagement in online courses (Conrad and Donaldson, 2012; Fink, 2013; Prinsloo and Slade, 2014), specifically focusing on the OSE (Dixson, 2015, 2010), have been performed. The survey was then validated by a panel of experts of the three Spanish partner universities. Finally, a second validation of

the survey was conducted involving a group of faculty registered on the Spanish GDEE courses.

The survey comprised seven closed questions, employing a five point Likert scale from ‘totally disagree’ to ‘totally agree’, which were complemented with four open-ended questions to ask respondents to discuss their training experience on different academic issues (see Appendix C). Table 6 shows the structure of the survey in detail. Contextually, an analysis of activities developed by participants to complete each course was conducted in order to obtain insights into the relevance of the programme in helping train faculty to change teaching routines, starting from respective fields of expertise.

Table 6 Survey structure.

Individual perception of the impact of the training		
Q1	Expectations and personal objectives	Likert scale
Q2	Knowledge and interest in SHD's crosscutting issues	Likert scale
Q3	Courses' usefulness to integrate SHD in teaching activities	Likert scale
Relevance and quality of courses' materials		
Q4	Relevance of courses' materials for integrating SHD in teaching act.	Likert scale
Q5	Overall quality of courses' materials	Likert scale
Q6	Usefulness of specific sessions	Open-ended question
Role of course coordinator		
Q7	Competence and knowledge of the topic	Likert scale
Q8	Promotion of participation, debate and exchanges of opinion	Likert scale
Q9	Details on the role of course coordinator	Open-ended question
Suggested improvements		
Q10	Missing topics	Open-ended question
Q11	Potential improvements	Open-ended question

5. Results

5.1 Perceived relevance and quality of the training proposal

5.1.1 Overall analysis of nationals training proposals

The GDEE courses ran from March 2014 to May 2015. Overall, roughly 220 people enrolled to one or more courses for a total of 885 enrolments; with a median average of 98 participants per course. Enrolled academics came from more than fifty European universities. The majority of participants (80%) are linked to a university, while NGO training personnel represented the second largest group, with 13%. The majority of participants from HEIs were academics or researchers (63%), PhD students (29%) and staff members (3%). Females appear to be more interested in this initiative, representing the 58% of the total university participants.

As reported in Table 7, the number of enrolments is significantly different among the three partners' countries. It is noted that, due to a very low number of enrolments, courses C8 and C9 in UK have been offered eventually through the Spanish online platform.

Table 7 Completion rates for online GDEE courses.

Country	Introductory Block			Mid-Level Block			Advanced Block		
SPAIN	A1	A2	A3	B4	B5	B6	C7	C8	C9
Enrolments	65	67	73	60	63	74	66	73	84
Completions (%)	26 (40%)	25 (37%)	21 (29%)	16 (27%)	13 (21%)	13 (18%)	11 (17%)	13 (18%)	15 (18%)
UK	A1	A2	A3	B4	B5	B6	C7	C8	C9
Enrolments	29	25	24	10	14	11	6		
Completions (%)	6 (21%)	5 (20%)	5 (21%)	3 (30%)	7 (50%)	1 (9%)	2 (33%)		
ITALY	A1	A2	A3	B4	B5	B6	C7	C8	C9
Enrolments	23	23	23	14	14	14	10	10	10
Completions (%)	9 (39%)	7 (30%)	3 (13%)	6 (43%)	7 (50%)	3 (21%)	3 (30%)	2 (20%)	2 (20%)
TOTAL	A1	A2	A3	B4	B5	B6	C7	C8	C9
Enrolments	117	115	120	84	91	99	82	83	94
Completions (%)	41 (35%)	37 (32%)	29 (24%)	25 (30%)	27 (30%)	17 (17%)	16 (20%)	15 (18%)	17 (18%)

The distribution of enrolments in each of the three training centres is, respectively, 71% Spain, 13% UK, and 16% Italy; and courses' completions follow, roughly, the same trend. Besides, the analysis of the composition of participants shows that, in the case of Spain and UK, academics make up the majority of participants, respectively with 65% and 77% over the total registered, while Italy courses attracted primarily PhD students, representing 53%.

As reported in Table 5, completion rates of GDEE courses varied across different courses and thematic blocks. Overall, the highest rates of completions were registered during the introductory (A1, A2) and the mid-level blocks. The trend indicates a decrease within the first thematic block, then a slight increase for courses B4 and B5, then a clear decrease for the last thematic block. Overall the completion rates of GDEE courses can be considered very high when compared with other free online courses, such as Massive Open Online Courses (MOOCs), with completion rates of less than 10%, with a median average of 6.5% (Jordan, 2014).

At national level, completion rates varied among the three national training implementations. In the case of Spain, the introductory block of courses presented the highest rates (respectively with 40%, 37,31% and 28,77%); then rates decreased for the mid-level block, and then presented similar values for advanced block. In Italy and UK rates followed a different trend, courses B4 and B5 of the Mid-level Block – addressed to academics who want to advise students involved in field-work within an international cooperation project – presented the highest values. Then, for the other courses, rates presented a more uniform distribution. Given the limited time that academics have to devote to CPD programmes, and compared with other free online courses, it can be argued that there is a good propensity to complete the training courses. This can be related to a perceived high relevance and usefulness of curricula and proposed activities.

5.2 Perceived quality/relevance of Spanish training courses

As mentioned above, data shows that the implementation strategy in Spain, based on online training courses through a VLP, has maximised the number of enrolments and completions of the courses. As it appears to be the most successful of the three strategies, the analysis of the learning process of participants will focus on courses offered through Spanish platform.

Another indicator of perceived relevance and usefulness of training programmes relates to the level of engagement of academics in training programmes. It has been measured through the number of extra “academic activities” completed, i.e. activities that were not initially required to complete a course. These activities were specifically designed to help participants develop innovative ideas on how SHD concepts, learned through the theoretical sessions, could be embedded within their in teaching activities, taking the specific discipline and expertise of academics as starting point. They were aimed at gaining insight into relevant SHD issues, with a pedagogical approach that go beyond theoretical concepts, helping faculty questioning their teaching and explore new pedagogical approaches. Figure 4 presents the percentage of participants that carried out these activities. With the exception of courses A2 and A3, more than 60% of participants completed at least one activity. Overall, the majority of participants completed 2 activities.

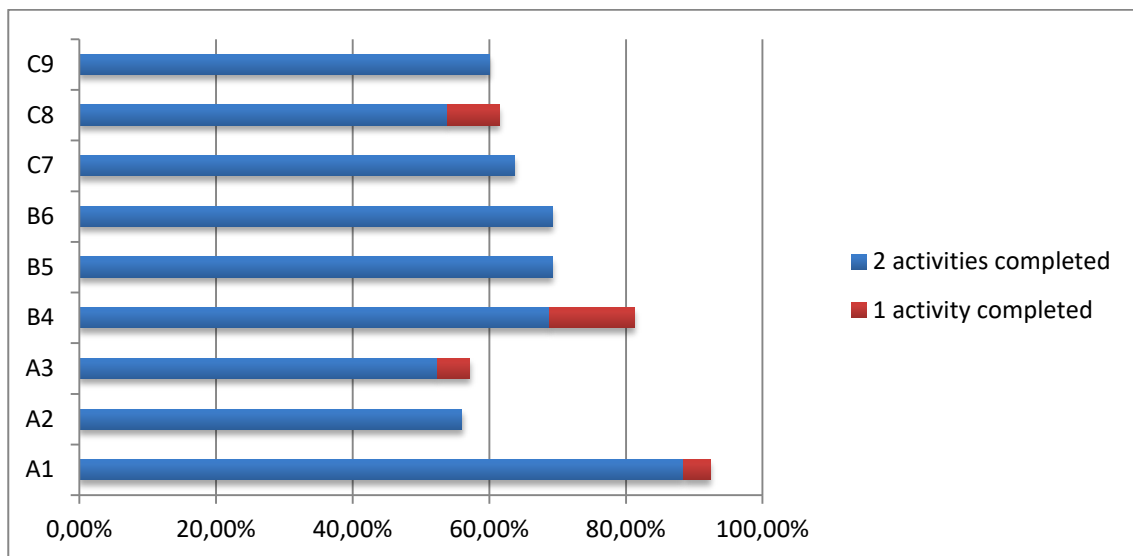


Figure 4 Percentage of academic activities completed per course.

5.3 Learning acquisition of participants

Overall grading of participants that completed one or more courses helped to quantitatively assess the knowledge acquired by the trainees. Figure 5 shows the detail of participants’ grades for the nine courses. A minimum of 70 points was required to complete a course but it is noted that a very high percentage of completions obtained a higher score (80-100), and six over nine courses show that 45 to 50% of participants obtained the highest score (90-100). This can be assumed as an overall indicator of

increased knowledge and understanding of a specific set of outcomes linked to each course.

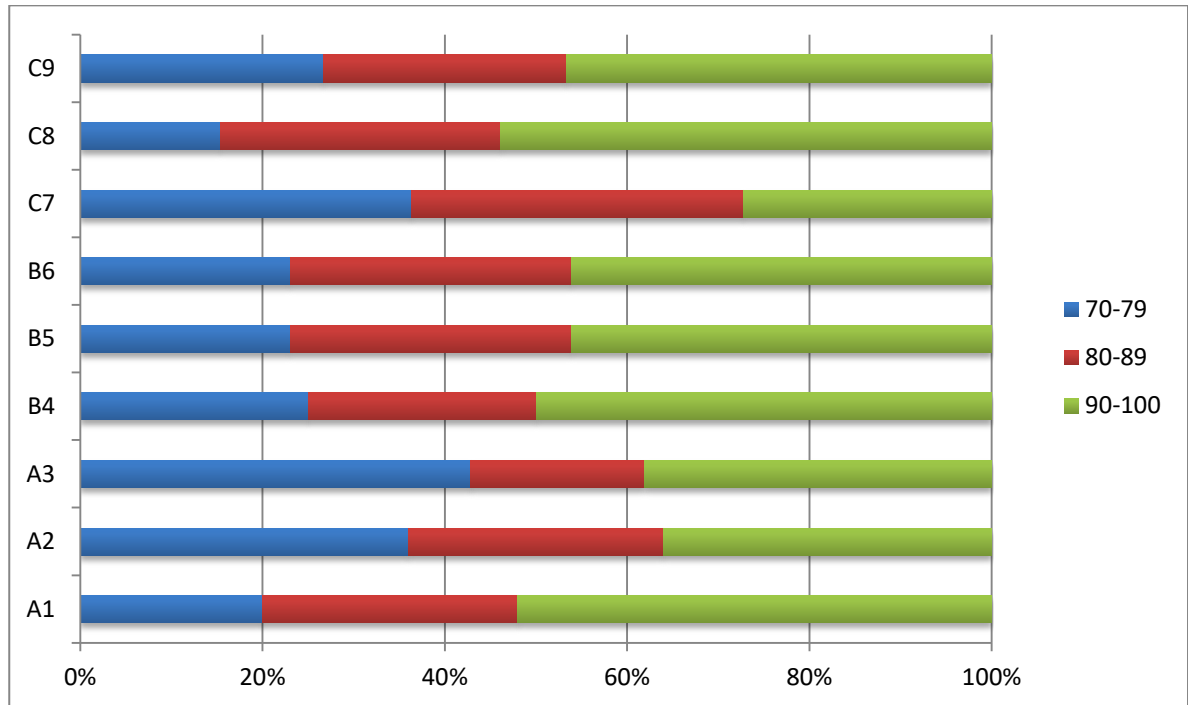


Figure 5 Grading of Spanish completions.

Quantitative performance data of the courses was complemented with individual perception of participants on: i) impact of the training; ii) relevance and quality of courses' materials and; iii) suggested improvements. Data was collected through surveys after courses completion, and aggregated in the analysis into the three thematic blocks for analysis giving an overall picture of participants' perception of the training impact. Figures 6, 7 and 8 present the answers, aggregated for thematic block, of the following questions:

- Q2. Please rate your agreement to the following statement: My knowledge and interest in cross cutting issues (such as MDG, HD, extreme poverty, climate change, etc.) has increased as a result of this course.
- Q3. Please rate your agreement to the following statement: Overall, this course is useful for integrating crosscutting issues in teaching activities.
- Q4. Please rate your agreement to the following statement: The course materials provided are relevant and effective for integrating crosscutting issues in teaching activities.

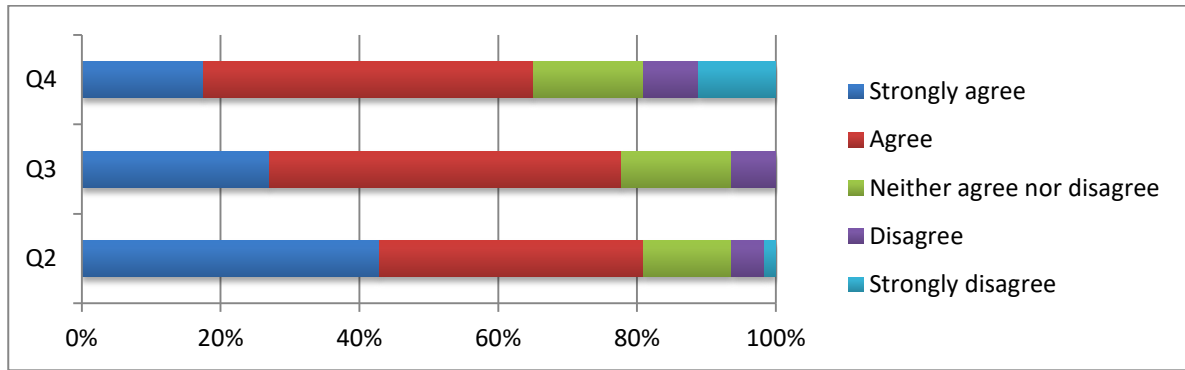


Figure 6 Block A, responses to questions Q2, Q3, Q4.

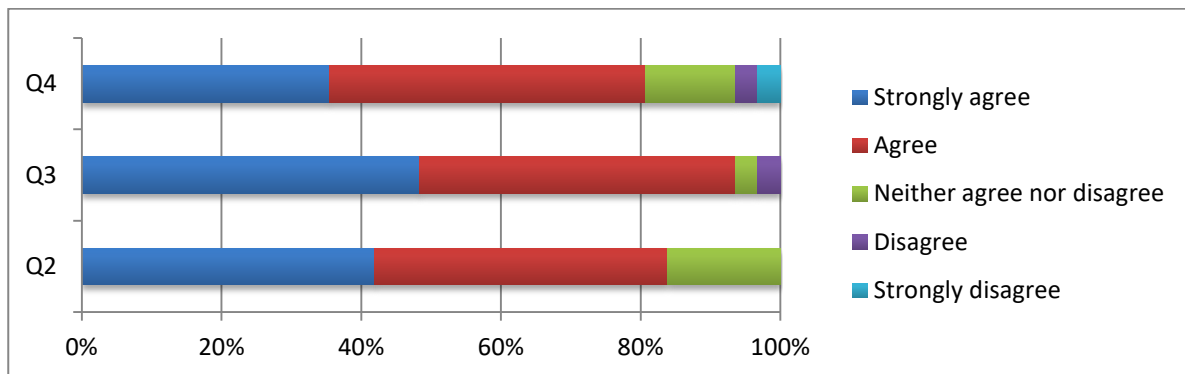


Figure 7 Block B, responses to questions Q2, Q3, Q4.

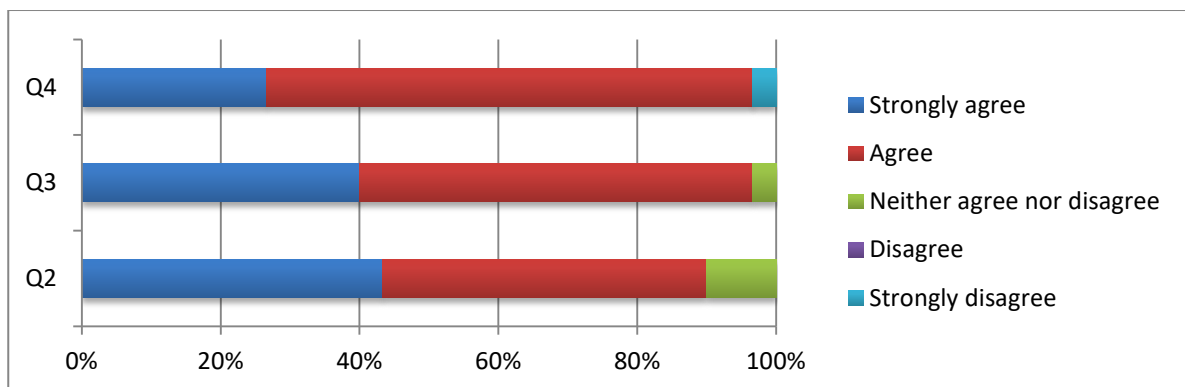


Figure 8 Block C, responses to questions Q2, Q3, Q4.

Within each thematic block, a very high percentage of participants agree or strongly agree that, as a result of taking a course, their knowledge and interest in SHD cross cutting issues has increased. Likewise, a very high percentage of participants agree or strongly

agree that the courses were useful for integrating crosscutting issues in their teaching activities and materials were relevant and effective.

Open-ended questions highlighted general considerations and suggestions of improvement that are common for the three blocks. First of all, time availability stood out as the main barrier described by participants in order to engage with the GDEE training activities. On the one side, participants stressed the need for more time to deeply examine interesting topics and, on the other side, that courses' schedule was too densely packed with activities and tight deadlines. Extending training periods and deadlines may improve engagement and effectiveness of courses.

Discussion forums are perceived as important spaces of interchange and debate, with high levels of engagement, especially for the courses in block A. Various criticisms converge on the fact that participants' contribution is intermittent and, overall, a lack of more levels of reflection is explicitly claimed. Participants recommended encouraging participation to the forums through possibly grading the contribution to discussions. Regarding the assessment of the courses, some academics suggested exploring alternative assessment methods for future editions. Quizzes were perceived as the best method, however, they recognized that, given the type of course and the limited time available, is probably the most effective.

With regard to Block A, participants pointed opposed positions that can be described as distinct polarities. Some stressed the appropriateness of materials and proposed training topics (the sessions that explicitly link technology with SHD issues were particularly appreciated by a large number of participants), while others underlined an excessive neutrality of courses' materials. In fact, several improvement suggestions asked for a more critical perspective on international development issues and the need of a more explicit questioning of traditional science and technology. A participant explicitly stated that he perceived courses approach too 'paternalistic and ethnocentric'. Others pointed out that materials 'avoid talking openly about politics' and that approximation was in general too politically correct. Also gender issues have been perceived, by few participants, not adequately integrated in the materials (inclusive language, examples, etc.).

Participants of the second block share the same general suggestions cited above for the three blocks. Furthermore, they highlight the need to integrate in courses' materials case studies on real international cooperation experiences. Especially suggested are videos and

virtual seminars involving professors and NGO practitioners. Regarding the third block, more practical examples of teaching guides, evaluation schemes and activities have been claimed.

6. Discussion

The research discussed in this paper analysed the extent to which a continuing professional development approach addressed to engineering academics, based on a series of online courses aimed at raising awareness and promoting the integration of SHD in teaching activities, have positive effects on academics offering theoretical and practical tools through web-based learning.

The different implementation strategies, promoted at national level, have led to significant differences in the results among the three partners' countries, as can be appreciated from the data on enrolments and completion rates. Online courses fostered through the Spanish online learning platform represented roughly more than 70% of total enrolments and completions; while courses promoted in Italy and UK have not meet initial expectations.

Overall, the differences observed between the training proposals may highlight problems in the implementation strategy followed in the different countries. This can be related to different factors, interlinked and mutually reinforcing: i) different time availability for faculty professional development; ii) preference to traditional learning environments, such as university VLP; iii) academic relevance of national promoting institutions and iv) different degrees of permeability of the concepts promoted. Accordingly, the success of Spanish strategies, in terms of the number of participants, points out specific characteristics. Firstly, it was a more scalable training proposal, compared to the Italian offer, implemented with a blended learning approach. Secondly, courses were offered through a traditional online learning environment, such as VLP, possibly a more comfortable learning environment for academics, compared to social networks. Thirdly, the academic relevance of partners promoters; in fact, in Spain the three major polytechnic universities have locally promoted the GDEE courses, unlike Italy and UK where only one university has lead the promotion. Finally, the interest in concepts related to SHD, promoted through the heading of 'Global Dimension'; in Spain the GD represented a novelty while in the other countries other initiatives were promoted under this heading.

Completion rates of GDEE courses were particularly high compared to other e-learning proposals. Given the varied background and the broad range of motivation of participants, completion rate may be not the most robust indicator of the effectiveness of this training initiative among academics. Nevertheless, it can still be argued that GDEE completion rates, with values between 13% and 40%, are higher than other free online courses (Jordan, 2014).

The analysis of the learning process of participants has been focused on Spain, the most successful of the three national implementations, highlighting a significant interest of academics in the training proposal. From one side, participants showed a high propensity to complete training programmes. On the other side, data emphasised a high degree of participation in training activities. Specifically, the majority of participants engaged in time-consuming activities that were not required to formally complete a course but that were discipline specific. These data can be related to the degree of perceived relevance and usefulness of courses' curricula and materials, which has been confirmed and is reinforced by the other set of indicators, aimed at assessing the learning acquisition of the trainees. These results also confirm the fact that academics are willing to take responsibility of their own learning when the educational process and the contents proposed are perceived as useful and motivating, and when they are able to focus on what is really significant for them to learn (Knowles et al., 2005).

With regard to the knowledge acquired by participants, it may be reported that, as a result of taking a course, their knowledge and interest in SHD issues have increased. Besides, a very high percentage of participants indicated that courses were useful for integrating SHD issues in their teaching activities and that proposed materials were relevant and effective. This highlights important findings. First, that contents and methodologies employed, based on e-learning, have fostered successful knowledge acquisition and an effective learning experience, reinforcing previous initiatives (Barth and Rieckmann, 2012; Luppi, 2011); and confirming other studies reporting that e-learning approaches, compared with regular training options, can provide relevant learning (Psillos, 2017; Pundak et al., 2014) and similar knowledge retention (Girard et al., 2016). Second, that cooperation of academia with civil society, specifically from international development NGOs, can be beneficial for the professional development of faculty (Zolezzi et al., 2013). It can be argued that the development of curriculum and support materials addressed to faculty can be enriched through transdisciplinary collaborations including non-academic

entities. Specifically, the academic approach can be improved through field experiences offered by NGO.

In all courses, special attention has been devoted to fostering knowledge acquisition related to the complexity and interconnection of SHD issues, following Lozano García et al. (2008); particularly emphasising the links between different dimensions of sustainability, such as environmental issues, global and intergenerational justice, poverty and human well-being, sustainable use of resources, etc., as recommended by Boni and Pérez-Foguet (2008). Relevant content about global SHD principles and challenges, especially related to developing contexts, have been integrated in blocks A and B. Furthermore, concepts related to ethics and values (Holsapple et al., 2012) have been embedded in all nine courses, not only in materials but also in activities and forums.

Participants of courses of thematic blocks B and C acquired substantial knowledge about different learning and teaching methods as well as the ability to develop innovative practices for engaging with students. Advising students involved in field-work during BSc projects or MSc thesis (the specific topic of the block B), provided teaching staff with essential information on transdisciplinarity and its importance in finding practical solutions to SHD challenges in development contexts. Besides, they had the opportunity to deepen issues related to the cultural dimension of sustainability problem definition. Block C, addressed to academics that want to design a course relating technology and SHD from their own expertise, questioned the traditional discipline-oriented pedagogies developing SHD methodological competencies. Specifically, it developed appropriate teaching methodologies, interdisciplinary approaches and assessment strategies as well as practices aimed at fostering students' engagement.

SHD knowledge has been acquired combining theoretical and practical knowledge. Nevertheless, it is noted that the short duration and the full e-learning approach have not allowed the inclusion of , as part of the training, specific activities aimed at applying the concepts learnt in real teaching situations, ideally with the supervision of experts, as described by Barth and Rieckmann (2012) and Lozano García et al. (2008). In order to overcome this shortcoming, courses included practical activities providing learners the opportunity to apply their acquired knowledge on the integration of SHD concepts, developing proposals of class activities starting from the respective disciplines and expertise of academics involved (Holmberg et al., 2008; Svanström et al., 2012). Course coordinators gave detailed feedbacks on each activity submitted, including suggestions

aimed at further developing proposed ideas into full teaching modules. Contextually, case studies were integrated as complementary tools, providing examples of class activities based on different disciplines and SD contexts. Practical activities were complemented by discussion forums specifically focused on teaching practices, where learners shared their experiences and discussed different opinions and approaches. Activities and forums, implemented through the VLP, aimed at facilitating respectively the integration of elements of active learning and the enhancement of the social dimension of the learning process. Learners' perception of online courses highlighted their usefulness to integrate SHD into teaching. Accordingly, it can be argued that they helped, at least, questioning the teaching routine and providing ideas to develop personal pathways to SHD integration.

Time availability of participants and tight schedules of courses were emphasised as the main obstacle to adequately engage with the GDEE courses. To meet the project timeline, courses had to be scheduled one after another with only one week of break among courses. This overload, in combination with demanding development training, might have affected participants' motivation to complete all course activities. In other words, one of the advantages of the web-based learning, namely the flexibility related to the learning pace of participants, has not been fully exploited. For further replication, it is strongly recommended employing flexible schedules, planning activities with an adequate timeframe allowing learners to deeply examine courses topics.

Other important recommendations focus on discussion forums. Specifically, it is suggested trying to devote adequate attention to make discussions effective, ensuring a constant engagement of participants and robust and rich discussions. Online discussions have a tremendous potential for the emotional engagement of learners (Conrad and Donaldson, 2012) and specific strategies, aimed at encouraging participation, should be integrated in a solid course strategy at the earliest stages, contextually to material development, as suggested by Bae et al. (2015). Furthermore, a lesson from this specific experience is that it is worth taking into account that political correctness (in course coordination, material development and discussion forums) and efforts aimed at assuring the neutrality of materials' content can be a double-edged sword, with the risk of compromising the engagement of a large part of participants. In this sense, it is worth stressing that several suggestions aimed at improving the courses materials called for a more explicit questioning of traditional science and technology and a more critical perspective on development issues.

The research presents some limitations, primarily inherent to the methodology employed. First of all, a highly quantitative approach was followed during the initiative. Complementing this data with more qualitative assessment, such as discussion groups or personal interviews, could have enriched and better described the learning experience of participants, including those who did not achieve course completions, providing important information to improve the replicability of the training initiative. Second, due to the fact that the specific profile of the target public analysed was university academics with similar backgrounds in engineering, results cannot be generalised to more generic adults' lifelong learning approaches.

CHAPTER 2

RESEARCH PROFILE OF ENGINEERING ACADEMICS ENGAGED WITH SUSTAINABLE HUMAN DEVELOPMENT

Abstract

Over the last decades, engineering faculties and universities have become increasingly engaged in integrating sustainable development into their different functions. Notwithstanding, more effort is required to effectively integrate sustainability principles as a whole-university approach, and specifically, in technical universities. Scientific literature highlights the main barriers to the success of initiatives that address this shortcoming. A better understanding of the scientific profile of the academics who engage in sustainable development activities can help to develop and promote initiatives for increasing faculty engagement in all academic functions.

For this purpose, this study presents a bibliometric analysis of the scientific production of an academic community involved in a European initiative aimed at capacitating engineering academics for sustainable development. Specifically, two groups of academics with different degrees of expertise and involvement in sustainable development were characterized and compared, revealing common trends and similarities of their research production. The results have different implications for future strategies aimed at engaging specific academic profiles in the field of engineering, highlighting especially health science-related fields linked with engineering as a potential opportunity of promoting the integration of sustainable development in engineering education. Further analysis is required to determine the university rankings and their potential implications for the integration of sustainable development, as well as appropriate policies and mechanisms of faculty rewarding and promotion.

Keywords: Sustainable Development, Bibliometrics, Global Dimension, Engineering, Interdisciplinary Research.

This chapter is based on:

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Lazzarini, B., Pérez-Foguet, A. 2015. Global Dimension in Engineering Research: A characterization of the scientific profile of GDEE community, in *Global Cleaner Production and Sustainable Consumption Conference Proceedings*, 1-4 November 2015, Sitges, Spain.

1. Introduction

Human factors, such as the empowerment and the commitment of academics, have been recognised as critical issues for fostering organisational changes (Verhulst and Lambrechts, 2014). Accordingly, the importance of identifying and empowering committed academics, often heralded as sustainability champions, is central to overcoming resistance to fully engaging with SD and to promoting institutional changes towards sustainability (Lozano 2006; Ferrer-Balas et al. 2008). Furthermore, maximising the engagement of interested academics with little or no experience in SD is critical for fostering cultural changes in educational organisations. Indeed, integrating SD into academic activities requires a large effort and motivation, as changes are necessary not only in content but, above all, in methods (Segalàs et al., 2009), and as approaches go beyond disciplinary (Barth and Rieckmann, 2012; Cebrián et al., 2015). For these reasons, HEI should motivate and incentivise the efforts aimed at integrating SD into the different functions of universities (Lozano et al., 2013b). Regrettably, the traditional disciplinary and rewarding structures too often leave these efforts unrewarded, such that it relies instead primarily on the individual commitment of a limited number of academics (Hoover and Harder, 2014; Krizek et al., 2012).

Additionally, conventional academic rewarding mechanisms, which are mostly characterised by a narrow disciplinary focus, represent major impediments to a more socially engaged higher educational system (Ferrer-Balas et al., 2008; Krizek et al., 2012). Commonly, these mechanisms discourage researchers from developing a proper outreach to non-academic stakeholders, which consequently hinders inter- and transdisciplinary collaborations, or the complex and integrated systems approaches required for addressing SD challenges (Stephens et al., 2008).

The effects of the conventional rewarding mechanisms are reinforced by current trends of globalisation of higher education, through which HEI have become inevitably part of competitive national and global networks, characterised by the increased relevance of rankings and benchmarking, which intensifies the attention on the productivity of universities (Morrissey, 2013). These trends emphasize primarily the research function of universities, which in turn underpin or accelerate changes related to the academic identity and work practices of academics (White, 2015). This increases the importance of the ‘performance’ of academics—specifically, the type of research they perform and the journals in which they publish (Hazelkorn, 2014). Thus, research productivity is an increasingly predominant part of the evaluation and promotion of academics, and the

potential barriers and incentives related to this function that influence the willingness of academics to engage with SD should be better explored. However, during the literature analysis carried out for the present research, authors did not identify scientific literature that specifically analysed the characteristics of scientific production of academics engaged in SD activities. Nonetheless, having a better understanding of this aspect is essential to replicate successful initiatives and to promote appropriate policies that lead academics to engage with SD.

In this context, this chapter addressed the open question of whether the research profiles of academics engaged with SD practices share any common patterns, using comparative analysis and characterisation of the scientific productivity of academic communities involved in activities related to SD. Specifically, two groups of academics with different degrees of expertise and involvement in SHD were compared and characterised, which highlighted common trends and similarities of their scientific production. The analysis focused on the scientific production of a community of academics involved in the activities of the European initiative GDEE (GDEE, 2014; Pérez-Foguet et al., 2018), aimed at promoting the integration of SHD as a crosscutting issue in teaching activities of technical universities.

2. Research for Sustainable Development

Integration of SD into university research has remained, to some extent, underconsidered in the studies addressing sustainability in higher education, compared to other university functions (Hugé et al., 2016). This can be attributed to the fact that research for SD is difficult to define, due to different factors: i) the existence of different interpretations, and misconceptions, of the concept of SD (Filho, 2011, 2000); ii) the different use of the terms “sustainability” and “SD” among researchers, which has changed over time (Kajikawa et al., 2007); and iii) the diversity of stakeholders engaged with research in SD, bringing a multiplicity of perspectives and interpretations of research for SD (Hugé et al., 2016).

Different efforts have been made to define research for SD. Waas et al. (2010) define university research for SD as: “all research conducted within the institutional context of a university that contributes to SD”. In order to avoid ‘business as usual’ research practices or even ‘unsustainable research’, the authors proposed the following sixteen characteristics of university research for SD, which they argued should be compulsory: action-oriented;

continuity; environmental; safety and security management; independence; knowledge transfer; local–global level of scale; local knowledge; multidimensionality; multi-/interdisciplinarity; participation; precautionary principle and uncertainty; public interest; short-, medium-, and long-term perspectives; societal peer review; sustainability impact; sustainability relevance; and transparency. In more recent research, other scholars conceptualise ‘research for sustainability’ with a set of characteristics including: multi-, inter-, and transdisciplinary research; co-production of knowledge; normative and positive inputs; systemic integration; exploratory character; recognition of own limitations and assumptions; contextual knowledge; learning-oriented perspective; production of socially robust knowledge; and attention to system innovation and transition (Hugé et al., 2016).

Bibliometric analyses have been useful for determining the principal domains of research for SD, highlighting those disciplines and subdisciplines in which researchers predominantly focus their research efforts (Hassan et al., 2013; Quental and Lourenço, 2012; Xu and Marinova, 2013; Yarime et al., 2012). The status of research in sustainability science was analysed by Kajikawa et al. (2008) using a topological clustering method. The results highlighted fifteen main research domains: agriculture, fisheries, ecological economics, forestry (agroforestry), forestry (biodiversity), forestry (tropical rain forest), business, tourism, water, urban planning, rural sociology, energy, health, soil, and wildlife. Four main clusters are predominant among these domains: agriculture, fisheries, ecological economics, and forestry (agroforestry). Furthermore, the author combined the citation analysis with a natural language processing analysis, emphasising others common topics of research in sustainability science, such as education, biotechnology, medicine, livestock, climate change, welfare, and livelihood clusters (*ibidem*).

The landscape of the research for SD has changed in more recent years. In fact, the current scientific literature indicates that most of the previously separated domains have been integrated into larger domains that focus on the study of coupled systems, such as environmental systems, economy and business systems, fishery and forestry, energy systems, water resources, health, and urban and transport systems (Kajikawa et al., 2014). Other studies investigating the research strengths in SD highlight five main research clusters, emphasising the systemic focus of such domains: climate change, renewable energy, rural development, sustainable agriculture, and sustainable production and consumption (Hassan et al., 2013).

These changes in the research landscape reflect wider societal expectations and educational perspectives about SD that have also undergone changes in the last decades (Dlouhá et al., 2013) – specifically, from narrowly focused environmental issues to wider concerns related to global SD challenges. In addition, the acknowledgement that sustainability challenges require alternative ways of knowledge production and decision-making (Miller et al., 2014) has brought new imperatives for the research that addresses SD: on the one side, the need to focus on the linkage between various disciplines that range from biology to political and social sciences deepening dynamics and cross-systemic analyses (Waas et al., 2010); on the other side, the necessity of a new ‘social contract’ for research, in order to explicitly address scientific efforts towards the creation of a more sustainable future (Gibbons, 1999; Lubchenco, 1998). This implies not only a diverse and better knowledge communication (Dlouhá and Burandt, 2015) and outreach to the society at large, but also the active involvement of actors from outside academia in the research process (Lang et al., 2012; Max-Neef, 2005).

In this sense, a new conception of science and research for SD has emerged that transcends the boundaries of disciplines and academia; this is reflected in new fields of research, such as sustainability science (Clark and Dickson, 2003). This new approach acknowledges the complex interactions between human and natural systems and is value-based, problem-oriented, solution-driven, and focused on knowledge co-production between science and society. It specifically acknowledges that research should be transformative – in other words, go beyond the description and analysis aspects that characterise traditional research (Heinrichs et al., 2016; Lang et al., 2012; Takeuchi and Komiyama, 2006). Compared to traditional disciplinary research, multi- and interdisciplinary research – which incorporate the combination of conceptual and methodological issues as well as diverse scientific disciplines – have greater potential to address sustainability challenges through specific research actions (Hugé et al., 2016; McCormick et al., 2016). Interdisciplinary research has been recognised as critical for addressing SD challenges (Lang et al., 2012), as well as an important driver towards more sustainable universities (Ferrer-Balas et al., 2008). However, transdisciplinarity – which refers to the involvement of non-academic actors in the research process – has the greatest potential to create relevant and robust knowledge that drives transformative actions forward (Binder et al., 2015; Gaziulusoy and Boyle, 2013; Lang et al., 2012; Max-Neef, 2005). Gaziulusoy and Boyle (2013) summarise the characteristics of the transdisciplinary research as: i) aiming to solve socially relevant and contextual problems; ii) based on evolving methodologies throughout the research; iii) requiring collaboration and

coordination among different disciplines; iv) requiring participation or inclusion of the knowledge and perspective of non-scientific stakeholders in research; and v) normative, as it aims to transform the problem domain.

While transdisciplinary research has made substantial improvements in the broader understanding of the relevant complex problems related to SD and potential transformative solutions, progress on its integration into the research and educational functions of universities is limited (Miller et al., 2014). The scientific literature emphasises different barriers to integrating SD into HEI (Lozano, 2006; Lozano et al., 2013b; Velazquez et al., 2005), some of which are related specifically to research, such as: i) the conservative disciplinary structures and resistance to change by research; ii) the focus on short-term profit as a result of managerial thinking and policy making; and iii) the lack of appropriate qualitative and quantitative performance indicators (Verhulst and Lambrechts, 2014). In addition, the research function of universities is currently strongly conditioned by an increasing emergence of a corporate facet of universities, which some authors describe as an extension of the rationality of the market to the different academic functions (Boni and Gasper, 2012; Morrissey, 2013). In this context, the ‘performance’ and ‘productivity’ of academic practices have acquired growing relevance, to the extent that different scholars highlight a trend of ‘commodification’ and ‘marketisation’ of higher education (Locke, 2014; Tomlinson, 2015). Contextually, the globalisation agenda has constrained HEI from becoming part of competitive networks at national and global levels, with university rankings becoming increasingly more important for measuring universities global competitiveness.

Over the last years, university rankings have underpinned and accelerated changes of academic work practices, supporting the introduction of market-based salaries with merit or performance (Hazelkorn, 2014). Specifically, recruitment and promotion strategies have become increasingly reliant on ranking data, on the basis that these help to improve institutions’ rankings. As a consequence, more weight has been given to the type of research that faculty undertakes and where it is published, prioritising international high-impact journals rather than other formats. Although there are various criticisms about ranking methodologies and their implications for the quality of education and research of HEI (Collins and Park, 2015), as well as sound proposals for alternative models that better fit the idea of sustainable universities (Boni and Gasper, 2012; Lukman et al., 2010), the increased relevance of rankings strongly influences strategic HEI decisions (Rauhvargers, 2014). Consequently, those universities willing to ‘compete’ in global rankings could,

formally or informally, influence the academics to be aligned with the institutional goals. Examples of this include discontinuing research activities that negatively affect institutional performance, urging academics to increase their research output, quality, and citations in specific fields or disciplines, and rewarding faculty for publishing in highly cited journals (Hazelkorn, 2015). Consequently, unless universities have a clear institutional commitment to SD, these globalising and competitive trends can affect the proper integration of SD in research functions as well as other university functions.

3. Research methods

The research aim here was to compare and characterise the scientific production of a community of academics involved in activities related to the GDEE initiative (Pérez-Foguet et al., 2018).

The methods included the following steps:

1. Analysis of key international reference rankings and their data sources.
2. Sample selection within the GDEE community
3. Analysis of the research publications registered in the Scopus database.
4. Definition and operationalization of disciplinary diversity indexes.
5. Generation of an overlaid journal map based on data downloaded from Scopus.

First, key international reference rankings and their data sources were analysed as current external drivers of university transformations. Second, two groups of academics were selected based on their role within the GDEE initiative and SHD expertise. Third, a bibliometric analysis of the research publications of the GDEE community using Scopus database were performed. The fourth step was focused on the definition and operationalization of two disciplinary diversity indexes: i) the Shannon diversity index for the analysis of the degree of disciplinary of individual researchers, and ii) the Rao-Sterling index for the analysis of portfolio of publications of the two groups. These two indexes, characterised by different level of complexity, provided complementary information. Finally, results were analysed using journal maps generated from the Scopus database. These maps can be interactively overlaid with journal distributions and used as a basic framework to project and visualize a specific dataset, such as portfolio assessment (Leydesdorff et al., 2015).

3.1 Analysis of key international university rankings and their data sources

Over the last decade, university rankings have become increasingly more important in measuring the global competitiveness of universities. The Academic Ranking of World Universities (ARWU, 2015) started in 2003 and is considered the most influential of university ranking systems; it was soon followed by others, such as the QS World University Rankings and the Times Higher Education World University Rankings, leading to the current proliferation of ranking systems.

The indicators of the top university rankings are linked to the main scientific databases. The Web of Science (WoS) and Scopus are, by far, the most frequently used databases by different scientific fields for literature searching purposes. Table 8 compares the number of journals covered by both databases. The Scopus database, introduced by Elsevier Science in 2004, is the largest searchable citation and abstract source of scientific literature. WoS, provided by Thomson Reuters, includes the largest historical citation trackbacks (1990 to present) and a unique search method, using cited reference searching. It includes the Science Citation Index-Expanded database (SCI-E), with over 8,500 major journals across 150 disciplines, and the Social Science Citation Index database (SSCI), with over 3,000 journals across 55 social science disciplines (see <http://wokinfo.com>). Both databases are commonly used for calculating the impact factor of scientific journals, through the Journal Citation Report. WoS also includes the Essential Science Indicators (ESI), available as a 10-year rolling file with slightly over 6,500 journals from SCI-E/SSCI, which cover emerging science trends as well as influential researchers and institutions in different fields of research.

Table 8 Coverage of the Scopus and WoS databases. Titles of journals, books and proceedings. Source: <http://adat.crl.edu> (September 2015)

	Overlap Titles	Unique Titles	Total Titles
Scopus	11377	8432	19809
Web of Science	11377	934	12311

Scopus classifies journals into 27 subjects, which in turn are clustered into four main subject areas: health, life, physical science, and social science. The category ‘multidisciplinarity’ is considered a subject itself but is used only for a reduced number of

journals. Both specialized and general journals can be classified in more than one subject. For this reason, a total of around 30% of the records are estimated to be duplicated in Scopus (that is, journals classified into two or more subjects of Scopus) (Chadegani et al., 2013). Conversely, the ESI classifies journals in only one of its 22 subjects.

In the ranking systems, universities are mostly evaluated with a limited number of scientific domains that rely on main scientific databases. For instance, indicators of the ARWU related to scientific publications in the field of engineering/technology and computer science (ENG) only consider the articles indexed in specific engineering-related fields of the SCI-E/SSCI and the articles of the highly cited authors of engineering-related ESI fields. Consequently, and especially in technical universities, institutional policies could discourage those research initiatives that are not aligned with the specific engineering fields of the main scientific databases, by not providing appropriate incentives or visibility. As a result, the described trends represent potential barriers to the research production based on knowledge areas that are still perceived to be ‘peripheral’ with regard to traditional core engineering research areas, such as SD. One specific contribution of this research is the analysis of the scientific publications of the sample using the ARWU categories, after a conversion of bibliometric data from Scopus.

3.2 Sample selection

More than three hundred academics, mostly lecturers in the field of engineering from different European technical universities, were involved in diverse activities of the GDEE project, such as: i) elaboration of training materials; ii) coordination and evaluation of online courses addressed to academics; and iii) attendance of courses. A detailed description of these activities can be found elsewhere (Pérez-Foguet et al., 2018). With respect to this research, it is worth mentioning that almost one hundred contributors, mostly academics, closely collaborated to develop training materials and teaching resources and to give, coordinate, and evaluate online courses. In addition, more than two hundred academics, interested in receiving trained in SHD, participated in one or more GDEE online courses offered in three European countries.

For the purpose of this study, two groups of the GDEE community, with different degrees of expertise and involvement in SHD, were selected to analyse their scientific production. The first group contained 43 ‘contributor’ experts in SHD issues, who are authors of the GDEE training materials, including both theoretical (GDEE, 2014) and practical (GDEE,

2015) resources that were used to developed the nine online training courses addressed to engineering academics. The contributor group comprised mostly academics and researchers in the field of engineering, who were selected from 16 universities from five European countries (Ireland, Italy, Spain, Sweden, and United Kingdom) based on their expertise in specific SHD issues. (Note that professionals involved in global learning issues and NGOs practitioners also collaborated on the development of different materials and courses).

The second group contained 47 ‘participants’ in the GDEE training initiative, who completed one or more online courses offered through the Spanish learning platform. The course structure consisted of nine online short courses, each lasting approximately three weeks. All registered participants could access materials and activities without completing the course. For this research, only those participants who completed all activities to satisfy the courses’ criteria for earning a certificate were selected. These were mostly lecturers and engineering PhD students, from fifteen Spanish, two Portuguese, and one Swedish university, who were interested in acquiring SHD competences. Figure 9 presents the percentage of the professional categories of the sample for the participant group (left) and the contributor group (right). The category ‘other’ comprises professionals in training of entities and NGOs related to global learning issues.

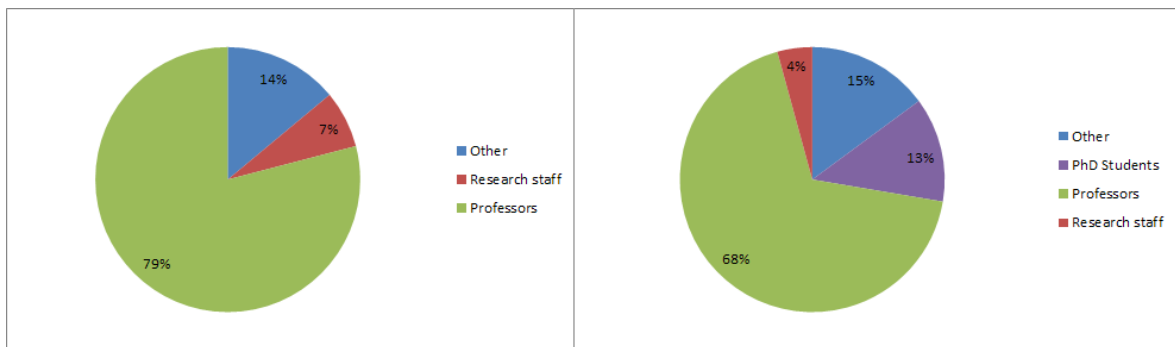


Figure 9 Professional categories of the groups of participants (left) and contributors (right).

Our research included: i) a bibliometric analysis of the scientific publications of the two groups, and ii) a characterization of common trends and similarities of the scientific productivity of these collectives, following the insight of previous research (Hassan et al., 2013).

3.3 Analysis of the research publications of the GDEE community registered in the Scopus database

All information needed to select publications for each researcher, including the full name, university affiliation, and address, were available to the authors. As the analysis focused specifically on the scientific publications of a selected number of known authors, no advanced searching/analytic features were needed. For this reason, two main characteristics were prioritised for selecting the database for conducting the analysis: i) availability of accurate and comprehensive information on the scientific publications of the targeted researchers, to minimise possible author ambiguity issues; and ii) inclusion of a broad range of journals and publications for each researcher, in order to characterise researchers' profiles taking into account the highest number of scientific contributions.

Three scientific databases, namely Google Scholar, Scopus, and WoS, were initially taken into consideration prior to conducting the analysis. As the Google Scholar interface was found to be not particularly suitable, the authors excluded the possibility of using software interfaces to analyse specific Google metrics. Consequently, only Scopus and WoS were evaluated. After examining the most recent scientific literature comparing the two different databases (Lasda Bergman, 2012; Minasny et al., 2013; Roales-Nieto and O'Neill, 2012; Torres-Salinas et al., 2009; Vieira and Gomes, 2009), different trials were conducted by selecting the publications of specific authors using Scopus and WoS. The Scopus searching feature 'Author Identifier' – matching author names according to their affiliation, source title, subject area(s), and co-author(s) – was found to be accurate and more rapid than the WoS feature 'Distinct Author Sets'. Contextually, a higher number of publications were included after performing author searches with Scopus than with WoS, confirming previous studies comparing the two databases (Abrizah et al., 2013; Chadegani et al., 2013; Harzing and Alakangas, 2016). This characteristic of Scopus was found particularly appropriate for analysing the GDEE community, which comprised a number of young academics and PhD students, with a number of publications in lower-impact journals. Further, as Scopus does not have complete references prior to 1996, it was not an obstacle for the purpose of this research. Thus, after comparing the two databases, Scopus was deemed to be better suitable overall than WoS for analysing the publications of the two groups.

Nonetheless, WoS presents some advantages for analysing the results using ARWU fields. In fact, the ARWU fields are based on the five categories of the ESI classification (with

the exception of multidisciplinary): natural sciences and mathematics (SCI); engineering/technology and computer sciences (ENG); life and agriculture sciences (LIFE); clinical medicine and pharmacy (MED); and social sciences (SOC). Journal articles classified under the category ‘multidisciplinary’ were clustered into one of the five ARWU fields on a per-paper basis.

The various journal-level taxonomies applied by scientific databases hampered a clear correspondence between the different database classifications. Although sound alternative classifications have been proposed (Science-Metrix, 2016), no single classification scheme has been widely adopted by the international bibliometric community to date. In order to analyse data gathered from Scopus through the ARWU categories, the authors developed a table of correspondences among Scopus Subject areas, including their subclassifications, the five ARWU fields, and the corresponding ESI categories (Table 9). Note that the Scopus area of physical sciences was split in SCI and ENG fields in the ARWU. Further inconsistencies, which are indicated in the table with an asterisk, included: i) the category of arts and humanities is not considered in the ARWU indicators; ii) psychology is not considered in the ARWU for the indicator of highly-cited researchers; and iii) the ESI category ‘social sciences, general’ is split and assigned on a paper-by-paper basis into the SOC or MED field of the ARWU (see website for an exhaustive description of the ARWU fields; ARWU, 2015). It is worth highlighting that, due to the relatively low number of documents examined in this research, all the unclear or doubtful cases that had the inconsistencies highlighted above were assessed on an individual basis.

An ‘author search’ was performed in the Scopus database for each member of the contributor and the participant groups, for a total of 90 authors, by entering each author’s last and first names and affiliation. Data was collected in September 2015, one year after completion of the GDEE courses (Pérez-Foguet et al., 2018). Only about 60% of the members of the GDEE community had a Scopus ID (31 contributors and 22 participants). The lack of an ID corresponds, among contributors, to NGO practitioners and other SD experts with no research publications and, among courses participants, mainly to academics, as well as a few practitioners and PhD students.

After examining the scientific literature of all members of the GDEE community with a Scopus ID, specific data were gathered for each member: the number of journal articles and the number of total contributions, the year of the first contribution registered in Scopus, the h-index, and the number of counts in the different categories of classification

for each journal. In Scopus, all journals can be classified in one or more areas, so that the number of counts in each category can be equal to, or higher than, the number of contributions. Finally, all data were organised in spreadsheets to facilitate a deeper analysis.

Table 9 Correspondence between subjects and categories of Scopus and WoS databases.

Scopus Subject Area	Scopus Subject Area Classific.	ARWU-FIELD	ESI subjects
Physical Sciences	Earth and Planetary Sciences	SCI	Geosciences
Physical Sciences	Chemistry	SCI	Chemistry
Physical Sciences	Mathematics	SCI	Mathematics
Physical Sciences	Physics and Astronomy	SCI	Physics
Physical Sciences		SCI	Space Sciences
Physical Sciences	Engineering	ENG	Engineering
Physical Sciences	Chemical Engineering	ENG	
Physical Sciences	Energy	ENG	
Physical Sciences	Materials Science	ENG	Materials Science
Physical Sciences	Computer Science	ENG	Computer Science
Physical Sciences	Environmental Science	LIFE	Ecology/Environment
Life Sciences	Agricultural and Biological Sc.	LIFE	Agricultural Sciences
Life Sciences		LIFE	Plant & Animal Science
Life Sciences	Bioch., Genetics and Mol. Biology	LIFE	Biology & Biochemistry
Life Sciences		LIFE	Molecular Biology & Genetics
Life Sciences	Immunology and Microbiology	LIFE	Immunology
Life Sciences		LIFE	Microbiology
Life Sciences	Neuroscience	LIFE	Neuroscience
Life Sciences	Pharmacol., Tox. and Pharmceu.	MED	Pharmacology
Health Sciences	Medicine	MED	Clinical Medicine
Health Sciences	Health Professions	MED	Social Sciences, General *
Health Sciences	Nursing	MED	
Health Sciences	Dentistry	MED	
Health Sciences	Veterinary	MED	
Social Sciences	Psychology	MED *	Psychiatry/Psychology
Social Sciences	Social Sciences	SOC	Social Sciences, General *
Social Sciences	Business, Manag. and Accounting	SOC	Economics/Business
Social Sciences	Econ., Econometrics and Finance	SOC	
Social Sciences	Decision Sciences	SOC	
Social Sciences	Arts and Humanities	SOC *	
(all 4)	Multidisciplinary	(all 5)	Multidisciplinary

3.4 Definition and operationalization of *Disciplinary Diversity Indexes*

Stirling (2007) outlines a heuristic of ‘diversity’ in science. Accordingly, the diversity can be generally defined as an ‘attribute of a system whose elements may be apportioned into categories’ (ibidem). Different attributes of the diversity of scientific production can be taken into account for its measurement: i) variety (the number of distinctive categories); ii) balance (the evenness of the distribution); and iii) disparity (the degree to which the categories differ from each other) (Stirling, 2007). The degree of diversity of researcher production can be measured according to these different attributes through specific

indicators, such as Shannon, Herfindhal, Gini, or Rao-Stirling indexes, which have been extensively described elsewhere (Leydesdorff and Rafols, 2011; Porter and Rafols, 2009).

The scientific literature discusses and analyses multiple concepts of disciplinarity in its different variant (multi-, inter-, and transdisciplinarity) (see Wagner et al., 2011, p. 16), some of which focused specifically on sustainability (Binder et al., 2015; Gaziulusoy and Boyle, 2013; McCormick et al., 2016). From a bibliometric perspective, a lack of consensus on the concept of disciplinarity and its measurement is noteworthy (Sanz-Menéndez et al., 2001), as it specifically implies differences in quantitative measurement and a lack of agreement on pertinent indicators aimed at measuring its different variants. Additionally, bibliometric literature explicitly indicates that the term interdisciplinarity has been cause of conflicting meaning. Indeed, Rafols and Meyer (2009) report that the concept of interdisciplinarity is ‘problematic, if not controversial’, and that it is not the most appropriate term to explain the cognitive dynamics at the boundaries of disciplines. The American National Academies (National Academies, 2004) identifies the process of integrating different bodies of knowledge as ‘interdisciplinary research’ (IDR), which includes all variants of disciplinarity (multi-, inter-, and trans-). Accordingly, in this research, the measurement of ‘interdisciplinarity’ refers to IDR including all variants of cross-disciplinary research, following Wagner et al. (2011).

Different approaches for diversity can be applied to compare the interdisciplinarity of researchers of university units: i) diversity of references (Sanz-Menéndez et al., 2001); ii) diversity of citations (van Leeuwen and Tijssen, 2000); and iii) diversity of publications (Carayol and Nguyen Thi, 2005). Due to the characteristic of this research, the latter approach in defining disciplinarity has been selected. Thus, disciplinarity is measured in terms of the spread of researcher’s publications over different scientific domains, according to the journal classification in the main scientific databases.

Two different indexes of disciplinarity diversity are used, respectively: i) the Shannon diversity index, for the analysis of the degree of interdisciplinarity of individual researchers; and ii) the Rao-Sterling index, for the analysis of portfolio of publications of the two groups. These two indexes, described extensively by Leydesdorff and Rafols (2011), are characterised by a different level of complexity and, in this research, provided complementary data. On the one side, the Shannon index reflects how many different types of journals – according to a specified classification of disciplines or categories – exist in a specific dataset (variety) and, simultaneously, how these journals are distributed

in a given classification (evenness). Higher values of the index indicate a more diverse set of publications, whilst values close to zero indicate that a researcher's publications fall into a lower number of disciplines. Hereinafter, the Shannon diversity index is expressed in relative terms with respect to the highest possible value given a specific number of categories. The values of the relative index fall between 0 and 1. On the other side, the Rao-Stirling index captures not only the variety and the evenness of researchers' publications in different disciplines (similar to the Shannon index) but also the degree of 'disparity' of such disciplines – that is, the difference of these disciplines among themselves, taking into account the ecological distance between different subsets of journals. Whilst the Shannon index can be easily computed for each researcher using a set of publication data downloaded from a scientific database, the Rao-Sterling index relies on a specific metric of distances between the various disciplines, provided by science maps (Rafols and Meyer, 2009). In contrast to the Shannon index, the Rao-Stirling index has no absolute reference values. Consequently, the value of this interdisciplinarity index is meaningful only when is compared to similar cases, for example by comparing the portfolios of publications from different research groups (Leydesdorff et al., 2015). Accordingly, this study specifically compared the two groups of the GDEE community analysed, respectively contributors and participants.

3.5 Generation of an overlaid journal map based on data download from Scopus

Bibliometric analysis can be greatly enriched with the help of appropriate visualisations. Science maps are suitable tools for this purpose, being visual representations built on the overall science interrelationship based on journal articles (Boyack et al., 2005; Leydesdorff et al., 2015; Rafols and Meyer, 2009). Science maps allow to visually identify major areas of science and their sizes, similarities, and interconnectedness. In fact, similar to cartographic maps, they provide a broad view of the whole scientific landscape, representing a base upon which particular research cases can be situated and intuitively analysed. They are particularly helpful as they allow different aspects of disciplinarity to be analysed, such as: i) variety (e.g., the number of disciplines); ii) balance (e.g., the distribution of the disciplines, expressed by the relative size of nodes in the map); and iii) disparity (the degree of difference among the disciplines, expressed by the distance between the nodes of the map) (Porter and Rafols, 2009).

Given the purpose of this study, the base map tool called 'Overlay.exe for data from Scopus' (Leydesdorff et al., 2015) was selected, This is a global map of science that can

be interactively overlaid on journal distributions in sets downloaded from Scopus. Any set of publication downloaded from Scopus can be projected onto a base map by displaying specific mapping information. Subsequently, the portfolio of documents can be assessed in terms of the spread across journals and journal categories. Furthermore, base maps can be used as distance metrics for measuring interdisciplinarity in term of journal composition, using the Rao-Stirling diversity index (Leydesdorff et al., 2015).

4. Results

Table 10 summarizes the overall results of the analysis of the two groups. It is worth highlighting some differences between GDEE contributors and participants. First, the contributors presented a higher number of research profiles in Scopus (ID) than the participants. Nonetheless, the participants with Scopus ID were scientifically more productive, with 16.5 papers/person instead of 7 of contributors. Second, the research publications of the contributors, with both articles and total contributions considered, were more concentrated in the category of engineering than those of participants. Finally, the contributor articles showed a higher degree of disciplinary diversity, with an average of 2.63 categories, versus 1.98 for the participants. Equivalent results were found when considering total contributions, with 2.53 and 1.87 categories for contributors and participants, respectively.

Table 10 Summary of the main characteristics of analysed groups. From left to right: number of people with or without a Scopus ID, number of papers (Np), number of total contributions (Nt), percentage of contributions in engineering subjects, total number of hits in different categories (Ncat), ratio of Ncat over Np, number of hits of total contributions (Ntca), and ratio of Ntca over Nt.

	ID	No ID	Np	Nt	Eng/ Np	Eng/ Nt	Ncat	Ncat/ Np	Ntca	Ntca/ Nt
Contributors	31	12	220	352	60%	64%	578	2.63	891	2.53
Participants	22	25	362	536	36%	42%	715	1.98	1003	1.87
Total	53	37	582	888	45%	51%	1293	2.22	1894	2.13

Figure 10 presents the total number of scientific contributions of the whole sample analysed, which comprises all members of the two groups, according to Scopus classifications. It can be appreciated that, in coherence with the target of the project, the average profile of the academics of the GDEE community has the most relevant activity in the field of engineering, followed by environmental science and chemical engineering.

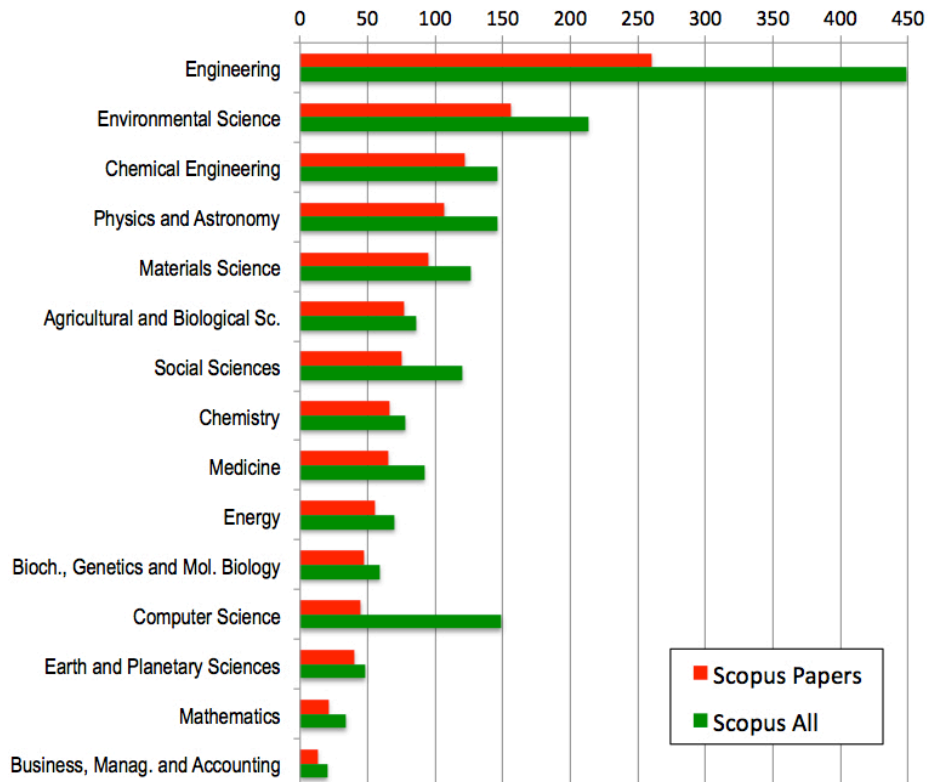


Figure 10 Number of scientific contributions by Scopus categories of the whole sample analysed (only the categories with more than 10 contributions are displayed). Scientific articles are displayed in red. All researchers' contributions (including articles, conference papers, and book chapters) are displayed in green.

Figure 11 presents the relative distribution of the scientific publications, papers, and all contributions for the two groups.

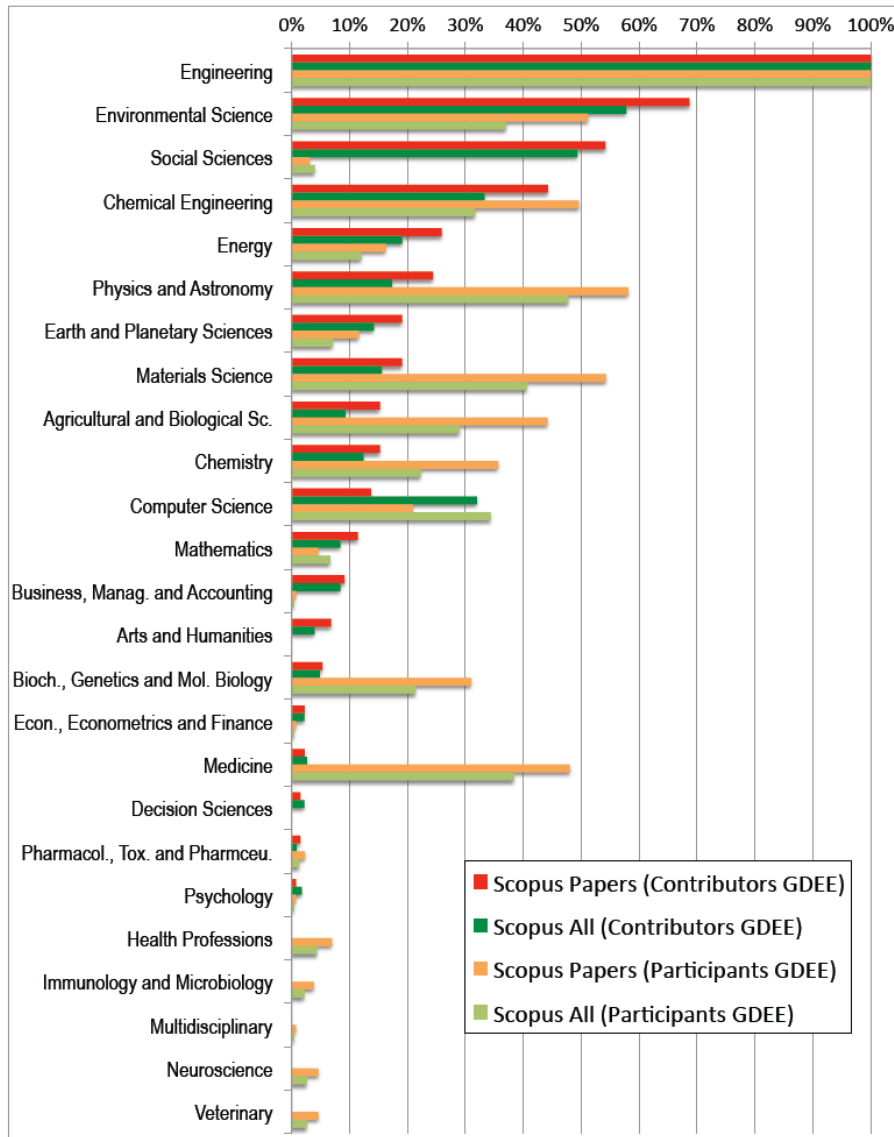


Figure 11 Relative distribution of Scopus subjects in the four sets of data: journal articles of contributors (red), all contributions of contributors (green), journal articles of participants (orange), and all contributions of participants (pale green).

Engineering was the predominant subject in all four cases; thus, it was set as the reference value of 100% for all. Subjects were ordered by decreasing the relative value of articles of contributors. The highest values for the contributor group are in environmental science and social sciences, while the participant group had higher relevance in more categories (such as physics and astronomy, material science, agricultural and biological sciences, and medicine). The relative behaviour of the metrics of the two categories of ‘journal articles’ and ‘all contributions’ can be considered equivalent, except for the subject of computer science. Remarkably, the key areas that differentiate between the two groups are social

science and medicine. In both cases, a particularly relevant research activity of one group in one field is contrasted to a significantly lower activity in the other.

Figure 12 presents the number of articles (left) and all contributions (right) of both groups classified according to ARWU fields. After a conversion of data provided by Scopus, the total number of contributions is displayed, rather than the relative percentages shown in Figure 11. It is worth noting that the influence of potential inconsistencies in correspondences indicated in Table 9 are not relevant since any unclear or doubtful cases were assessed on a per-paper basis. The four groups appear similar at first, except for scaling. With aggregated data, however, it is clearer that the participant group was scientifically more productive than the contributor group in each area except for social sciences. Further, Figure 12 clearly summarizes the main difference between both groups: namely, the scientific productivity in the categories of medicine and social sciences.

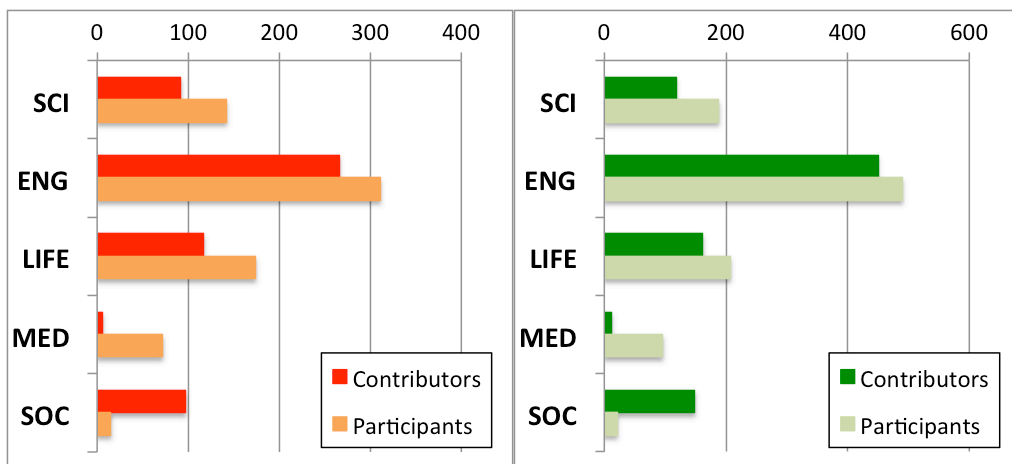


Figure 12 Number of journal articles (left) and all contributions (right) in Scopus by GDEE contributors and participants, classified by ARWU fields.

Figure 13 shows disaggregated data of the number of articles published and the year of the first contribution registered in Scopus of three groups: participants (red circle), contributors (pale blue triangle) and contributors with more than five publications in social science (blue triangle). The decision to display contributors active in social science in a separate series responded to the need to analyse the distribution of the researchers with publications in significantly diverse areas of science, such as engineering and social science. The figure shows that all levels, from junior to more consolidated profiles, were evenly represented among the three groups analysed. No top scientists, that is, with more than one hundred articles, were represented in the collective examined. Remarkably, there

was no polarisation – meaning, a clear distinction into two completely opposing groups – in the distribution of the groups of participants and contributors. Similarly, the researchers of the contributor group who were ‘active in social sciences’ were evenly distributed throughout the whole chart, with no dependence relationship with either timing or volume of publications.

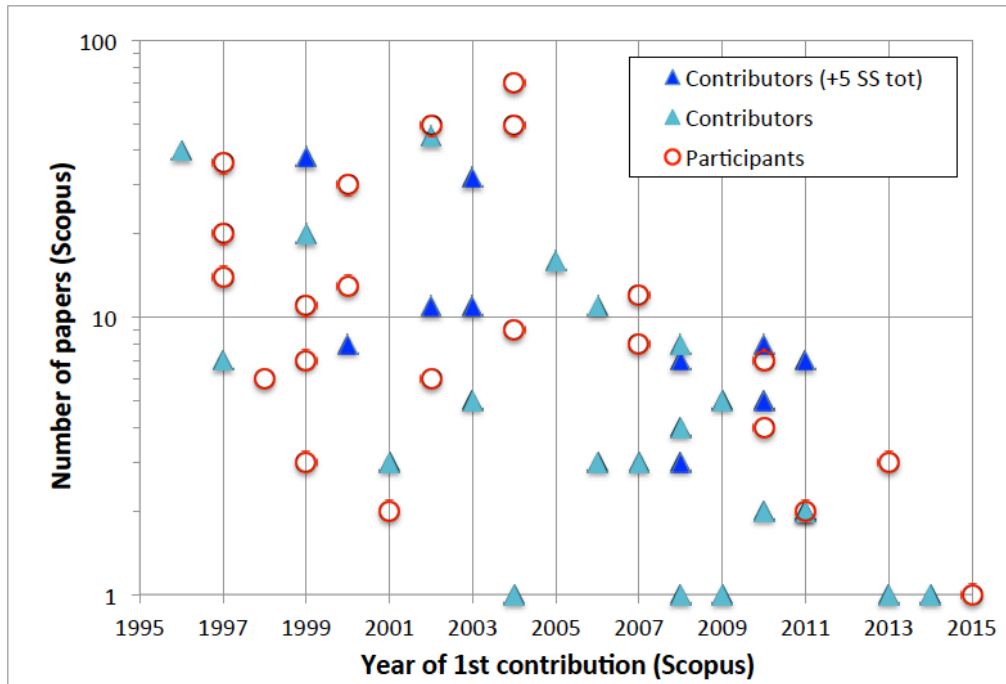


Figure 13 Number of journal articles in Scopus compared to year of first contribution, disaggregated by three different groups: contributors with more than five publications in social sciences (blue triangle), contributors (pale blue triangle), and participants (red circle).

Three subgroups of junior to more consolidated researchers, with different research profiles, were well identifiable. It is worth noting that two-thirds of participants were active in Scopus before year 2005, roughly one third of whom had a higher research profile of more than 30 articles. Focusing on participants, it is notable that people with diverse profiles were interested in being trained in SD. A more junior profile can be noted in the lower-right quadrant (e.g., those with less than 10 publications and a first contribution in 2007 or later). The lower-left quadrant shows academics who started their activity before 2005 but most likely did not follow it (possibly focusing on teaching). Finally, the upper-left quadrant shows a group of consolidated researchers.

Figure 14 presents the number of total contributions in Scopus related to the Shannon Index. The index is expressed in relative terms, with respect to the value of a completely uniform distribution between the 27 categories. The value of the index for each researcher depends on the percentage of his/her contributions in each one of the different Scopus categories in which the journals are classified. The spread of subgroups was similar to that previously analysed. The cases with few contributions to a single subject were easily identified in the lower-left quadrant. The highest value of the Shannon index corresponds to a contributor with 53 publications in 12 subjects, quite uniformly. Note that the relative index value multiplied by 27 is 11.5. The second highest value of the relative Shannon index, 37.9%, corresponds to a participant with 14 publications in total, distributed also uniformly and in 12 categories. The maximum number of categories to which a single academic has contributed is 15 (specifically, this was by a contributor with an index value of 25.4%). Medium-to-high scientific productivity was not related to the interdisciplinarity of research and, again, there was no polarisation between the two groups. Additionally, neither the volume nor the disciplinarity of the research characterize the contributors with scientific production in social sciences.

The majority of the researchers of the two analysed groups had a Shannon index score between 9% and 17%, which roughly corresponded to 2 to 4 Scopus subject areas. It could be argued that research productivity of the majority of the community was not very diverse. Nonetheless, it is worth stressing that the diversity expressed with these data was related to the number of disciplines in which the different researchers are active (the degree of variety), according to Scopus classification. No information was provided on the degree of difference among disciplines (disparity).

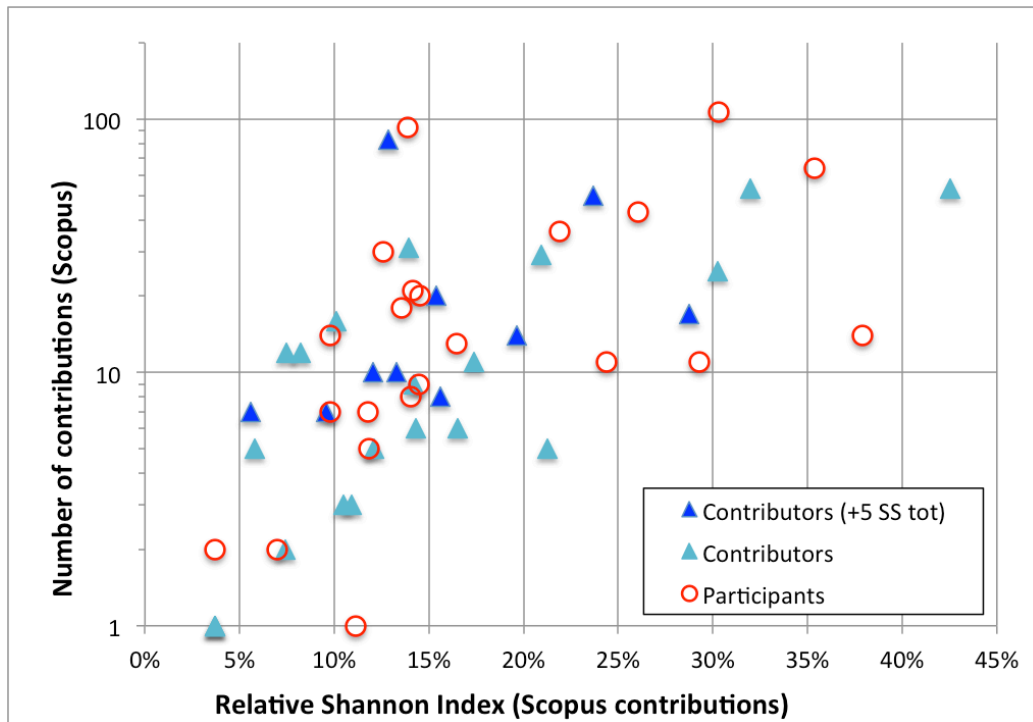


Figure 14 Number of total contributions in Scopus compared to Relative Shannon Index, disaggregated by three different groups. Contributors with more than five publications in social sciences (blue triangle), contributors (pale blue triangle), and participants (red circle).

Figures 15 and 16 show the journals distribution of the scientific production of the groups of contributors and participants, respectively, highlighted onto a base map of global science (in pale green), according to Scopus classification.

The visualisation, with the help of overlaid Science Maps, significantly improves the data provided by the indicators. Journals of engineering fields were well visible at the top of the two maps (blue and yellow), as these were predominant subjects of research for both groups. Thereafter, the contributors and the participants showed an opposing journal distribution, with journal categories related to social sciences journals (shown on the left) represented more by contributors (Figure 15), and categories related to medicine, biotechnology, and medical physics (shown on the right) represented more by participants (Figure 16).

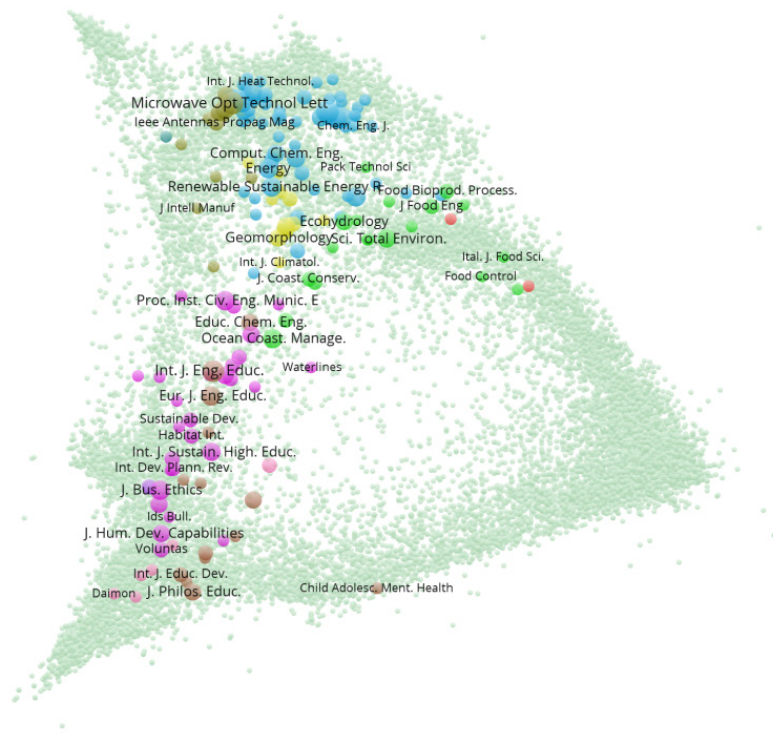


Figure 15 Journal distribution of the scientific output of the group of 'contributors'.

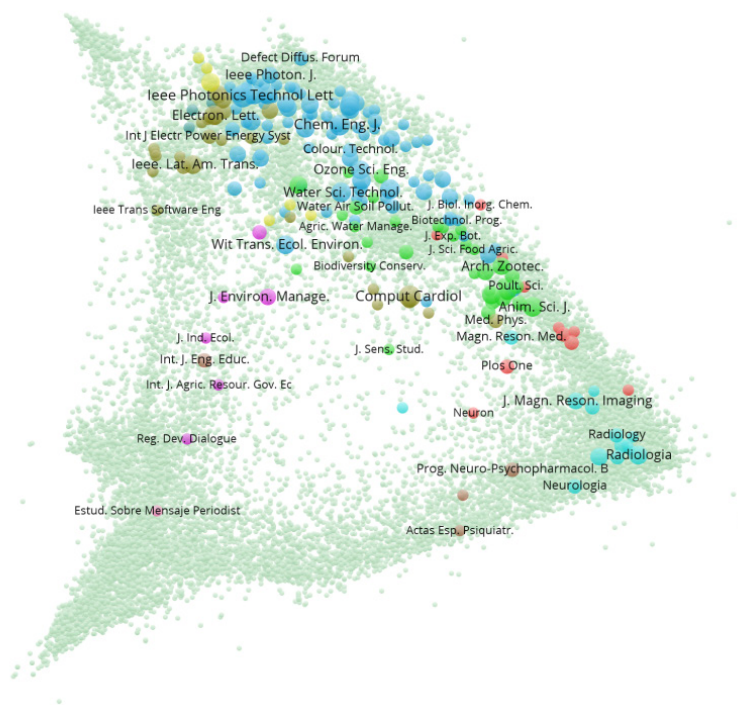


Figure 16 Journals distribution of the scientific output of the group of participants.

As outlined earlier, the visualisation provided by science maps was particularly useful to assess the interdisciplinarity of the different portfolios of publications of the two groups analysed. In addition, the Rao-Sterling interdisciplinary index can be operationalized using the metrics of the distance among the respective subsets of journals provided by the map. The calculation of the Rao-Sterling index showed that the degree of interdisciplinarity of the two groups was similar. In fact, the index was almost identical for the two groups, with 0.1848 for contributors and 0.1892 for participants. It can be visually appreciated that, although the two groups spread across the map in opposite directions, the relative distances between core engineering publications and other publications classified in different disciplines was similar.

5. Discussion

This research presented a comparative analysis and characterization of the scientific production of a community of academics involved in training activities aimed at facilitating the integration of SHD in academic practices. Specifically, two groups of academics with different degree of expertise and involvement in SHD were compared: a group of experts in SHD with a group of academics participating in training courses on SHD in the framework of the European initiative GDEE.

As mentioned above, the methods focused on bibliometric analysis, with specific attention paid to the role of university rankings as current external drivers of university transformations that potentially can negatively affect the integration of SD in university functions. Accordingly, data gathered from the Scopus database were analysed not only using Scopus categories, but also using the fields of one of the most influential ranking systems, the ARWU. The methodology was tested with a group of 90 people, the great majority of whom are academics.

The community analysed covered a wide spectra of academics, from junior to more consolidated research profiles. Unexpectedly, the analysis revealed that a high percentage of academics involved in the training initiative had no Scopus ID. Thus, it was assumed that they have had no scientific contributions in international conferences or indexed journals. This could be due to focusing their academic activity specifically on teaching and/or disseminating their research mostly at local level.

The main findings show that the academics of the two groups presented a scientific production specifically focused in engineering-related disciplines, in line with the sample analysed. Notwithstanding, their research extends to other disciplines, and the analysis indicates a significant difference between the two groups. After comparing the respective portfolios of publications, the main difference is that contributors showed relevant research activity in the disciplines related to social science, while participants were significantly active in health science disciplines. The relative concentrations of publications, which can be appreciated through overlaid science maps, shows that the distribution of publications from participants in the medicine disciplinary area of the map are mainly focused in disciplines somehow related to engineering, such as biotechnology, medical physics, magnetic resonance, and radiology. These results partially confirm previous bibliometric studies that highlight common topics of research in sustainability science related to engineering, medicine, and social sciences, of energy and urban planning, biotechnology and medical, and welfare and livelihood, respectively (Kajikawa et al., 2007). Also, more recent studies focused on larger coupled systems are partially reflected in current results (Hassan et al., 2013; Kajikawa et al., 2014). The emerging concept of sustainability science is especially reflected in new scientific approaches towards SD, focusing on inter- and transdisciplinarity, which respond to broader societal expectations and innovative educational perspectives on SD (Dlouhá and Burandt, 2015).

As pointed out earlier, articles of a specific journal can be classified in Scopus simultaneously under more than one subject (Chadegani et al., 2013). Even considering the possibility that a limited number of journals had a double classification, the distribution of publications of the two groups is clearly outlined. The results also confirms that traditional bibliometric analysis can be dramatically improved with the use of visual tools, such as science maps, thereby reinforcing previous bibliometric studies (Leydesdorff et al., 2015, 2013).

It could be argued that the academics within the group of course participants, which included academics with a consolidated research trajectory and a higher degree of interdisciplinary research, were looking for a wider perspective and understanding of the global challenges relevant to SHD, and its relationship to the field of engineering. However, the analysis shows that diverse profiles of academics of the engineering field, from junior to more consolidated ones, are interested in being trained in SHD. For this reason, identifying and helping interested academics to incorporate SD into their research

in all different variations – mono-, inter-, and transdisciplinary – should be included in university policies (Lozano, 2006; Lozano et al., 2013b). This would help to integrate sustainability issues into different levels of the university system (McMillin and Dyball, 2009; Ramos et al., 2015; Sterling et al., 2014). The relevance of the publications related to social science of the groups of experts also confirms previous studies. For instance, Segalàs et al. (2012) compared the understanding of sustainability between a group of experts and students of technical universities and concluded that the experts tend to give more value to the social aspect of sustainability. Specifically, this means how sustainability affects humans (social impact, unbalances, future), and how problems of unsustainability can be solved (values, education, and stakeholders) (ibidem).

It is worth highlighting that the broadness of the research of the two groups presented through the maps, in terms of disciplines covered by their research, is tremendously simplified through ARWU rankings, which consider only publications classified in the field of engineering/technology and computer science (ENG) to compile the ranking of engineering institutions. Bearing in mind the high level of internalisation and institutionalisation of ranking in HEI (Hazelkorn, 2014; Locke, 2014), it is likely that in technical universities, characterised by a strong disciplinarity, this trend could represent a further barrier for all academics interested in engaging in SD; this complements the conclusion from other research focusing on SD drivers and barriers at university level (Lozano, 2006; Lozano et al., 2013b; Stephens et al., 2008; Velazquez et al., 2005).

The indexes calculated for both individual researchers and the portfolios of publications of the two groups show that, at a general level, the two groups presented a similar degree of interdisciplinarity. The Shannon index shows that the diversity of publications of the majority of academics in the two groups was substantially similar in term of number of disciplines. In addition, the analysis shows that there is no relationship between the degree of interdisciplinarity and the scientific productivity of those researchers who focusing their scientific publications in disciplines related to social science. The Rao-Stirling index, analogously, presented almost identical values of interdisciplinarity between the two groups analysed. In this case, though, the index also captured the degree of disparity among the disciplines characterising the different subsets of journals of the two groups, relying on the values provided by the distance metrics of science maps, according to Leydesdorff et al. (2014). Within these metrics, the scientific publications related to the disciplines of social science and health sciences were at an equivalent distance from the central core of publications focused on engineering, which is similar for the two groups. It

can be easily appreciated, by visualising the maps, the specular distribution of the publications of the two groups onto the global map of science.

The limitations of this study are mainly related to the sample involved in the analysis and the methodology applied. A reduced sample size implies lower precision of estimates. This study, however, highlights the main differences between two groups of data, rather than focusing on a detailed comparison of similar characteristics of both groups. Thus, it can be considered that the reduced sample size did not affect main conclusions reached. Another limitation is related to origin of the sample, the GDEE initiative, integrated almost exclusively by academics related to European institutions, and specifically with interest in SHD initiatives. Further analyses including a broader community of researchers, from both origin and SD perspectives, would reinforce these preliminary results.

With respect to the methodology, it can be argued on the one hand that the characterisation of the community could be more accurate if it included qualitative information, in addition to research production. As this regards, the next chapter complements the present analysis by including a survey addressed to all academics within the cohort with information about their research, teaching activities, and social outreach activities. The improved understanding of the GDEE community did not modify results obtained here, but helps to define further strategies of SD promotion. On the other hand, comparing data provided by Scopus with the WoS database could have provided additional insight. This would be encouraged for further analyses involving larger communities; in the case analysed here, an initial screening of the WoS database showed a severe reduction in the research footprint of the community. Finally, the analysis of other university rankings could be also explored in order to find evidence to confirm the findings of this study.

CHAPTER 3

KEY CHARACTERISTICS OF ACADEMICS PROMOTING SUSTAINABLE HUMAN DEVELOPMENT WITHIN ENGINEERING STUDIES

Abstract

In the last decade, a growing number of technical universities and engineering faculties have been promoting various initiatives aimed at integrating sustainable development in their activities. Despite the fact that the commitment of the academic staff has been widely recognised to have a key role in university change processes towards sustainable development, few studies have specifically analysed the characteristics of academics engaged in such processes. The present study provides an analysis and a profile of a group of academics, participating in a training programme on sustainable human development, granted by a European fund. The methods employed include a semi-structured survey, focussing on the academic activities and social outreach of the participants, complemented by a bibliometric analysis of their scientific production.

The findings show: 1) an interdisciplinary profile of the academics, 2) an integration of sustainable development principles in all academic activities and 3) a promotion of those principles outside the university. It is emphasised that the commitment of this type of academics can facilitate a cultural change in engineering education, as well as more holistic transformations of universities towards sustainable development. The paper concludes by providing recommendations for leaders and policy makers of higher education institutions on the implementation of appropriate policies and mechanisms to facilitate faculty engagement in sustainable development.

Keywords: Engineering; Sustainable development; Academic staff engagement; Sustainable Development Goals; Higher education policy.

This chapter is partially based on:

Lazzarini, B., Pérez-Foguet, A., Boni, A., 2018. Key characteristics of academics promoting Sustainable Human Development within engineering studies. *Journal of Cleaner Production* 188, 237–252. doi:10.1016/J.JCLEPRO.2018.03.270

Lazzarini, B., Pérez-Foguet, A., Boni, A. 2016. A characterisation of the academic profile of a community of professors involved in Sustainable Human Development: the case of the Global Dimension in Engineering Education, in: *22rd International Sustainable Development Research Society Conference Proceedings*, 13-15 July 2016, Lisbon, Portugal, pp. 419–438.

1. Introduction

Scientists and scholars have analysed and discussed the multiple barriers that hinder the consolidation of SD into higher education (Ferrer-Balas et al., 2008; Lozano, 2006; Velazquez et al., 2006). In a more recent study, Verhulst and Lambrechts (2014) associate these barriers with different factors, such as: i) the lack of awareness or interest academics, students and staff have concerning SD issues; ii) the structure of higher education, characterised to be conservative and disciplinary with strong resistance to change in the functions of education and research; and iii) the lack of resources and adequate institutional support.

Despite there being many examples of SD implementation throughout the higher education system, those efforts made in universities are generally compartmentalised (Lozano et al., 2015). Contextually, scientific literature highlights that the role of academic staff engaged in sustainability practices in the different functions of universities is essential in order to promote transformation at university level (Krizek et al., 2012; Lozano, 2006) and to better connect with the wider society (Ferrer-Balas et al., 2008). These academics, often heralded as ‘sustainability champions’ (Lozano, 2006) are generally not sufficiently supported nor incentivised by academic institutions (Hoover and Harder, 2014).

Technical faculties and universities are particularly susceptible to barriers to change concerning SD. The main reason is that engineering education is primarily focused on technical aspects and, traditionally, there have not been many opportunities to develop broader knowledge and skills to respond to the complexity of global problems related to SD, as reported by Crofton (2000). Despite the calls for a reform of engineering curricula to integrate SD (Watson et al., 2013), and the need to restructure teaching approaches (Leal Filho and Nesbit, 2016), engineering methods and tools are still characterised by a strong practical orientation and mostly focus on finding and implementing solutions that work with certainty and predictability (Halbe et al., 2015). Responses to calls for curricula reform in engineering are, in general, relatively limited (Fenner et al., 2005; Lozano and Lozano, 2014; von Blottnitz et al., 2015). It is worth highlighting specific approaches and strategies aimed at integrating SD principles into technical universities (Egelund Holgaard et al., 2016; Lozano et al., 2015; Rose et al., 2015). In addition, complementary perspectives have focused on promoting the convergence between engineering and development studies (Boni and Pérez-Foguet, 2008; Pérez-Foguet et al., 2005), following

the theoretical framework of Sustainable Human Development (SHD) (Absell, 2015). However, significant updates of engineering curricula seem to be relatively limited (Davidson et al., 2010), and much of the strategies adopted by technical universities have primarily focused on developing individual courses on SD (von Blottnitz et al., 2015).

For these reasons, reconsidering the role of academics engaged with SD as agents of change within university institutions and as interfacial connectors between universities and societal organisations is of primary importance to enhance university transformation (Hugé et al., 2018). Limited research is available on the research and academic profiles of academics integrating SD into their practice.

Bearing this context in mind, this chapter aims to provide evidence to answer the question: are there any common patterns in the academic profile of academics engaged in SD practices? The research is designed to answer this question through a mixed approach. On the one hand, through a semi-structured survey aimed at analysing academic aspects such as: teaching innovation, the relation between teaching and research, the integration of SDGs in teaching and research, social outreach and collaboration, etc. On the other hand, through a bibliometric analysis – to expand the research profile of academics engaged in sustainability.

To accomplish this task, data have been collected by distributing the survey to a group of academics involved, at different levels, in the training activities promoted in the framework of the European initiative GDEE, a collaborative project promoted by a consortium of technical universities and NGOs, aimed at improving the competences of academics in SHD. The bibliometric analysis was carried out by using maps of science, and focused on the academics that answered the survey.

The rest of the chapter is structured as follows. The second section contains scientific literature on academic staff engagement, specifically focusing on technical universities. The third section describes the GDEE initiative. The fourth section introduces the research methods. The fifth section describes the empirical results. The sixth section contains the discussion of the findings. Finally, the seventh section presents our conclusions and proposes recommendations.

2. Methods

Starting from the context described earlier, this research aims to analyse and characterise a group of academics of the GDEE community, in order to enhance the understanding of the academic profile of academics engaged in SD issues in order to:

- identify the characteristics and common patterns of this community;
- foster the replicability of the initiative in different contexts.

The group comprises 90 academics with different degrees of expertise and involvement in SD practices, but who are all engaged and interested in integrating sustainability. On the one hand, 43 contributors who are experts in SHD, who closely collaborated in the development of training materials as well as in the delivery of online courses. On the other hand, 47 participants who are academics from engineering or science-based Spanish universities, who completed one or more courses offered through the Spanish virtual platform.

Methods included: i) an analysis of a semi-structured survey aimed at deepening the understanding of the academic profile of academics involved in activities related with SD; and ii) a bibliometric analysis of the scientific publications of those academics that have completed the survey in order to expand their scientific profile.

2.1 *Semi-structured survey*

A survey aimed at broadening the understanding of the academic profile of academics engaged in GDEE activities was carried out.

Following the work of Larrán-Jorge et al. (2015), as a reference point for the design and validation process of the questionnaire, the data collection tool was designed and validated through different steps. First of all, an extensive literature review was performed to design the survey. Various fields were explored prior to identifying a list of potential items to be included in the survey, such as: teaching innovation (Segalàs et al., 2010, 2009; Wiek et al., 2011), outreach (Lozano-García et al., 2006), SD research (Clark and Dickson, 2003; Kajikawa et al., 2007), academic satisfaction towards accreditation (Byrne et al., 2013; Caballero Rodríguez, 2013). Then, based on Foxcroft's methods (Foxcroft et al., 2004), two survey validations were conducted: the first involving a group of researchers belonging to the GDEE Spanish universities partners; and the second involving a group of

academics of the Institute of Sustainability Science and Technology of the Polytechnic University of Catalonia.

The survey was divided into six categories:

1. Academic profile of the respondents (affiliation, accredited years of teaching and research)
2. Teaching activities: including specific information on subjects taught by respondents (such as student evaluation and grading criteria) and engagement of respondents in teaching innovation activities.
3. Research activities: including the main research fields of respondents, especially focusing on the relation between research and teaching activities.
4. Degree of integration of SDGs in the teaching and research activities of respondents, as well as the perceived relation between crosscutting competences adopted by HEI and SDGs.
5. Social outreach and collaboration: entities with which respondents regularly cooperate and the type of collaboration.
6. Perception of the recognition/evaluation of academics merits including university evaluation and regional/national accreditation agencies.

The survey was comprised of 23 closed-ended questions, mostly employing a 5 point Likert scale from ‘totally disagree’ to ‘totally agree’, as well as ranking and multiple-choice questions, which were complemented with 13 open-ended questions to ask respondents for broader information based on their experience on various academic issues (see Appendix E). Table 11 shows the survey structure in detail.

Table 11 Survey structure.

Academic profile of the respondents	
Professional data	Open-ended questions
Teaching activities	
Subjects taught	Open-ended questions
Evaluation and grading criteria	Open-ended questions
Engagement in teaching innovation activities	Likert scale; Open-ended questions
Research activities	
UNESCO nomenclature for fields of science and technology	Open-ended questions
Relation between research and teaching	Likert scale; Open-ended questions
Sustainable Development Goals	
Degree of integration of SDGs in teaching and research	Likert scale
Relation between SDGs and university transversal competences	Likert scale
Social outreach and collaboration	
Collaboration with social entities	Likert scale; Multiple-choice
Research dissemination channels	Ranking
Perception of the recognition/evaluation of academic merits	
University monitoring of academic activities	Multiple-choice
Recognition of academic merits and promotion procedures	Likert scale; Open-ended questions

The aim of the survey was not to assess the engagement of academics in each specific SDG, but rather to identify the degree of integration of SDGs concept in the respondents' teaching and research activities, specifically those related to engineering. For this reason, SDGs were grouped into twelve items, described in Table 12.

Table 12 Sustainable Development Goals grouping.

Description	SDG
End of poverty and hunger	(SDGs 1, 2)
Ensure healthy lives and well-being	(SDG 3)
Inclusive, equitable and quality education	(SDG 4)
Reduce inequalities and achieve gender equality	(SDGs 5, 10)
Clean water and sanitation	(SDG 6)
Affordable and clean energy	(SDG 7)
Promotion of decent work and sustainable industrialisation	(SDGs 8, 9)
Sustainable cities/communities and sustainable production and consumption patterns	(SDGs 11, 12)
Climate change adaptation	(SDGs 13)
Conservation and sustainable use of ecosystems	(SDGs 14, 15)
Promotion of peace, justice and strong institutions	(SDG 16)
Promotion of global partnership for SD	(SDG 17)

Due to the characteristics of the survey, and the need to integrate it with a bibliometric analysis, the authors decided to send it only to those members of the two groups analysed who had an active research profile. Consequently, as a preliminary step, it was decided to perform an ‘author search’, using the Scopus database, for each member of the groups, for a total of 90 authors, by entering the authors’ last name, first name and affiliation. Findings showed that, roughly, 65% of the members of the community had a Scopus ID. The reasons for this are diverse. The group of contributors comprised of a number of NGO practitioners and other experts that do not have international research publications, whilst course participants included a number of professors without a Scopus ID, along with PhD students. Finally, the survey was sent to 56 academics using the survey tool SoGoSurvey (<https://www.sogosurvey.com/>), and made available for a period of three months.

2.2 Bibliometric analysis

In conjunction with the survey, a bibliometric analysis was performed, aimed at deepening the research profile of the academics completing the survey.

This analysis included the following steps:

- The selection and analysis of the research publications of the GDEE community registered in the Scopus database.
- The generation of an overlaid journal map based on data downloaded from Scopus.
- The operationalisation of a disciplinary diversity index.

A comparison of the two scientific databases – Scopus and Web of Science (WoS) – was conducted, taking insights from the analysis made by Chadegani et al. (2013). Finally, Scopus was selected as our principal data resource due to its better adaptability to the characteristics of the GDEE community. In fact, the interest of the research was to identify and analyse the highest number of publications of the group of academics and Scopus has a broader coverage of journals, although they may be of lower impact. The bibliometric analysis was only performed for those academics that completed the survey, following the methodological proposal of a recently published study on research profiling of academics engaged in SD (Lazzarini and Pérez-Foguet, 2018).

Traditional bibliometric analysis can be greatly enriched with the help of appropriate visualisations. Science maps, for example, are suitable tools for this purpose. They are visual representations built on the overall science interrelationship based on journal articles (Leydesdorff et al., 2015; Porter and Rafols, 2009), and help to visually identify major areas of science, their size, similarity and interconnectedness. Specifically, the use of science maps is particularly helpful since they enable the analysis different aspects of disciplinarity such as: i) the variety of “disciplines”; ii) the balance, or distribution, of disciplines (expressed by the relative size of nodes in the map); and iii) the disparity, or degree of difference, between the disciplines (expressed by the distance between the nodes of the map) (Porter and Rafols, 2009).

Given the purposes of this study, we opted for a base map tool called ‘Overlay for data from Scopus’ (Leydesdorff et al., 2015), namely a global map of science that can be interactively overlaid with journal distributions in sets downloaded from Scopus. Base maps can be used as a basic framework on which the journal distribution of a set of documents downloaded from Scopus can be projected. Subsequently, it is possible to

assess the portfolio of documents in terms of the spread across journals and journal categories.

Furthermore, base maps can be used as distance maps for measuring interdisciplinarity in terms of journal composition (Leydesdorff et al., 2015). Simple and more complex indicators have been developed for the purpose of assessing interdisciplinarity of researchers (Porter et al., 2007). For the purpose of this research we opted to use the Rao-Stirling index. Unlike other diversity indexes commonly used to assess interdisciplinarity, such as Shannon or Herfindal indexes (Leydesdorff and Rafols, 2011), Rao-Stirling accounts not only for the variety, namely the number of disciplines of the publications analysed, but also for the disparity, namely the ecological distance among different subsets of journals (Porter and Rafols, 2009).

3. Results and discussion

3.1 Analysis of the survey

The survey was answered by 18 respondents from 7 HEI, representing a 33% response rate of all the academics contacted. Even with the limitations related to the reduced number of respondents, the survey highlights important issues related to academic activity that complements the information provided by the bibliometric analysis.

3.1.1 Profile of the survey respondents

The respondents were mainly affiliated with Spanish polytechnic universities, with 7 respondents from the Polytechnic University of Catalunya, 4 from the Technical University of Madrid and 3 from the Technical University of Valencia. A further 3 respondents were from the Engineering faculties of different Spanish universities: Castilla-La Mancha, Rovira i Virgili and Alcalá. Additionally, an academic from the faculty of Architecture of the Universidade do Porto (Portugal), who completed GDEE courses through the Spanish learning platform, also answered the survey. Figure 17 presents the faculty affiliation of the respondents. The faculty of Industrial Engineering was the most heavily represented, accounting for 35%, followed by Civil Engineering (29%) and Telecommunication Engineering (12%). Other university faculties indicated were Agronomic Engineering, Architecture, Chemical Engineering and Environmental Sciences. Department affiliation followed roughly the same distribution.

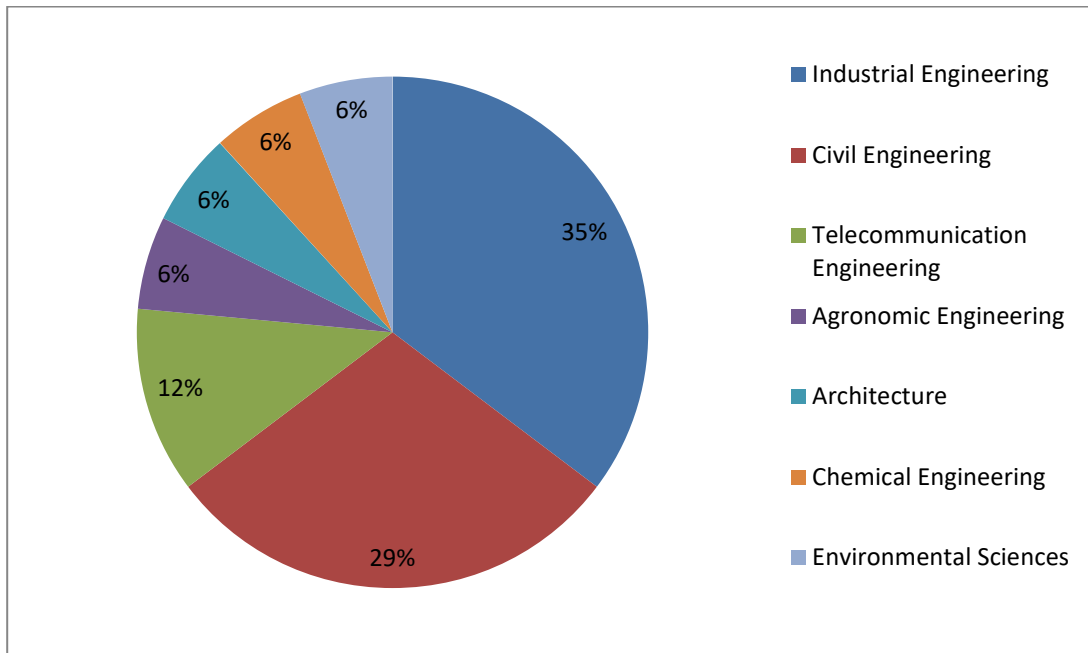


Figure 17 Faculty affiliation.

The majority of the respondents were doctors (83%), and females appeared to be more motivated to answer the survey (56%). A total of 56% of the respondents were aged between 40–49 years. The group of respondents comprised both junior and senior researchers. Figure 18 shows the distribution of the years of professional teaching and research accredited by quality agencies.

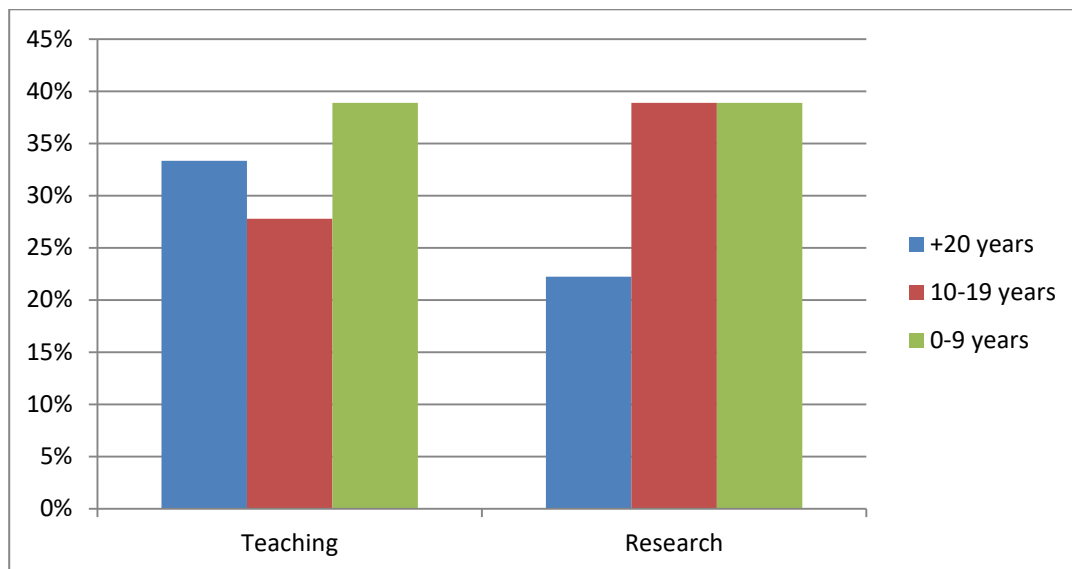


Figure 18 Distribution of accredited years of teaching and research.

3.1.2 Teaching activities

The respondents were asked to indicate 1 to 3 subjects they taught, with reference to the last 5 years of their academic activity. Subsequently, they were asked to provide further information on specific issues, namely: i) the integration of mechanisms for the active participation of students; ii) the evaluation and grading criteria employed to evaluate students. In total 28 subjects were indicated by respondents, 16 subjects of bachelor's degrees and 12 of master's degrees. Additionally, respondents were asked to provide information on their engagement in activities of teaching innovation.

The great majority (85%) of the subjects indicated by respondents had mechanisms for the active participation of students. Among the examples provided, shown in Figure 19, teamwork activities were, by far, the most important mechanism indicated, followed by online forums (offered via virtual platforms or social networks), then case study preparation and debates. It is worth mentioning a specific case highlighting teamwork activities in fieldwork, in the framework of a subject partially developed on-field, in Morocco.

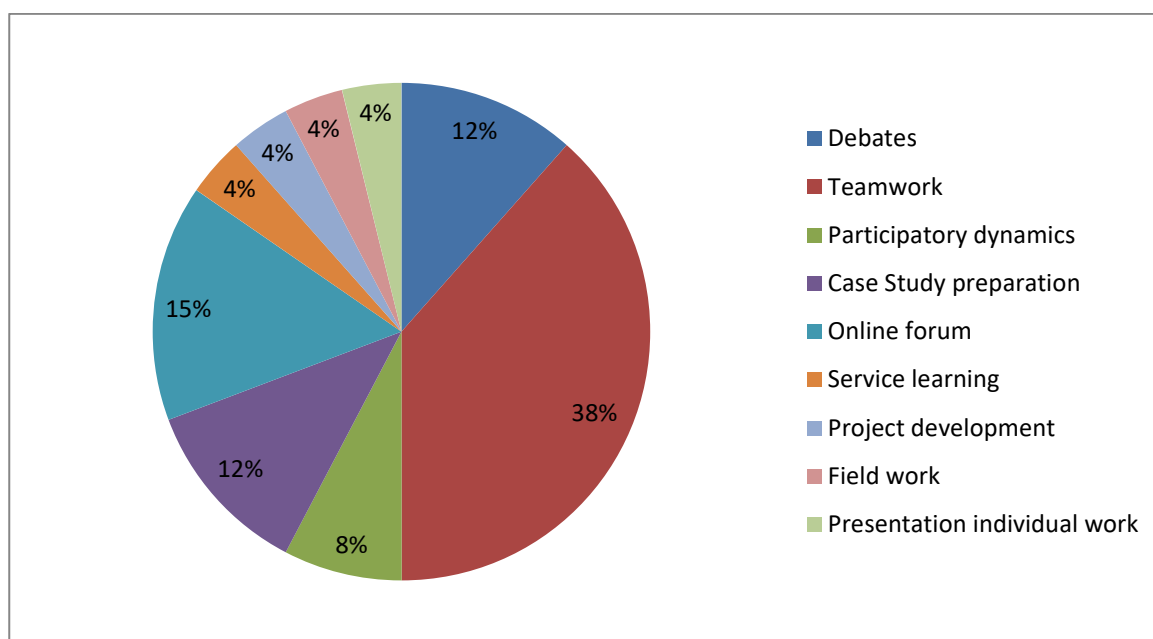


Figure 19 Active participation mechanisms.

Figure 20 presents the evaluation and grading mechanisms selected by respondents. It can be noted that the 'final exam' is the factor which respondents gave most importance to,

followed by ‘teamwork’ with a significant presence, and by ‘independent work’. Peer evaluation was indicated as the least important factor considered when grading students.

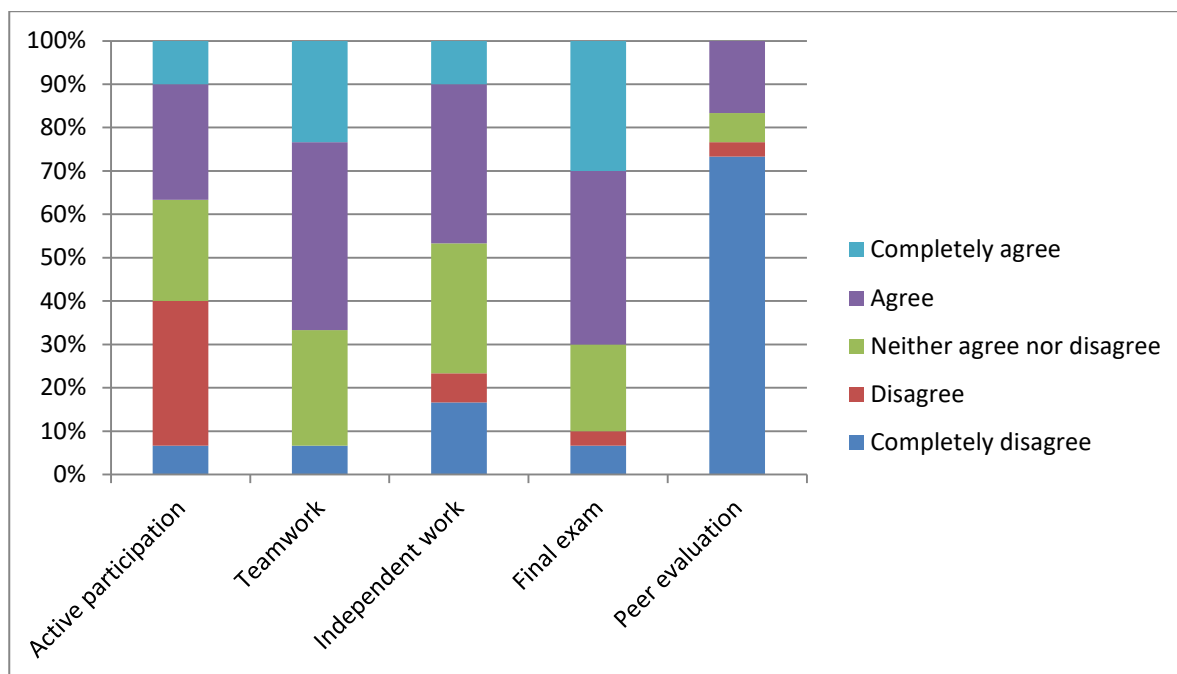


Figure 20 Evaluation and grading mechanisms.

The great majority of the respondents (94%) indicated that their respective universities have integrated transversal competences in their curricula. A total of 83% of these academics consider that these competences are related to GD. A thorough analysis of the websites of the universities where respondents are affiliated revealed that the great majority of these institutions have made efforts to increase their commitment to SD, specifically by including transversal competences in their teaching functions. The institutional promotion of the competences related to SD are formally focused on different concepts, which can be summarised as:

- Sustainability and social commitment
- Environmental and professional ethical responsibility
- Environmental and social responsibility
- Environmental awareness
- Knowledge of contemporary challenges
- Application of critical thinking

The institutions examined followed different strategies to implement transversal competences in teaching: proposing different levels of mastery of specific competences, placing the emphasis on specific concepts – sometimes not referring explicitly to SD – promoting the same transversal competences for all the courses offered or setting specific competences for particular courses, etc.

Overall, when related to environmental and social issues, the competences analysed generally aim to enhance the knowledge and comprehension of the main concepts related to SD, specifically from an approximation highlighting the complexity and interrelation of contemporary environmental, social and economic phenomena, particularly from the perspective of globalisation. Given that the decisions and actions of engineers and architects have a great impact on the environment and society, the message of the universities examined is that these categories should work for the public interest, following professional ethics and sustainability principles.

Those universities offering also bachelor's and master's degree programmes in geography also include transversal competences emphasising concepts such as:

- Sensitivity to ethnical and cultural diversity
- Acknowledgement of diversity and multiculturalism
- Promotion of human rights, democratic principles and gender equality
- Promotion of a culture of peace

More than half of the institutions examined offer resources through their webpage for those academics willing to expand these issues as well as courses addressed to academics. However, promoting these initiatives does not ensure that the respective institutions effectively implement transversal competences within their teaching systems.

A total of 83% of the respondents claimed that they personally integrate GD into their teaching activities through transversal competences and 67% and 61%, respectively, consider that GD are also integrated in bachelor's/master's thesis and in other subjects of the courses of study. The survey asked academics to indicate public links detailing information on personal teaching activity, such as syllabuses, subject guides, etc. A detailed analysis of this public material has been used to detail the ways through which academics integrate SD issues into their teaching subjects. The authors took the work of

Allen et al. (2008) as a reference for analysing the integration of sustainability concepts into engineering curricula in HEI in the United States. Following the proposal of the cited authors, the subjects indicated by respondents were divided into the four main approaches used to integrate SD in the curricula: i) integrating sustainable engineering concepts into traditional engineering courses, was the most represented category, accounting for 61%; ii) courses focusing on technologies predicted to be important in developing sustainable engineering solutions, with 18%; iii) dedicated sustainable engineering courses, with 11%; and iv) interdisciplinary courses developed in collaboration with a non-engineering department, represented 11%.

Overall, the respondents were involved in activities related to teaching innovation (Figure 21). It is noteworthy that a significant activity undertaken was that of promoters of courses of teaching innovation (50%). A total of 39% indicated that they were the author of publications or articles on this subject and only 22% participated in courses on teaching innovation. Among the most relevant issues specified as promoters, are noteworthy training activities relating SD (in its different variants as GD, SHD, Education for Development, Education for Sustainable Development) and engineering. Other issues indicated were: learning and service, urbanism, renewable energy and geographical information systems (GIS).

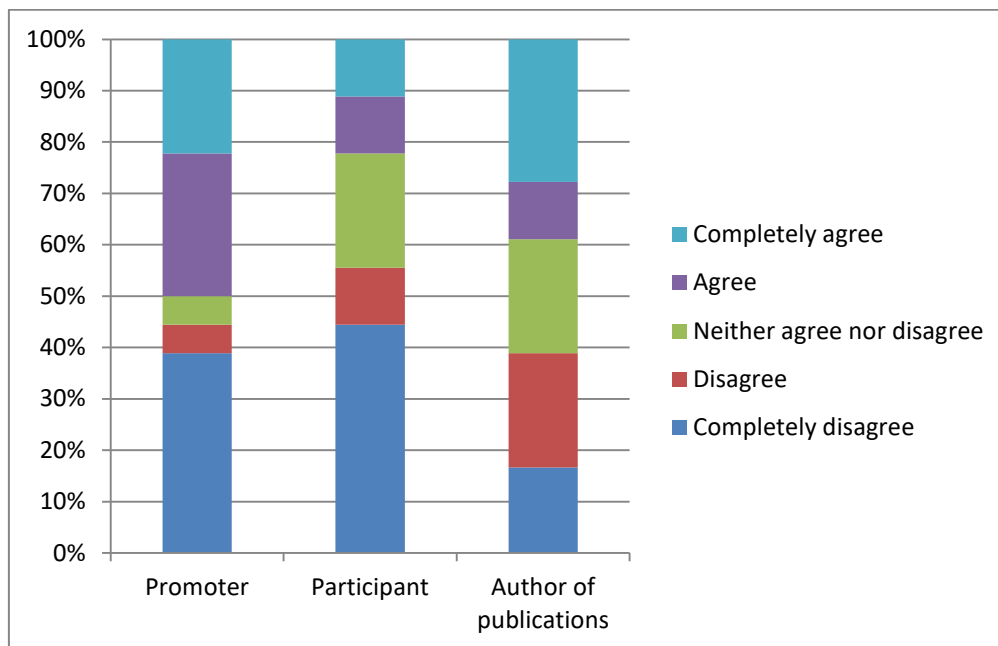


Figure 21 Engagement in teaching innovation activities.

Focusing on teaching activity, it is worth emphasising that the results indicate that transversal competences adopted by universities are, for the great majority, related to the SD, namely: extreme poverty, human rights, globalisation, equality issues and environmental challenges. Furthermore, respondents state that global dimensions are integrated, through transversal competences, in different subjects of the courses of study, as well as through bachelor's/master's theses. On the one hand, this is coherent with research on the implementation of sustainability practices in the Spanish university system, whose findings indicate that sustainability practices related to students are those most commonly implemented (Larrán-Jorge et al., 2015). The findings of the present research confirm the presence of sustainability integration, specifically regarding engineering faculties. On the other hand, this contrasts with scientific literature focusing on engineering studies (Davidson et al., 2010; Lozano and Lozano, 2014) that substantially reports that incremental improvements focused on individual courses on SD are more common approaches than holistic curriculum reforms; specifically in engineering faculties (von Blottnitz et al., 2015). For this reason, it is essential to further explore the effective integration of SD in engineering courses.

3.1.3 Research activities

Respondents were asked to indicate up to three codes from the UNESCO nomenclature for the fields of science and technology on which they focus their research activity. In order to facilitate the interpretation of the data, the responses of the academics were grouped into the 'fields' of this nomenclature, namely: the top concepts of Science and Technology, encoded with the first two digits of the complete six-digit code. They specifically refer to the most general sections of the proposed nomenclature, which comprise several related disciplines and sub-disciplines. Table 13 shows the main fields of research indicated by the respondents; the full response, including the digits indicating disciplines and sub-disciplines, can be consulted in Appendix D.

In coherence with the profile of the respondents, *Technological Sciences* was the most represented field, accounting for 53%. This field was followed by *Sociology*, with 10%, then by *Science of Arts and Letters* and *Economic Sciences*, both representing 8%. It is worth highlighting that sub-disciplines linked to Sociology were related to development studies and Urban Sociology; while those linked to *Science of Arts and Letters* were mainly related to Architecture and Urbanism.

Table 13 Foremost research fields of the respondents.

Code	UNESCO Fields	Responses	%
12	Mathematics	1	2%
25	Earth and Space Sciences	3	6%
33	Technological Sciences	27	53%
53	Economic Sciences	4	8%
54	Geography	2	4%
58	Pedagogy	3	6%
59	Political Science	1	2%
62	Science of Arts and Letters	4	8%
63	Sociology	5	10%
71	Philosophy	1	2%

The relation between teaching and research activities can be described, overall, as positive. Referring to the subjects indicated in the survey, 68% of the respondents indicated that the subject they teach is strongly correlated with their research activities. Furthermore, 94% consider that their teaching and research activities reciprocally feed into each other. This is confirmed in the related open-ended questions, where many academics describe that research conducted in the area of SD provides the basis on which most of their teaching activity is grounded. Specifically, case studies based on research outcomes are successfully used in class to complement theoretical issues. In fact, respondents highlighted that sharing the results of research initiatives with students provides the subjects they teach with more credibility, and is highly appreciated by students. It is also noted that teaching master's subjects adds an element of personal flexibility to professors by prioritising research topics that can easily be integrated into teaching practice.

The positive correlation between research and teaching expressed by the respondents is not consistent with the scientific literature that highlights, conversely, a lack of integration of these university functions as a barrier to further engage in efforts towards SD (Verhulst and Lambrechts, 2014). A deficit of integration is further confirmed by research conducted on Spanish universities that reports less practices aimed at fostering research on sustainability. Additionally, studies explicitly emphasise the insufficiency of interdisciplinary research groups capable of providing solutions according to the different perspectives of sustainability (Larrán-Jorge et al., 2015). This seems to reinforce the analysis of Ferrer-Balas et al. (2008) on the importance of interdisciplinary groups as connectors within and outside university boundaries.

3.1.4 Sustainable Development Goals

Figure 22 shows the degree of integration of SDGs into teaching activities. The SDGs that respondents integrated most into their teaching were ‘Climate change adaptation’ (SDG 13), followed by ‘Conservation and sustainable use of ecosystems’ (SDGs 14, 15) and, in third place, with the same value, ‘Clean water and sanitation’ (SDG 6) and ‘Sustainable cities/communities and sustainable production and consumption patterns’ (SDGs 11, 12). The SDGs with the lowest recognition were: ‘Promotion of decent work and sustainable industrialisation’ (SDGs 8 y 9), followed by ‘Promotion of peace, justice and strong institutions’ (SDG 16) and, in last position, ‘Promotion of global partnership for SD’ (SDG 17).

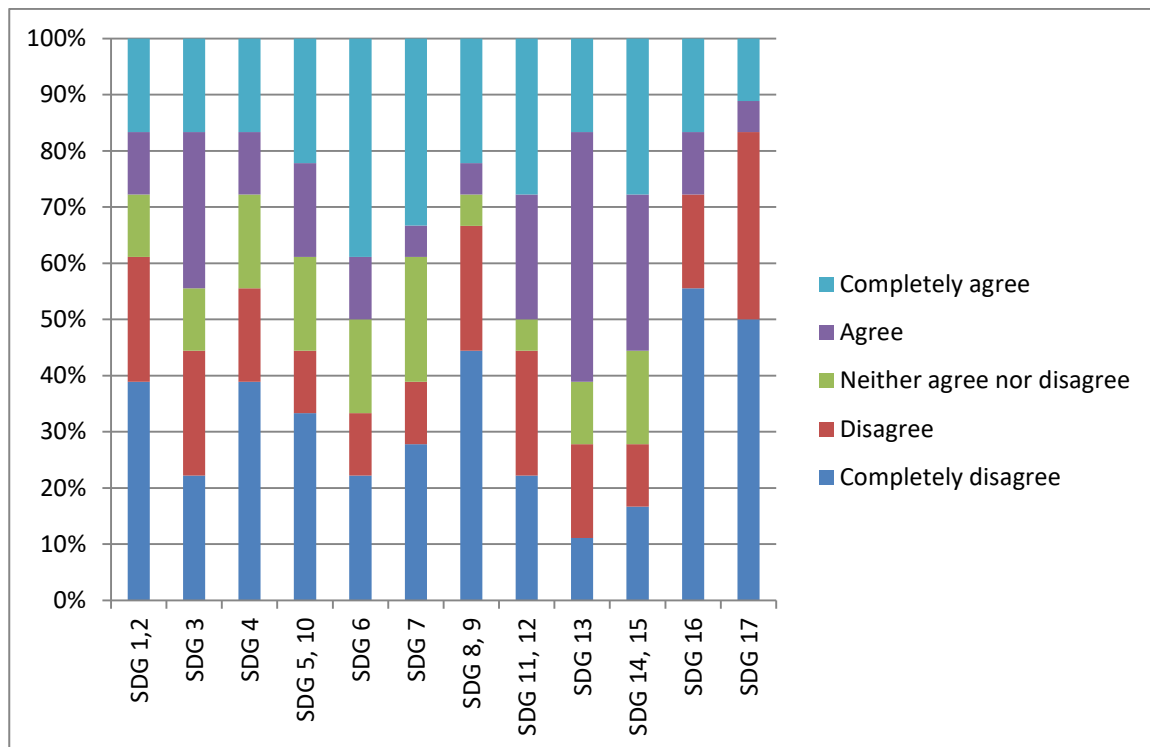


Figure 22 Integration of SDGs into teaching activities.

Figure 23 shows the degree of integration of SDGs into research activities. The SDGs most acknowledged were ‘Conservation and sustainable use of ecosystems’ (SDGs 14, 15), followed by ‘Clean water and sanitation’ (SDG 6) and ‘Sustainable cities/communities and sustainable production and consumption patterns’ (SDGs 11, 12). The SDGs least integrated into research were: ‘Promotion of global partnership for SD’ (SDG 17), ‘Affordable and clean energy’ (SDG 7) and ‘Promotion of peace, justice and strong institutions’ (SDG 16), in the last position.

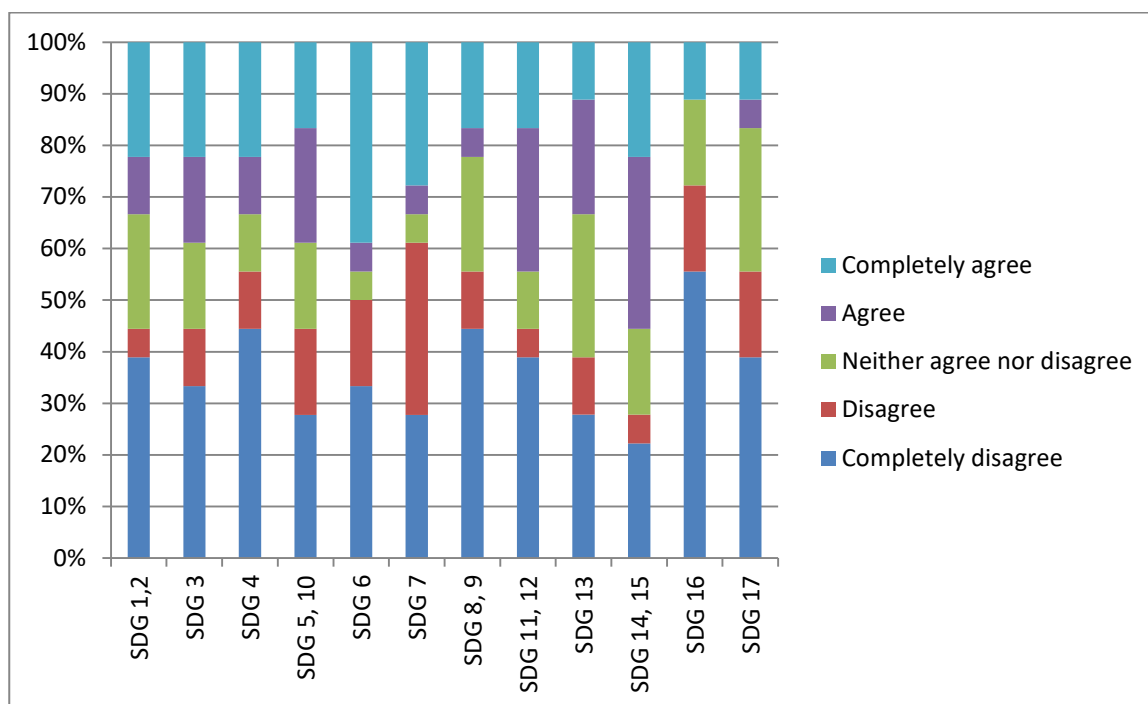


Figure 23 Integration of SDGs in research activities.

A further question in this section was the perceived relation between SDGs and transversal competences implemented in respective universities. In this case, between 28% and 39% of the respondents opted not to provide information on the various items corresponding with SDGs. Presumably, a lack of significant knowledge of the various transversal competences conditioned the answers to this specific question. Those academics that chose to respond indicated ‘Sustainable cities/communities and sustainable production and consumption patterns’ (SDGS 11, 12) as the item with the highest relation between transversal competences and SDGs, followed by ‘Affordable and clean Energy’ (SDG 7) and ‘Conservation and sustainable use of ecosystems’ (SGDs 14, 15). The lowest relations were accorded to ‘Promotion of peace, justice and strong institutions’ (SDG 16) and ‘Promotion of global partnership for SD’ (SDG 17), respectively.

Results show that the degree of integration of SDGs, in both teaching and research endeavours, is mostly related to topics traditionally closer to scientific and engineering competences (such as climate change adaptation, conservation and the sustainable use of ecosystems, clean water and sanitation, sustainable production and consumption patterns) while, unsurprisingly, other relevant topics more related to social sciences and humanities, such as gender equality, poverty reduction and inclusive/equitable education, show lower levels of integration. This could be related to the separation of disciplines and the lack of

the ability to work across different fields (Lozano et al., 2013a) – recognised as major challenges of engineering curricula reform (Crofton, 2000; Halbe et al., 2015). Nonetheless, bibliometric analysis shows that academics of the GDEE group present a substantial degree of interdisciplinarity in scientific publications.

3.1.5 Social Outreach

Respondents were asked to indicate with which type of entities they usually engage outside the university with the aim of disseminating their academic activities and the kind of relationship they have with such entities. Figure 24 presents the respondents' engagement with different societal entities. The entities with the highest frequency were, respectively: public entities, Civil society organisations (CSOs), NGOs and International Development NGOs. Social and Environmental third sector were the entities with the lowest frequency. Figure 25 shows the specific relationship that participants have with each of the entities stated. It is interesting to note that respondents engage with public entities because of the existence of a project with financial allocation or due to institutional relationship. Conversely, their engagement with CSOs/NGOs and International Development NGOs was mostly due to their own initiative. Student practice activities were mostly concentrated in domestic firms and SMEs.

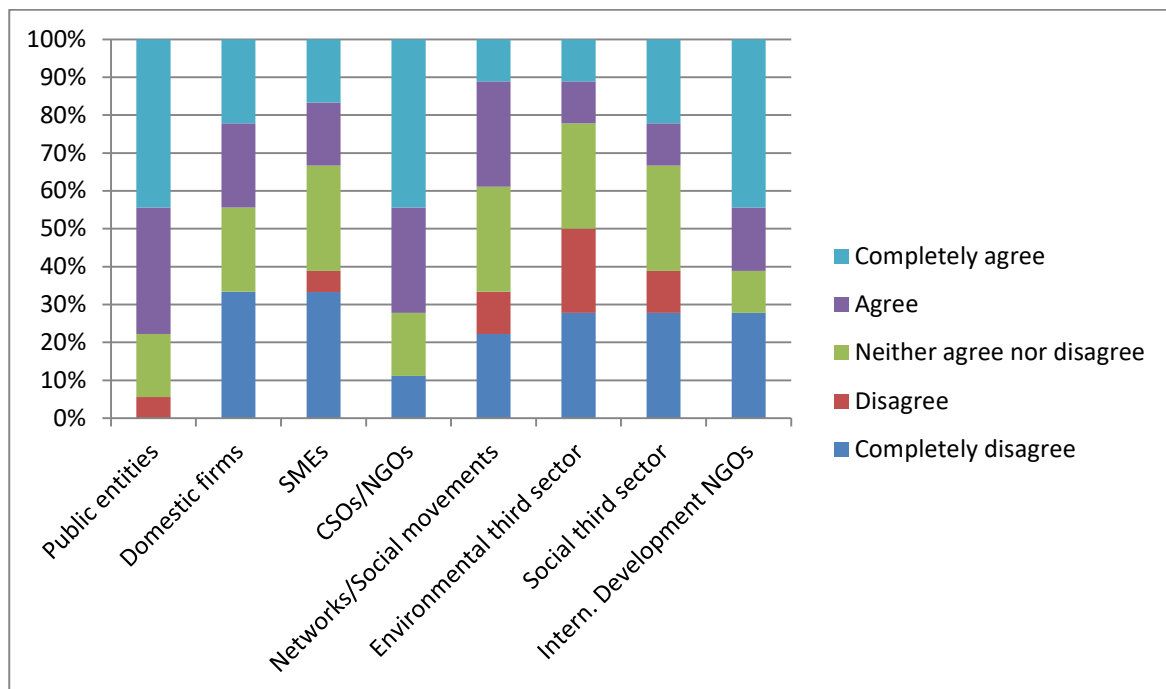


Figure 24 Respondents' engagement with societal entities.

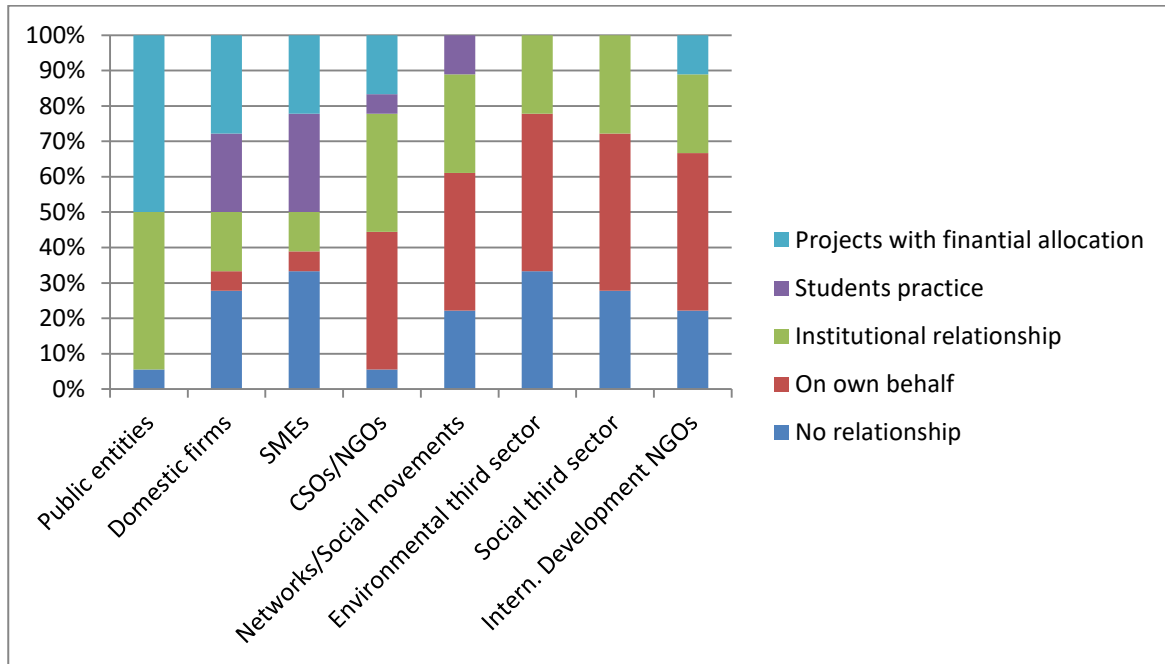


Figure 25 Respondents' relationship with social entities.

Regarding the dissemination of research outcomes, respondents prioritised first quartile scientific journals, followed by international conferences and journals of all databases, as shown in Figure 26. Dissemination addressed to a non-scientific audience, such as popular articles, blogs or press were the items with least relevance.

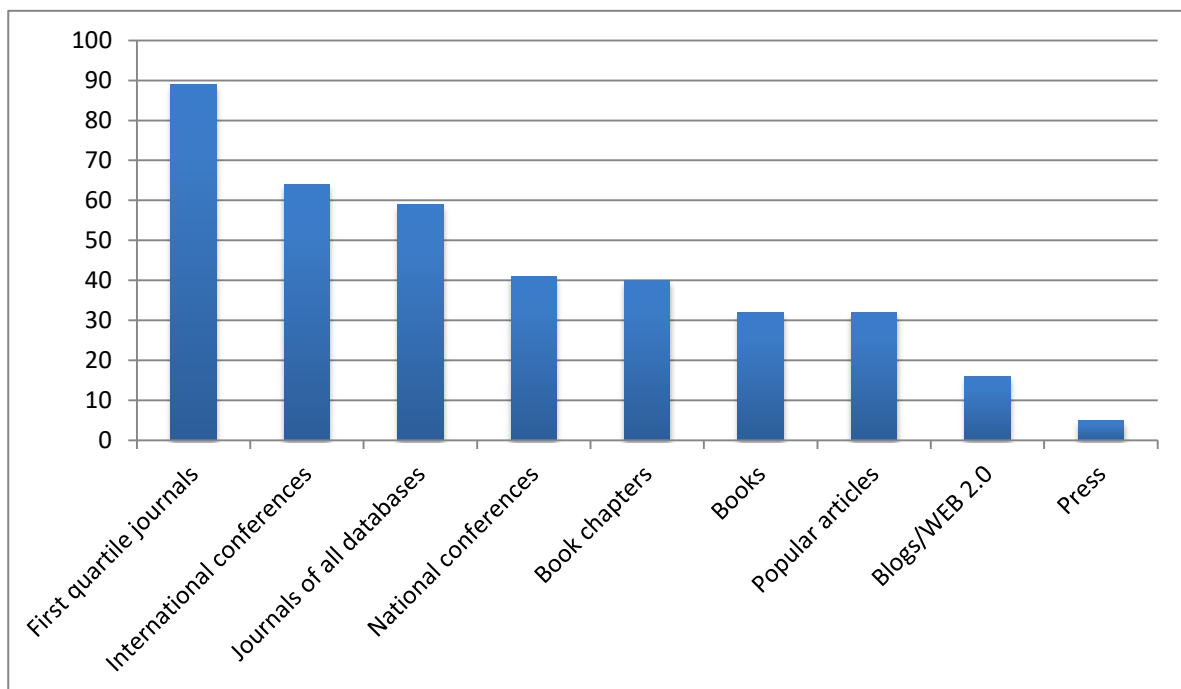


Figure 26 Dissemination of research outcomes prioritised by respondents.

It is noteworthy to mention a lack of consensus on the definition of social outreach of universities and thus also on potential metrics for tracking and measuring the effectiveness of universities' outreach programmes. Generally, social outreach is not included as a rewarded activity of academics. In this research, the analysis of social outreach portrays academics as primarily being engaged with public entities due to funded projects and institutional relationship. Conversely, their engagement with social entities such as CSOs/NGOs is mostly on a personal level. Furthermore, the efforts aimed at disseminating scientific outcomes are mostly concentrated on scientific contexts, while popular dissemination is quite insignificant. This description is consistent with other analyses on the role of academics in the contemporary university, which describe an increasingly "corporate approach" in HEI (Morrissey, 2013) where professional results are emphasised over public service and academics spend an increasing amount of time on managing activities and administrative requirements and less time is dedicated to connecting with the wider society (White, 2015). Furthermore, these results underpin the critics of different agents of the social sector, such as CSOs/NGOs, stating that university has been unable to enhance collaboration channels with social entities (Zolezzi et al., 2013).

3.1.6 Perception of the recognition/evaluation of academics merits

Respondents were asked to select, in a multiple-choice question, all relevant items of the university monitoring of academic activity of professors. Research, with 90% of responses, was the most relevant issue of the monitoring function that universities perform on academic activities, followed by teaching (83%) and knowledge transfer activities (78%). Social Outreach, unsurprisingly, was not indicated as an aspect monitored by universities.

University evaluation mechanisms were not particularly well appraised by respondents. Despite the fact that the Likert scale provides a central value (neither agree nor disagree), a high percentage of the respondents (33%) gave a negative assessment of the evaluation system. Open-ended questions highlighted both positive and negative factors related to the academic evaluation system. Among the former, respondents highlighted the possibility to have access to resources managed by universities, for example resources that the university dedicates to finance specific projects for research or doctoral scholarships. Another positive issue highlighted was the reduction of the teaching load of academics involved in successful research initiatives. The most critical views indicated that the majority of activities carried out by academics are usually not taken into account in the

recognition of academic merits, and that research merits often are not considered for the reallocation of the teaching load among other colleagues.

According to the answers, more than 80% of the respondents have been evaluated by quality accreditation agencies. The majority of them negatively assessed the process of accreditation of academics, indicating various reasons. Firstly, they emphasised that the procedures for accreditation involve burdensome bureaucratic requirements, which are often not entirely transparent. Secondly, some of them criticised the concept of academic quality accepted and applied in accreditation processes, especially stressing the ambiguity of criteria and scales that may lead to considerable disparities between colleagues. Finally, younger academics highlighted different accreditation requirements between senior and junior academics. In fact, in recent decades, Spanish accreditation requirements have been tightened and more demanding requirements, such as leading a European project as Principal Investigator, now concern younger academics.

It is worth emphasising the critical view that the majority of the academics expressed on the evaluation system, for both universities and accreditation agencies. This perception is consistent with research conducted in Spanish universities highlighting that incentives to improve the teaching and research activities of academics are not perceived as adequate (Caballero Rodríguez, 2013). Research is the most relevant item monitored by universities and accreditation agencies, and social outreach was not indicated as a monitored item. This reinforces previous studies suggesting that universities are increasingly focusing on research to evaluate academic merits (Hazelkorn, 2014; Locke, 2014) and that HEI do not foster social outreach (Stephens et al., 2008). Furthermore, the literature indicates that accreditation agencies can play a great role in advancing sustainability in engineering education (Rose et al., 2015). Unfortunately, this role is not always clearly recognised by accreditation agencies.

3.2 Analysis of scientific production

An analysis of scientific publications for each of the 18 academics completing the survey was performed, using the Scopus database. Data were gathered and grouped in order to be processed with the application *Overlay.exe*.

Findings of the bibliometric analysis can be easily visualised in Figure 27, with the help of overlaid Science Maps. The figure shows the journal distribution of the scientific

production of the 18 academics answering the survey, according to Scopus classification, highlighted onto a base map of global science (in pale green). Clearly visible at the top of the two maps, in blue and yellow, are the journals of fields related to engineering disciplines, which are predominant subjects of research of the academics analysed, coherent with the target of the GDEE initiative, as well as journals of Environmental Science, shown in green. Thus, the journal distribution shows a spread in opposing research areas, respectively left for categories related to social science journals and right for categories related to medicine and engineering, such as biotechnology, biomaterials, biophysics, etc.

The degree of the spread of publications onto the base map of global science, and the interdisciplinarity of the researchers involved in the analysis, can be better discerned by comparing the GDEE group with other groups analysed with the same method.

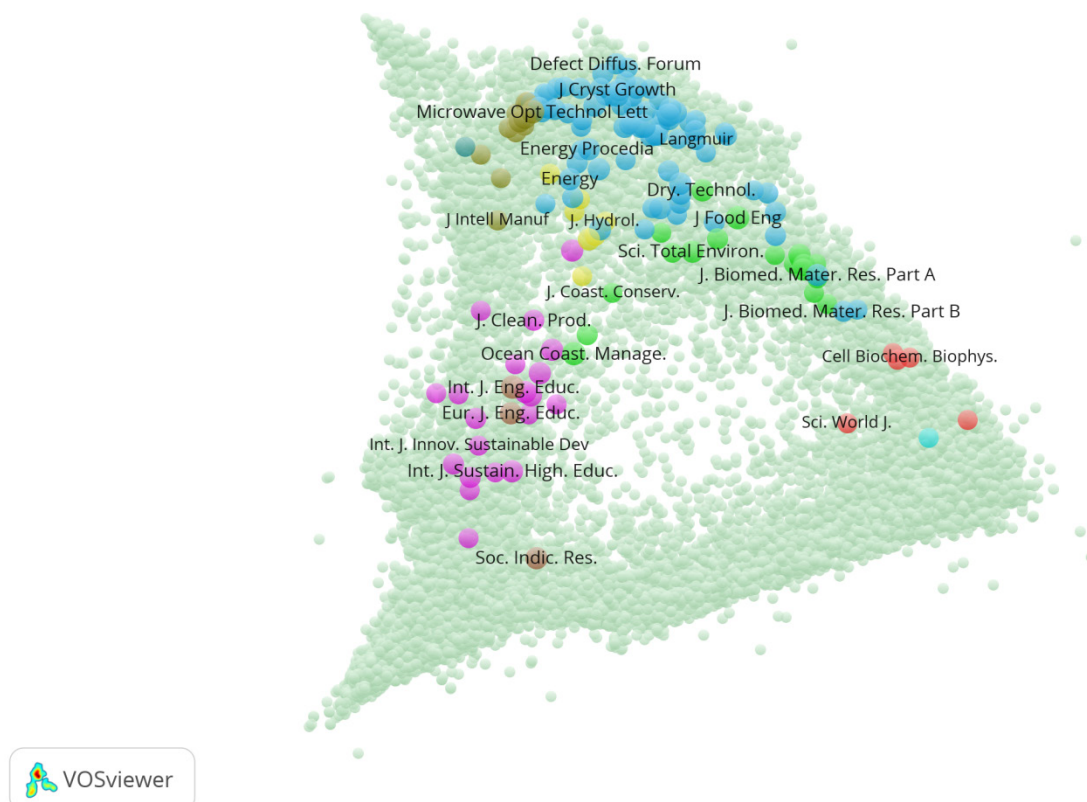


Figure 27 Journal distribution of GDEE academics.

As an example, Figure 28 shows Scopus-based overlay maps, presented in the framework of a study conducted by Leydesdorff et al. (2015) comparing journal publication portfolios

between the Science and Technology Policy Research Unit (SPRU) at the University of Sussex (on the left) and the London Business School (on the right). The interdisciplinarity of different portfolios of publications can be visually assessed with this tool.

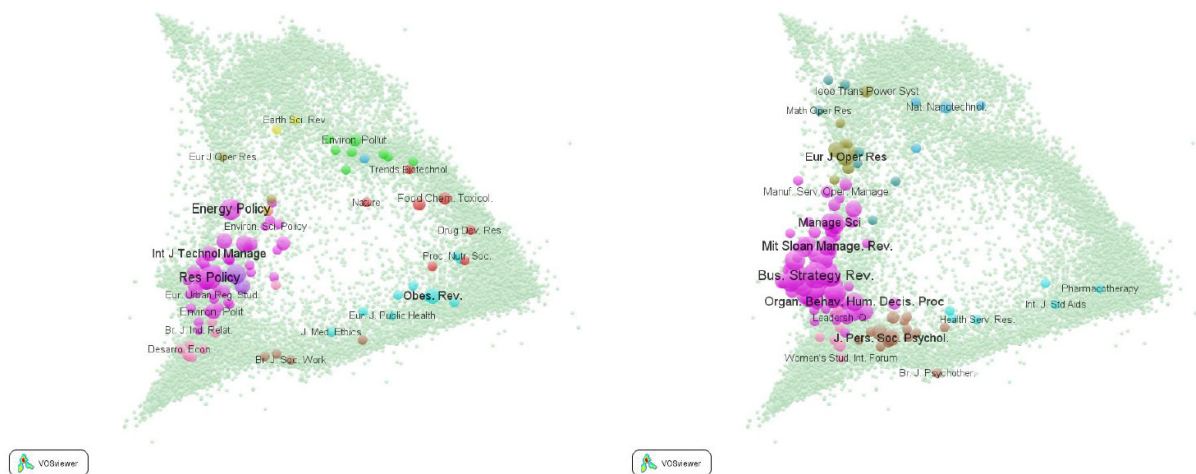


Figure 28 Scopus-based overlay maps comparing journal publication portfolios between the Science and Technology Policy Research Unit SPRU at the University of Sussex (left) and the London Business School (right). Source: Leydesdorff et al. (2015).

Furthermore, the Rao-Sterling interdisciplinary index can be operationalised by integrating the values of the distance between the respective subsets of journals provided by the map. The calculation of the Rao-Sterling index confirms that the degree of interdisciplinarity of the GDEE group is higher than the other two portfolios. Specifically, the Rao-Sterling diversity index is: 0.1713 for the GDEE group analysed while for the SPRU Unit and the London Business School the values are 0.149 and 0.091, respectively, as reported by Leydesdorff et al. (2015).

The bibliometric analysis of the scientific publications of academics completing the survey highlights relevant issues. The members of the group analysed are involved in research activity in different disciplines of the map of science. It is relevant to note that there is an intense research activity not only in engineering related disciplines, but also in social sciences. In addition, participants are particularly active in disciplines related to medicine and engineering. It can be argued that academics, including those with an established research career and a high degree of interdisciplinary research, are looking for a wider perspective and understanding of global challenges relevant to SD, and their relations with the field of engineering. Furthermore, the GDEE profiles can be seen, at least from the

research perspective, as potential connectors with diverse disciplines, in line with the analysis of Ferrer-Balas et al. (2008).

CHAPTER 4

TRANSVERSAL INTEGRATION OF SUSTAINABLE HUMAN DEVELOPMENT IN BASIC ENGINEERING SCIENCES COURSES

Abstract

The integration of SD in higher education is increasingly recognised as a priority for a growing number of universities; nonetheless, numerous barriers for change remain, and particular attention should be given to the success factors fostering an effective integration. The present contribution analyses the extent to which a professional development programme, aimed at engaging and empowering faculty, has positive effects at integrating SHD principles into existing courses of engineering. Specifically, the research focuses on the effects of the integration of SHD in new teaching modules in a subject of basic engineering science, implemented in regular courses of the first year in an engineering degree programme.

The methodology includes i) a standardised test to assess sustainability literacy of the students; ii) a focus group conducted with the students of the engineering courses involved in the initiative; and iii) two in-depth interviews conducted with the academic coordinator of the subject analysed.

The results of the present case study highlight the relevance of professional development programmes addressed to academics with regard to the integration of sustainability principles specifically in formal science disciplines. The conclusions highlight relevant insights from the case study that are useful for supporting further integration of SD in engineering disciplines.

Keywords: Engineering, sustainable human development (SHD), continuing professional development (CPD), higher education policies

This chapter is partially based on:

Pérez-Foguet and **Lazzarini, B.** (Submitted). Continuing professional education for engineering faculty: Transversal integration of Sustainable Human Development in basic engineering sciences courses. *Journal of Cleaner Production*

Pérez-Foguet, A., **Lazzarini, B.** 2017. Continuing professional education for engineering faculty: Transversal integration of Sustainable Human Development in basic engineering sciences courses, in: 23rd International Sustainable Development Research Society Conference. 14-16 June 2017, Bogota, Colombia, pp. 342–355.

1. Introduction

Engineering is recognised as a critical discipline for addressing SD challenges (Davidson et al., 2010; Karatzoglou, 2013). Engineers-in-training will be future leaders and specialised professionals who will hold important positions in economic and political spheres. In both cases, they will play a critical role in the promotion of a more sustainable future, bearing the responsibility of making important decisions that have a wide impact on social, economic, and environmental domains. For this reason, there have been many calls in the last decades for a renovation of engineering competencies and a change in curricula and pedagogies integrating SD concepts and principles (Boni and Pérez-Foguet, 2008; Lozano and Lozano, 2014; Mulder et al., 2015; Segalàs et al., 2009). A number of technical faculties and universities have been reconsidering the content of their curricula and adopting diverse strategies (Lozano and Lozano, 2014; Rose et al., 2015; von Blottnitz et al., 2015), but further efforts are needed in order to properly integrate SD in teaching contents and pedagogies. The transformation in learning in education for sustainability requires the commitment of faculty and the engagement of students (Leal Filho et al., 2018). Faculty members can be considered as the foremost contributors to curriculum renewal (Barth and Rieckmann, 2012). For this reason, building capacity of academics towards SD is critical to fostering the transformation of learning and training environments (Cebrián et al., 2015; Sammalisto et al., 2015).

Scientific literature reports different experiences of capacity building of academics in SD, specifically focused on technical universities such as ‘educate the educators’ approaches aimed at integrating SD into regular courses (Barth and Rieckmann, 2012; Ceulemans and De Prins, 2010; Lozano García et al., 2008; Pérez-Foguet et al., 2018), or aimed at the development of new degrees (Lozano and Lozano, 2014). Other approaches, rather than focusing on the process of ‘training’ academics, are specifically aimed at fostering their personal contributions to SD, namely, by promoting reflection on how to help integrate SD in regular subjects based on their expertise and disciplines (Holmberg et al., 2008; Svanström et al., 2012). Among the different approaches indicated to promote the integration of SD in curricular activities (Watson et al., 2013), intertwining SD as a concept within regular courses has been described as the most favourable approach for integrating SD (Lozano and Lozano, 2014), providing suitable chances to incorporate into professional practices the SD principles (Rose et al., 2015).

Specific initiatives have focused first and foremost on the integration of SHD in engineering curricula (Boni and Pérez-Foguet, 2008, 2006; Pérez-Foguet et al., 2005). SHD has been defined as the “the expansion of the substantive freedoms of people today while making reasonable efforts to avoid seriously compromising those of future generations” (UNDP, 2011, p. 18). The concepts of SD and SHD do not present precise theoretical boundaries and are subjected to different interpretations. Specifically, in this contribution, the concept of SHD is employed when emphasising the fulfilment of basic needs and the expansion of human capabilities within SD approaches.

Engineering approaches to teaching and learning are characterised by technical paradigms and a strong disciplinarity (Halbe et al., 2015). Consequently, it is particularly challenging to integrate the principles of inter-, multi-, and transdisciplinarity characterising SD. Recently, Lazzarini et al. (2018) and Lazzarini and Pérez-Foguet (2018) have analysed the characteristics respectively of the academic and research profiles of engineering faculty involved in continuing professional development (CPD) programmes aimed at fostering the integration of SD into regular courses. The results showed a strong interdisciplinary profile of the faculty involved, as well as a general commitment towards the integration of SD principles in their different academic functions and its promotion outside the university. However, these engaged academics are far from representing the typical profile of an engineering professor. Academic engagement towards SD is especially difficult for those disciplines included in ‘formal sciences’, such as mathematics, logics, and statistics, which are characterised by abstract structures and languages. It would be especially important that students start their training in integrating sustainability principles from the very beginning, yet these formal science disciplines are commonly taught in the first year of engineering degrees. For professors of formal science disciplines, it is particularly challenging to include SD into their teaching practices, and CPD programmes are especially useful to provide them with pedagogical and practical resources to be used in their teaching practices. The current literature offers very limited research that focuses on educating the educators for interconnecting formal science disciplines and SD, and specifically, for evaluating the impact of specific training programmes addressed to academics.

In light of these challenges, this contribution aims to describe a professional development programme on SHD focused on the engineering faculty, assessing the degree to which such programme has positive/desired effect on both academics and students, and especially focusing on formal science disciplines. Specifically, the research focuses on the

effects of integrating SD into new teaching modules in a subject of basic engineering science, which is implemented into regular courses of the first year of the engineering degree. The specific objectives of this study are to determine:

- the perception of a group of students of the subject analysed in the present case study;
- the perception of the academic coordinator of the subject incorporating SD concepts.

This contribution seeks to explore these research objectives by analysing a case study of professional development of academics, specifically focused on basic engineering science courses, in the framework of a continuing professional education programme addressed at engineering faculty implemented at the Polytechnic University of Catalonia (UPC; Barcelona Spain).

To accomplish this task, methods include: i) a test aimed at assessing student knowledge about SD prior to exposure to the subject modules; ii) a focus group aimed at deepening students' perception of their learning experience; and iii) an in-depth interview specifically aimed at exploring learning acquisition and factors related to motivation an academic involved in the training.

2. Context of the case study

The present contribution focuses on a CPD programme aimed at engaging and empowering faculty of the UPC to integrate SHD concepts into their existing courses. This initiative, started in 2016 with duration of two years, was funded by Barcelona City Council and involves different profiles of engineering faculty, including academics with little-to-no previous experience in SD/SHD as well as professors who already integrate SD/SHD into their academic functions. Faculty has been engaged through diverse training activities aimed at improving the competencies and attitudes of academic staff towards sustainability, such as periodical workshops, engaging all trainees, and individual coaching sessions. Furthermore, the training approach promoted the development of case studies dealing with SHD issues that are relevant at a local scale, as an effective way to increase the perceived relevance of basic science courses within engineering studies, and to complement traditional approximations that focus mainly on technology courses. The final goal of the programme was to engage faculty in proposing and developing teaching

contributions to SHD based on their own disciplines and expertise, and to apply these to real-world teaching situations, ideally in regular courses.

The methodological approach driving this professional development initiative was founded on previous relevant experiences of faculty capacity building promoted in technical universities across Europe. The European GDEE initiative (GDEE, 2015b), coordinated by the authors and described earlier, was developed with the aim of mainstreaming SHD in engineering education, and specifically for improving the competences of faculty of engineering universities to effectively integrate SHD as a crosscutting issue in teaching activities. Additionally, the meaningful training experiences promoted by Svanström et al. (2012) at the Chalmers University of Technology (Sweden), and Peet et al. (2004) at the Delft University of Technology (The Netherlands), were taken into account. In both cases, the main focus of the CPD initiatives is to explore how lecturers can contribute to SD from their own disciplines with an open approach, rather than training academics in a rigid, traditional manner on how they should incorporate sustainability concepts.

Following these two initiatives, the training programme presented here specifically combined workshop sessions, including training and discussion activities, with individual coaching sessions. The purpose of this method was two-fold. First, workshops aimed to foster discussion on relevant topics related to embedding SHD into engineering courses, finding common grounds between respective disciplines and contents related to SHD. In addition to the specific contents related to SHD, workshops included discussions on active learning pedagogies, competencies articulation and outcomes assessment, and successful experiences, among other issues. Furthermore, one of the purposes of the workshop activities was to foster a supportive learning environment and group engagement, giving participants the possibility to share personal experiences and to discuss relevant sustainability topics and how they can be reflected in respective courses. Second, individual coaching sessions were held that aimed at increasing engagement and motivation of professors for embedding SHD into real-world teaching modules and subjects. Academic were provided numerous type of support, such as for the process of exploring potential topics to be included into their regular subjects, determining the most appropriate pedagogies, and assessing students.

2.1 Incentives for academics

The participation in professional training and potential engagement in teaching activities offered within the professional development initiative presented diverse incentives for the academics participants, which are briefly described below. Note that in Spain, the incentives related with teaching performance of academics are more dependent on the faculty promotion/evaluation rules of each university; in contrast, the incentives linked with research and technology transfer results are more uniform and, in general terms, are more likely to follow internationally-accepted standards.

Teaching innovation: the participation in teaching-innovation training programmes, as well as the development of teaching-innovation materials, are both a prominent part of the evaluation of academics. The evaluation process of these teaching merits includes, specifically, a self-evaluation form presented by the academic; this self-evaluation needs to be accompanied by the respective evidence, which are qualitatively analysed by a specific competent commission.

Student satisfaction surveys: Standardised surveys addressed to students (which were traditionally paper-based but now are usually online questionnaires) also are an essential point of academic evaluation. Teaching-innovation initiatives, particularly those related to SD and development cooperation, are traditionally well received by students; consequently, this can contribute to higher rates in student satisfaction surveys.

Engagement in development cooperation projects: The academic initiatives focusing on the countries of the global south are considered strategically relevant for their contributions on capacity building, as well as for their innovative features, for both professors and students. Thus, having engaged in teaching projects or training practices related to development cooperation, or having participated in awareness raising activities and development education, is considered an added value in the evaluation process.

Conference papers/contributions: Depending on their academic recognition, conference contributions can be considered (with more or less weight) in the evaluation of academic performance. Notably, the professional development initiative in this research actively promoted the participation to national/international conferences that focused on teaching innovation, by financing attendant expenses (registration fees, travel expenses, etc.). Furthermore, the participating professors were offered a personalised follow-up aimed at

the development and improvement of conference papers/contributions specifically focused on teaching innovation.

Scientific publications, research projects, and knowledge-transfer contracts: In some cases, the aforementioned incentives can contribute to the development of scientific publications, research projects or knowledge transfer contracts, which are especially well rated in the process of academic evaluation, in concordance with international standards.

2.2 *The case of linear algebra*

In the framework of the CPD programme, a professor of the UPC proposed to embed elements of SHD into a regular subject of linear algebra – for which she was the academic coordinator – using a new teaching project focused on the ‘Long-term viability of a possible construction of a dam’. Specifically, a decision was made to integrate and assess UPC transversal competence ‘sustainability and social commitment’, which aims at fostering different competencies of engineering students using: i) knowledge and understanding of the complexity of the welfare society economic and social phenomena; ii) the capacity to relate well-being to globalization and sustainability; and iii) the ability to use technique, technology, economics and sustainability in a balanced and compatible way.

The pedagogical approach of the teaching project was based on project-based learning (PBL) including aspects of collaborative learning. In PBL – an approach particularly suitable for integrating SD into the engineering curriculum (Lehmann et al., 2008) – students are provided with complex authentic situation problems as well as with guidelines on how to solve them. The participants’ learning processes are enriched through the analysis of the different approaches and perspectives applied to solve the problems. This methodology enables different competencies to be approached in a collaborative way, allowing students to understand environmental and societal problems as a whole (De Graaff and Kolmos, 2006).

The students had to work in small groups on the project “Long-term effectiveness of a potential construction of a dam”, which has been described extensively elsewhere (EScGD, 2018; Garcia-Planas and Taberna, 2017). In brief, the activity was design to propose the possibility of building a dam to regulate the basin of one of the contributing rivers, with the objective of satisfying the needs of water for irrigation. Student were provided with the maximum capacity of the dam, the amount required for irrigation, and

the amount that should be left to maintain the water quality standards for other uses, provided that the water level of the dam plus the weekly contribution of water from the river does not reach a minimum preventing the provision of water. Using linear algebra, students were required to assess the viability of the irrigation strategy, analysing the temporal evolution of the reservoir water balance under the given conditions as well as considering any possible influences that climate change effects would have on it. In addition, students were asked to assess the social benefit of the dam by counterbalancing the benefits obtained by the irrigation versus potential social conflicts caused by land expropriations and consequent displacement of the inhabitants of such area. Finally, they were asked to discuss in small groups, with the objective of agreeing or disagreeing with the proposal to build the dam.

2.3 Data collection

A mixed approach was used to collect data for the research. First, a standardised questionnaire was conducted to assess the students' general knowledge on sustainability issues. Second, a qualitative approach consisted of both a semi-structured interview of the professor in the professional development programme that promoted the teaching initiative, and a focus group, conducted with students in the linear algebra course.

2.3.1 Sustainable literacy test

With the aim of assessing the general knowledge of the principles and current global challenges related to SD of the students involved in the subject of linear algebra, a standardised test was conducted at the beginning of the course using the 'Sustainable Literacy Test' (available at <http://www.sulitest.org/>). This web-based tool is designed to measure individual current knowledge on SD through a multiple choice questionnaire aimed at covering the main issues of SD. Core or specialised modules can be included in the test. Core modules comprise 30 international questions, identical for all users throughout the world, which allow trends to be benchmarked and identified at global level. In contrast, specialised modules comprise a battery of locally-focused questions, including regional and cultural specificities. The core module, which was expressly used in this research, aims at assessing students' knowledge on four main themes: i) sustainable humanity and ecosystems; ii) global and local human-constructed systems; iii) transition towards sustainability; and iv) roles to play, and individual and systemic change. The overall test architecture is fully explained elsewhere (Sulitest, 2016).

2.3.2 Focus group

The focus group is a qualitative research method aimed at obtaining (usually from small groups of people) the perceptions, attitudes, and opinions of the participants about a specific area of interest (Krueger, 2015). An informal, interactive, and non-threatening environment encourages an open group discussion, providing the opportunity to deepen specific topics (Sharma et al., 2017). In this research, a focus group was specifically employed to get detailed perceptions of students about a learning experience promoted in the framework of the professional development programme of academics. Data were transcribed verbatim and subsequently reviewed by two researchers independently.

The focus group was aimed at assessing the overall perception of students on the subject of linear algebra described earlier, and specifically focused at assessing the following issues:

Organisation and approach of teaching proposal

- Organisation of the subject (modules, activities, assessment, etc.)
- Novelty and impact of the pedagogical approach
- Relevance of the learning experience (in connection with previous experience and/or future expectations)

Contents of the teaching proposal

- Relevant issues studied/discussed
- Issues that should have been deepened

Individual competencies acquired as citizens and future engineers

- Cognitive: relevant knowledge, concepts, etc.
- Non-cognitive: empathy, solidarity, compassion, intercultural sensitivity, etc.
- Professional: team work, innovation, multidisciplinary work, etc.

2.3.2 Semi-structured interviews

The qualitative interview is a research tool that aims at identifying the personal vision of the interviewees in relation to a specific topic through their way of capturing the complexity of a given situation, using their own perceptions and experiences as well as their own words and terminology (Patton, 2015). The semi-structured interview, starting from a guide comprising the main issues that have to be deepened, is flexible and allows

freedom to both the respondent and the interviewer about which topics should be discussed in detail.

Based on previous relevant experiences (Brockhaus et al., 2017), a guide to be used for interviews was developed to guarantee consistency; this was later validated by a panel of experts, after including suggested modifications according to Charmaz (2006). Two interviews were conducted with the academic coordinator of the subject of linear algebra; the second one after approximately one year from the end of the training initiative, in order to assess the continuity of the intervention. The interviews were both conducted on site and lasted approximately one hour. They were recorded, transcribed verbatim, and then analysed by two different researchers.

Following the research of Barth and Rieckmann (2012), the first interview was aimed at exploring diverse issues related to the professional development initiative:

Individual competencies: increased knowledge, competencies, and skills related to SHD:

- Cognitive: knowledge, concepts, relations, etc.
- Non-cognitive: awareness, motivation, values, etc.
- Professional: knowledge of different teaching strategies and methods

Issues related to the professional development of academics: The research aimed at identifying changes in the teaching routine, and specifically if the professor attempted appropriate/innovative pedagogical approaches in the classroom. In addition to the ability and motivation of each participant as a result of the training activity, interviews were aimed at exploring, within this framework, specific factors that favour or limit the changes in teaching practices, such as:

- Student expectations
- Curriculum requirements
- Time investment of academics
- External factors (coaching, availability of teaching resources, etc.)

Potential impact within the organization: Beyond the changes strictly related to the teaching function of academics, another important aspect to consider is the potential involvement of teachers in disseminating and promoting SHD principles in their university organization. Possible contributions in this regard may have different levels of involvement, from the personal to the institutional sphere:

- Dissemination of professional activities to colleagues
- Promotion of changes in curricula
- Encouraging political / institutional strategies for promoting SHD

The second interview was purposefully less structured than the first one, and specifically aimed at exploring to which extent the professor continued to integrate SHD aspects into her teaching activities, at one year after the end of the professional development training. Additionally, attitudes and motivation towards SHD were planned to be assessed, as well as any problems or barriers that might have been encountered during this time.

3. Results and Discussion

3.1 Sustainable literacy test

The test was conducted through the webpage of the ‘Sustainable Literacy Test’ at the beginning of the semester. Students were invited to participate by a test coordinator, after which signed up and accessed the test using an access code. The tool provided both global and individual results. In total, 26 students (of 49) completed the core module questionnaire, representing the 53% of the students in the subject. As compared with both national and international sessions conducted with the application, the overall results of the student’s responses are lower in every one of the four themes explored (Figure 1).

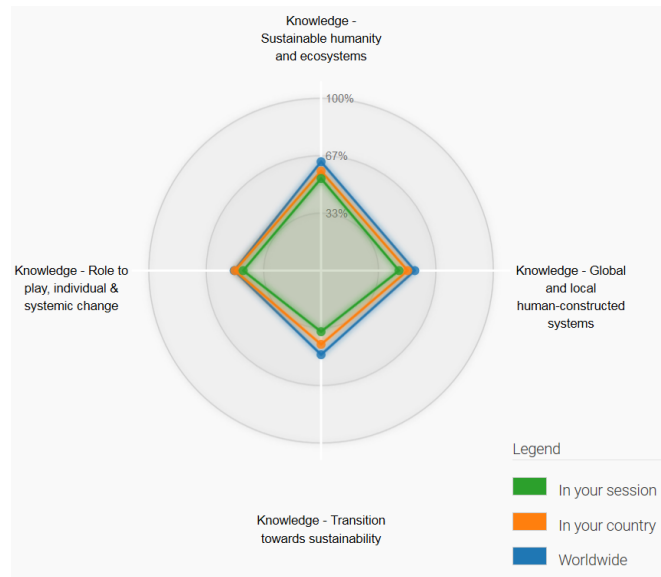


Figure 29 Results of the sustainability literacy test.

3.2 Focus group with the students of linear algebra

The results of the focus group conducted with the students of linear algebra are presented and discussed in this section. Overall, students showed a very good acceptance of the active learning pedagogies employed and of the topics integrated into the subject. Students initially minimised the importance, in the context of the subject, of those embedded topics related to water use and socio-environmental aspects; rather, they focused primarily on issues related to the mathematical resolution of the problems raised in the case study. It is probably that mathematical aspects were generally perceived to be the most important factors.

"The subject assessment was in mathematics, the sustainability part came from the mathematical problem. You had to draw the conclusions... I mean, at the social level, but what it was assessed and the most important and difficult issue was the mathematical problem."

Subsequently, during the group discussion, student perceptions gradually began to emerge that were more related to the specificity of the problems studied, as well as to personal considerations about the potential applications in the real world of an abstract matter such as linear algebra. Furthermore, more general aspects related to the professional role of engineering came into the discussion.

"I didn't think that linear algebra could have such a direct application Right now, I like to see that what I am doing is useful, and that they are not just numbers but can also have a social application. This is quite different from the other subjects..."

"It has a real application after all... from what we have seen so far, this is the only subject that has some application to our future as engineers. Besides that, algebra is a subject that, when you first see it, you say ...well, what is it for? Any initiative like this one is welcome".

Despite the markedly mathematical nature of the subject, it can be noted that the content and teaching methodology favoured important reflections of the students, which came up from group dynamics and discussions on various topics raised in the subject, addressing both mathematical and environmental/social issues related to the sustainability of a dam. The students, who had been divided into small groups of 5 people, had to find an agreement for the solution of a problem with different variables, keeping in mind to include: *i*) mathematical elements (balance/water efficiency of a dam); *ii*) environmental factors (water as a natural resource, ensuring sufficient water supply for irrigation, etc.); and *iii*) social factors (e.g., the possibility that residents would be required to move to other areas, with consequent social tensions). The requirement that the group find a mutually agreed-upon solution for the possible construction of the dam stimulated discussion and comparison of different points of view and perceived priorities on sustainability issues. It is worth highlighting that this was the only subject of the first year of the degree on which students worked mainly in a group.

"Working in a group, we were forced to debate about what we were going to decide [about the dam construction], and you can't agree with every one of the group. So we had to debate about water problems in order to find a solution. This has been very different from the others [subjects]. Even though I knew that engineering has a lot of applications, but to see an example so clearly like that in the first year...., well, I liked it."

This confirms that these group activities can be an effective way to promote interactions with people with different views and paradigms (Halbe et al., 2015); while they cannot replace experience, they do prepare students for future working experiences with real-world stakeholders in a group project (ibidem).

These group activities, conducted predominantly outside the classroom, have favoured a better relationship with peers in the group, and even with the other classmates. However, the work outside the classroom entailed an extra important effort, which students considered would be excessive if all the annual subjects had the same requirements. The students agreed that, if this were the case, all the subjects of the first year should reach an agreement to develop a common project, an event that students considered to be unlikely. Student commentaries emphasised two of the main challenges for effectively integrating SD in university curricula, namely overcrowded curricula and existing disciplinary boundaries (Holm et al., 2015; Sammalisto et al., 2015).

It should be noted that some groups carried out additional and time-consuming activities for their blog, which were not required in the subject programme, for example creating short videos focused on global issues, with special references to water. These initiatives started from the students' need to understand the global challenges in a more visual and straightforward way. It can be argued that this deepening on issues related to SD is related to an heightened interest in global challenges arisen within the subject.

What appears to be missing, in the opinion of the majority of the students involved in the focus group, is a final discussion at the end of the course with professors and classmates. This would have allowed an overall discussion on the issues studied during the course and favoured a deeper reflection on the decisions taken by the different groups on the dam construction. Through the methodology of the portfolio, each group had developed its own blog, and the different conclusions could be consulted online. Nonetheless, the students reiterated that the discussion would have facilitated the sharing and discussion of ideas and decisions.

"In fact, I also think that professors should do a closer follow-up of our work, right? So, after we turn in our conclusions, we should debate them in class among all the students and share all the conclusions".

"I think that you can look at it [the presentations and conclusions in the blogs of the other groups], but it would have been better to discuss it in class to know the opinions of each group.... I don't know, it is better in class".

It is important to note the considerations of the students on the 'social' role of the engineer. Their comments emphasise how the engineer's professional role is commonly associated

with the world of the industrial production and the maximization of profit for private enterprises. Students recognise the social role of this professional profile and identify themselves professionally as bearers of change rather than only for profit. The social value of engineers is widely recognised in academic literature (Davidson et al., 2010; Karatzoglou, 2013) as well as by international institutions (UNESCO, 2010).

"I believe that society has a very selfish concept of the engineer, and we have to be the ones who see that we can help other people and not just work in a company for economic profit. It's thanks to projects like this one that we start to believe in ourselves, that yes—we *can* change things."

Consequently, they were requesting that higher education be less abstract and more centred on real-world problems. Contextually, they highlight the need to be educated as 'persons', implicitly recognizing the presence of values in educational practices despite being primarily abstract (as linear algebra can be). This contrasts with most of the paradigms and educational models commonly used in engineering studies (Halbe et al., 2015).

"... I think that besides learning to do calculus, it is important to be trained as an engineer and also as a person. I think that contributes to providing a more critical vision... let's say... about everything I have, the global society and water, for example..."

Finally, students claim that, along with water topics, they are interested in other major SD issues, such as waste, pollution, and labour exploitation.

3.3 First semi-structured interview

In this section the first semi-structured interview conducted with the academic coordinator of the subject of linear algebra is presented and discussed. The interview was conducted in the professor's office, at the end of the semester in which SD training was implemented, and lasted approximately one hour.

The professor acknowledged the usefulness of the training process, and especially highlighted the benefits in terms of professional competencies. She remarks that, after identifying the potential topics to be integrated in the subject, the real challenge was how to embed these concepts into the subject. For this reason, she believed that the training process, and especially the interchange of experiences with colleagues participating in the

programme, were constructive and rewarding. On the one hand, she partially ascribed the difficulties encountered to the fact that linear algebra is a scientific discipline characterised by abstract structures that does not offer many examples to integrate sustainability related concepts. On the other hand, the professor stated that she believed SD concepts should be integrated into regular subjects at the very beginning of engineering studies, in order for students begin to actively reflect on such issues from the beginning, without having to postpone these reflections to future courses (either regular or specific for SD). This perspective confirms prior research on the incorporation of SD in universities curricula, specifically that incorporating SD concepts into regular courses contributes to raising student awareness on such principles and thereby increases their opportunities to integrate them into their professional life (Kamp, 2006; Lozano and Lozano, 2014).

The interviewee describes some activities conducted during the training programme in a particularly positive way. First, the use of a set of contextual case studies based on real SD projects, jointly developed by academics and members of non-governmental organizations (GDEE, 2015a), aimed at providing academic staff with specific materials to be used in the classroom. The usefulness of these cases is described specifically in terms of providing examples of ‘what can be assessed and how to assess SD issues’, although cases might deal with issues not directly related to the expertise of the professor. This confirms the lack of appropriate material as a problem to integrate SD (Peet et al., 2004), as well as the fact that the availability of practical teaching resources is valuable and useful for embedding SD into engineering subjects (Boni and Pérez-Foguet, 2008; Pérez-Foguet et al., 2005). Another issue emphasised as a relevant group exercise for professional competencies of academics was the joint creation of a general rubric to assess UPC transversal competence ‘sustainability and social commitment’, which stands apart but complements the regular subject’s disciplinary assessment. Despite reporting the relevance of this activity in terms of training, however, the final result was described by the professor as not entirely applicable to the subject of linear algebra. Specifically, the assessment rubric that was developed was described as being overly complex and time consuming, especially considering that it should assess the transversal competence of a basic science subject.

The professor expressed great satisfaction with reference to student commitment to SD issues presented in the subject. She reported that the vast majority of the students were engaged in developing reflections into their works and portfolios on water issues as SD challenge. Although some of the student contributions might be considered as too general

or without sufficient depth, she emphasised the fact that it must be taken into account that first year students are commonly struggling with some of the most demanding subjects of the course, some of which they often do not recognise as having any practical usefulness. In this particular teaching project, the perception of the coordinator was that students, in addition to gaining insight on SD topics, also understood the importance of abstract languages (such as mathematics) and recognised their potential for resolving real-world problems.

The preparation of the teaching project represented a considerable investment of time for the professor. The main difficulty to overcome was described as the process of identifying a complex problem that embedded SD, and that was mathematically resolvable with the level of student; at the same time, the solution should not be obvious, but rather stimulate the students' motivation to take up a challenge. In other words, the problem should not be resolved by simply applying a mathematical formula, but should remain open for different positions, fostering reasoning and discussion among students. Noticeably, the preparation of this educational project was a challenge primarily for the professor who, after dedicating a great deal of effort into this project, is currently working on a second one addressed for repeating students for the following semester. The considerable engagement of this professor highlights the fact that, although the engagement of academics with SD is commonly favoured by appropriate incentive structures at university level (Krizek et al., 2012; Stephens et al., 2008), often the efforts towards the integration of SD emerge from personal motivation and narratives, which outline a different and individual manner to engage with SD (Wood et al., 2016).

Different barriers hindering a broader integration of issues related to SD in university courses were highlighted during the interview. First of all, resistance to change by academics was mentioned, and specifically, resistance to: the integration of innovative topics in the curriculum, such as SD; to using the appropriate assessment methods, which involve the need to rethink the teaching routine of professors; to student assessment methods; to specific professional training; etc. This represents a strong disincentive for potentially interested academics. Furthermore, the professor emphasised the lack of a clear and consistent message from the institution regarding SD; specifically, she claims that "sustainability should not remain only in the institutional statements" and that its integration should be actively fostered in the curriculum, even with top-down coercive strategies. This validates the extensive literature on the barriers for the integration of SD into the university system (Lozano, 2006; Lozano et al., 2013b; Velazquez et al., 2006;

Verhulst and Lambrechts, 2014). The professor was aware of the fact that her involvement could be a wasted effort if permanent structures of the university only recognise the importance of SD principles in communications and declarations but do not additionally provide active support for the integration of such principles into their different functions. It can be argued that the interviewee did not fully perceive the complexity of the process of institutionalisation of an innovation. In fact, as properly reported by Lozano (2006), coercive strategies “generates conflicts and the innovation is bound to lose strength with a change of authorities”. Nonetheless, she acknowledged the fact that the integration of SD concepts into courses and curricula requires a concerted effort among different university stakeholders (Lozano-García et al., 2009).

Finally, the professor asserted that she will follow-up and further deepen the integration of SD issues, exploring potential new topics to be incorporated into the subject of linear algebra. Contextually, she reported that her involvement will not be limited to her teaching function, believing in the importance of promoting SD issue also at the institutional level, for example, by disseminating and discussing with colleagues the teaching innovation related to the integration of sustainability, with a particular focus on mathematics. Currently, her dissemination activities are not limited to the sphere of UPC; in fact, this case study was recently presented by the professor as a contribution for a national congress on 'University and Sustainable Development Goals' (Garcia-Planas and Taberna, 2017). Moreover, she claimed to be firmly convinced of the need to actively promote changes in engineering curricula to effectively include the transversal competence 'sustainability and social commitment', and stated that she will be personally engaged in this goal. As highlighted in other research focused on continuing education of academics (Barth and Rieckmann, 2012) this case study confirms that faculty professional development on SD has positive effects that go beyond teaching function, fostering transformative changes towards a sustainable university.

In conclusion, the approach employed to facilitate the integration of SHD produced positive effects on faculty involved, reinforcing previous experience based on similar methods (Holmberg et al., 2012; Peet et al., 2004). Specifically, the case study analysed brought about positive effects not only for the professor who introduced SD into the courses but also, and most importantly, for the engineering students, who not only acquired subject-specific concepts but also developed important insight that allowed them to self-reflect about the engineering profession and the social benefits to which they could contribute at once finished their studies. It is especially important to highlight that students

involved in these courses recognised the social utility for the promotion of SHD not only in engineering *per se* but also in an otherwise abstract discipline such as linear algebra. Finally, the professor interviewed was highly positive and strongly motivated about the value of integrating SHD, and was engaged in further promoting sustainability concepts in formal and informal university spheres.

3.4 *Second semi-structured interview*

The second semi-structured interview was conducted in the office of one of the authors, approximately after one year since the previous interview, and lasted about one hour. After having briefly introduced the purpose of the interview and asked the professor to describe her current involvement with SD in her academic functions, the situation depicted by the interviewee, at one year into the professional training, was quite unexpected and jarring.

For five semesters at UPC, this professor was coordinator of the linear algebra courses; she introduced SD into her sixth semester course (and this is the course that received positive evaluations from students; see above). However, before the start of the following teaching semester, this professor was removed from her role as coordinator and relieved of her teaching duties for linear algebra (note that, as a civil servant, she is still employed by the university).

These circumstances forced the authors to adapt the structure of the interview that had initially been planned to the actual situation of the professor, and to go more in-depth into some professional aspects that were not covered in the first interview. At the same time, the decision was made to leave more space to the interviewee to describe any significant aspects that could have led to the current situation.

As a possible cause, the professor described significant resistance from her colleagues in the department, especially related to the introduction of a new pedagogical approach and student evaluation, which would have been expected to also be followed by the other professors teaching linear algebra. This reaction overlapped with other internal dynamics related to the evaluation and promotion of the departmental teaching staff. For this reason, it is very difficult to identify if and to what degree the activities specifically fostered by the training action might have contributed to the currently dismal situation of the professor. In the opinion of the professor, this resistance was not specifically directed against the integration of the principles of the SD *per se* (notably, the crosscutting

competence ‘sustainability and social commitment’ is mandatory in every course of study at the UPC) but rather was a reaction to the modification/improvement of the “traditional” way of teaching mathematics. The interviewee emphasised that, for her colleagues at the department who are engaged in teaching, innovation processes do not represent a competitive advantage; on the contrary, it makes them feel insecure because their role as experts can be questioned. For this reason, it might be preferable to avoid asking for initiative rather than taking advantage of it. The resistance, therefore, seems to be aimed first at protecting the comfort zone and self-confidence of the teaching staff (Cebrián et al., 2015; Lozano, 2006) and second, at preserving the formal and informal departmental power structures and mechanisms.

The professor stated that this unfavourable condition has not discouraged her, and that her interest in teaching innovation and SD has not diminished. On the contrary, she took advantage of the “teaching break” to complete and publish a book of teaching materials aimed at integrating SD into linear algebra (García Planas et al., 2018). She is convinced that the integration of SD fosters students’ interest for algebra and helps them to identify the importance of mathematical disciplines for global challenges. Given the current lack of opportunities at UPC to put into practice her teaching experience, she is currently planning to intensify research collaborations on teaching innovation with colleagues of other universities. Her interest and personal motivation for teaching innovation has progressively evolved from the traditional teaching of mathematical disciplines to the PBL approach and, recently, the integration of the SD principles. Her narration confirms that the incentives offered by UPC have been systematically used and have led to the achievement of her objectives. This is consistent with the scientific literature on sustainability champions (Hoover and Harder, 2014; Stephens et al., 2008; Wood et al., 2016).

These positive results, in terms of professional development and direct incentives to the professors, unfortunately could not overcome the barriers of internal competitiveness and academic promotion. In other words, personal motivation and incentives are necessary but will not be sufficient, if the mechanisms of academic evaluation and promotion do not recognise and encourage these efforts.

CHAPTER 5

CONCLUSIONS AND WAYS FORWARD

1. Conclusions

During the last decades, a growing number of HEIs have attempted to integrating SD principles into their functions. Polytechnic universities and engineering faculties have made major progress in this direction. Nevertheless, more effort is needed to advance to the stage of in-depth reforms. Current trends characterizing higher education — in particular, the increasing competition on national and international education ‘markets’, and the growing emphasis on research results — have strongly affected university policies in recent years, influencing the teaching role of professors and institutional expectations and priorities on the teaching functions. In this context, the success of the policies aimed at integrating SD in the different university functions largely depends on the willingness and the capability of academics to engage with and to sustain reforms towards SD over time. Academics have a critical role in the adoption of SD in HEIs, and they can influence social, political, and business strategies as well as public policies towards SD.

For these reasons, specifically designed CPD programmes are crucial to help engaging academic community. It is not sufficient to promote simple informative initiatives that only focus on disseminating concepts and principles and developing understanding among academics. While these informative initiatives might prepare professors with a better knowledge of SD issues, they unfortunately do not provide them the appropriate skills needed to engage deeply and to bring about transformative changes to their organisations or society. Undoubtedly, there has been a significant change in terms of university practices towards SD; nonetheless, in terms of education and research for sustainability, the changes have been limited. In particular, when considering engineering sciences, it can be affirmed that pedagogical approaches currently employed are not sufficient to enable the development of significant SD capabilities in students. In other words, technical universities still empower students as experts and keepers of knowledge but not sufficiently as agents of change. Along the same line, research frameworks and paradigms in technical knowledge areas are still not focused on research for change, in terms of SD.

Consequently, the current role of HEIs is still far from being able to actively contribute to social transformation in SD, and importantly, it negatively affects the way universities engage with their respective communities.

The specific contributions of this research are to provide essential information and insight about the critical factors conditioning the success of appropriate strategies aimed at promoting the integration of SD in technical universities, through professional development initiatives addressed to academics, and more specifically: i) the design and development of continued professional development programmes, and ii) the characteristics of the academic profile of the academics engaged with SD in their functions and activities. This knowledge can improve the promotion and replication of successful initiatives aimed at empowering academic staff.

This thesis is divided into four constituent parts: i) the assessment of online professional development strategies on SD addressed to engineering academics; ii) the characterisation of the research profile of engineering academics engaged in SHD; iii) the definition of the key characteristics of academics promoting SHD within engineering studies; and iv) the assessment of the integration of SHD in basic engineering sciences courses. Consequently, the conclusions are presented in the same order.

1.1 Online professional development strategies on SHD

The first part of the research focused on the assessment online training courses within CPD strategies addressed to academics. Two main conclusions are highlighted.

Firstly, online training approaches can be effective to promote academic staff development in SHD. From one side, due to the limited amount of time available of academics to invest in continuing professional development, online training options can be well regarded by different profiles of academics. From the other side, the success of these training initiatives depends on specific conditions. Learning design framework should be aimed at maximising users' control over their own learning process, fostering opportunities for knowledge construction and personal sense making of learners. The workload and the pace of activities should be adequately planned in order to motivate participation and ensure continuity. Furthermore, the practical implementation of courses should take into account academic preference, specifically in terms of adequate/comfortable learning environments and expert trainers.

Secondly, an online, practical and collaborative learning environment facilitates successful learning and SHD knowledge acquisition. Beyond theoretical knowledge, academics are willing to engage in activities based on real-world problems, perceived as relevant and useful for their work environment. Furthermore, they are motivated to share personal experiences and debate on diverse perspectives and potential solutions in virtual spaces of discussion. Web-based environments can especially enhance these interactive situations, accommodating learners' preferences and goals. In brief, online learning approaches and technologies can maximise the involvement of teaching staff and, in some cases, can be used as a way to overcome barriers related to universities' funding constraints.

In the light of these conclusions, the authors propose the following recommendations for the leaders of higher educational institutions, in their efforts aimed at holistically implement SHD into all of their institution's activities:

- Acknowledge that CPD of academics plays an essential role in the process of integration of SHD within institutional frameworks.
- Further explore the integration into university policy and strategies of digitally-mediated learning addressed to academics, in its different delivery approaches, as a way to promote professional development and the engagement of academics for SHD.
- Carefully consider the demands of professional development of faculty, as well as specific characteristics, interests, motivation and goals towards SHD, in order to promote online learning experiences customised and centred on the academics.

1.2 Characterisation of the research profile of engineering academics engaged with SHD

In the second chapter, a comparative analysis and characterization of the scientific production of a community of academics involved in training activities was presented, comparing two groups of academics with different degree of expertise and involvement in SHD, focusing specifically on bibliometric features. The three main conclusions, which may be useful for informing university leaders as well as academic communities of technical universities, are as follows:

Firstly, this study shows that the academics in the field of engineering with proven expertise in SHD present an unusual integration/complementation of their research activity of disciplines related to engineering and social sciences, as well as a high degree of

interdisciplinarity. This outcome can have different implications for the promotion of SD in engineering universities. On the one side, these interdisciplinary profiles conjugating expertise in such diverse academic fields can be actively involved in the processes of promotion and assessment of activities related to sustainability in HEI, such as professional development initiatives. On the other side, these profiles can help to foster cultural changes in those universities and faculties engaged in processes aimed at shortening the strong disciplinary dimension characterising engineering academic environments.

Secondly, academics willing to be trained in SHD present a high degree of interdisciplinarity, and their scientific productivity is specifically related to the academic fields of engineering and health sciences. These characteristics have potential implications for future strategies aimed at identifying and engaging specific academic profiles in sustainability, for example through training initiatives addressed to engineering faculty. Traditionally, the environmental aspects of SD have been particularly relevant in the perception of the academics of engineering and have been the main focus of the promotion of SD and its integration in technical institutions. Medicine-related fields linked with engineering, such as biotechnology, could be a new promoting opportunity to explore. In this sense, the diverse perceptions that academics have about of the nature of SD, and the personal contributions that can be provided starting from a personal expertise, are important drivers for the engagement with SD. This ‘interpretational flexibility’ of SD (Sammalisto et al., 2015) should be better explored as an opportunity to integrate SD in engineering.

Thirdly, university rankings may represent a critical barrier to embedding SD in HEI. This study emphasises that rankings might amplify the disciplinary dimension of university performances, conditioning academics to align with respective institutional goals. Specifically, in the case of engineering, this can contribute to increasing the disciplinary evaluation of academics and, consequently, to discouraging specific research initiatives not aligned with specific fields or disciplines. For these reasons, further analysis of the outcomes of ranking and their implications for the integration of SD, as well as appropriate policies and mechanisms of faculty rewarding and promotion are recommended.

- Acknowledge that the increase relevance of university rankings influences strategic decisions of HEI and have potential implications for the integration of SD in HEI.

- Promote interdisciplinary research for SD through calibrating incentives and through appropriate policies and mechanisms of faculty rewarding and promotion.
- Explore alternative research fields linked with engineering, such as health-sciences, as potential opportunity of promoting the integration of sustainable development in engineering education.

1.3 Key characteristics of academics promoting SHD within engineering studies

The third chapter was specifically addressed at enhancing the understanding of the academic profile of academics engaged in training activities related to SD, complementing the second chapter and providing an analysis based on qualitative and quantitative methods. Hereafter, the main conclusions are highlighted.

Firstly, the results indicate that the faculty involved in SD practices, in the framework of GDEE training activities, are academics whose teaching and research activities range from engineering to social science, as well as fields related to medicine and engineering, and the great majority are involved in activities with societal entities and movements. Thus, they may be described as potential ‘connectors’ with other research groups at universities as well as with the wider society. It can be argued that they are promoters of those educational principles and values related to SD – such as inter- and transdisciplinarity, integrating the social dimension in technical-related approaches to SD – that can facilitate a cultural change in engineering education, and lead to more holistic transformations.

Secondly, a critical aspect emphasised by the results is related to the role of academics as agents of change. This research confirms that academics are not sufficiently engaged, through their activities, in facilitating a transition of societal setting toward SD. Specifically, their efforts aimed at disseminating scientific outcomes are mostly concentrated on scientific contexts, while popular dissemination is quite negligible.

Thirdly, results reveal that sustainability champions do not feel sufficiently supported in their activities and that their efforts mostly go unrewarded. Universities are expected to function as leaders of societal change and should support actions and initiatives promoting SD in the different university functions.

Finally, participants consider that accreditation procedures are not entirely transparent and potentially lead to disparities between colleagues. The role and commitment of accreditation agencies and professional accreditation bodies can be extremely positive in

advancing SD, especially for engineering education. HEI committed with SD should advocate for a reform of competency requirement of engineering that integrates SD principles, as well as accreditation procedures that recognise social outreach activities.

In any case, universities should devote more efforts towards exploring internal mechanisms to promote the engagement of academics in SD. On the one hand, because each university can better calibrate incentives, assessing specific situations and personal efforts within particular academic functions. On the other hand, because complex bureaucratic procedures are reflected in substantial time lags in the reform of accreditation systems.

Various recommendations addressed to higher education leaders in the faculty of Engineering are suggested:

- Support the engagement of sustainability champions and potential ‘connectors’ (within the university system and outside university boundaries) in all efforts aimed at implementing SD throughout the university system, including staff development programmes.
- Integrate appropriate policies and mechanisms to recognise the work of academics engaged in SD. Specifically, recognise academic merit to all those activities and initiatives aimed at promoting, in non-academic contexts, a deeper understanding of SD global challenges, as well as all contributions aimed at enhancing liaisons outside academia focused on SD.
- Explore potential advantages of the integration of SDGs in the different university functions, as well as for improving the connection/engagement with non-academic stakeholders and society.
- Advocate at regional and national level for a reform of competency requirement of engineering that improves the integration of the social and global dimension of SD principles.

1.4 Assessment of the integration of SHD in basic engineering sciences courses

The last chapter was aimed at assessing the effects of the integration of SHD in regular subjects of basic engineering science, implemented in the first year of engineering studies. Specifically, the perception of the students involved and the academic coordinator of the

subject integrating SHD were analysed and assessed. Among the lessons learnt arisen from this initiative it is worth emphasizing:

Firstly, the results of professional development initiatives on SHD have positive effects not only on students' knowledge and specific competencies related to sustainability, but also on their vision as future professionals of the engineering field, engaged with sustainability in its multiple dimensions.

Secondly, the integration of SHD in regular courses is a complex process involving academics mostly with a strong disciplinary expertise. Professional development initiatives based on bottom-up approaches aimed at fostering personal opportunities of integration of sustainability principles, starting from personal expertise of academics, are effective approximations to train and engage faculty in SHD.

Thirdly, professional development activities usually involve a large investment of time and effort for academics, specifically regarding abstract disciplines, such as those comprises in formal science. Individual coaching, as well as specific teaching materials and contextual case studies, can help faculty to embed SHD in their subjects. Furthermore, group activities conducted with lecturers are effective to stimulate interest and sense of community among academics.

Finally, professional development initiatives focused at integrating SHD into teaching can have positive effect beyond teaching practices. Specifically, once academics are sufficiently involved and have acquired self-reliance on the effectiveness of their teaching, they can further engage in promoting SHD in other functions and spheres of the university as well as in outreach activities.

The conclusions described above allow the proposal of some recommendation addressed to the leaders of HEI. These are as follows:

- Explore blended and mixed SHD professional development approaches integrating individual coaching to more traditional training strategies.
- Promote pedagogical approaches aimed at empowering students and engage them as agents of change, not only as experts and keepers of knowledge.
- Foster academic engagement, actively support the integration of SD principles into the different academic functions, not only acknowledging SD commitment in

institutional declarations, but also effectively implementing it throughout the system.

2. The way forward

The research work presented in this thesis deals with the identification and the analysis of factors affecting the engagement of academics in engineering studies with SD. The study was specifically aimed at providing reliable inputs for university leaders in order to effectively promote SD in engineering studies, and specifically, to foster faculty engagement. Despite successful initiatives that have been promoted in a limited number of universities, and the large amount of studies addressing the integration of SD in HEIs, it is widely recognised that, whilst university practices have experimented important improvements towards SD principles, existing dominant structures in technical university have largely remained unchanged. This is possibly due to not only of having limited institutional commitment and support at the university level, as described throughout the present thesis, but also to the lack of involvement by external key stakeholders.

From this viewpoint, it is worth emphasizing that other actors should be contextually engaged in order to promote a substantial shift in curricula and research approaches, which would provide an opportunity of success to innovative policies promoted at universities; these actors are i) university accreditation agencies and ii) professional engineering institutions. The possibilities – especially in terms of policy for mutual collaboration – to potentially engage the aforementioned stakeholders, such that they collaborate with universities in promoting more holistic transformations towards sustainability, are beyond the scope of this study but are strongly recommended as the way forward for progress in this venture.

In the same vein, the fact that the world community is currently engaged with the United Nation's SDGs, and that every government will be requested to incorporate these goals in their agendas and policies, can provide an unrivalled opportunity for universities to: *i*) engage in introducing SDGs into their functions; *ii*) reinforce their commitment to educating for SD; and *iii*) foster strategic and systemic transformation. Consequently, understanding how to promoting scientific research on the effects of integrating SDGs into teaching and research, and to facilitate forms of mutual collaboration between policy makers and professional stakeholders, in order to align priorities on SDGs, are future research fields that should be of the highest priority.

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APPENDIXES

APPENDIX A.

GDEE Courses' outline

<p>Block A - The Global Engineer</p>	<p>Addressed to those academics that want to introduce crosscutting issues in their activities; i.e., including a session related to SHD within, typically, a BSc course.</p> <p><i>Course A.1: Making the case for a critical global engineer</i> <i>Course A.2: Key elements for addressing the global dimension of engineering</i> <i>Course A.3: The Global Engineer in Sustainable Human Development</i></p>
<p>Block B - Supervising BS/MS thesis with fieldwork</p>	<p>Addressed to those academics who want to advice students involved in field-work or other extension activities during BSc projects or MSc thesis, typically within or close to a formalised International Cooperation Project.</p> <p><i>Course B.4: Supervising Engineering Students</i> <i>Course B.5: Knowing the context and partners</i> <i>Course B.6: Knowing International Cooperation</i></p>
<p>Block C - Integrating GDE into teaching and research</p>	<p>Addressed to those academics (or professionals) who want to design a course relating Technology and SHD, from their own technical expertise.</p> <p><i>Course C.7: Integrating GDE into the academia</i> <i>Course C.8: Integrating GDE into Teaching: Theory and Practice</i> <i>Course C.9: Integrating GDE into Research</i></p>

APPENDIX B.

Intended learning outcomes of GDEE courses

Block A. The Global Engineer

Course A.1: Making the case for a critical global engineer

1. Compare and contrast historical and contemporary views on engineering for development, applying relevant STS theories.
2. Evaluate a set of guidelines or standards governing the social responsibility of engineers in professional practice.
3. Identify relationships between technology and society, both in theory and practice.

Course A.2: Key elements for addressing the global dimension of engineering

1. Analyse and examine critical debates on contemporary sustainable development practice, especially where these relate to engineering.
2. Analyse the complexity and interconnectedness of sustainable development issues across different domains (society, environment, economy, etc.)
2. Evaluate the relationship between ideas such as equality, citizenship and gender to development practice. Reflect on how these same ideas are represented in the engineering profession.

Course A.3: The Global Engineer in Sustainable Human Development

1. Describe various theories of relationships between society and technology, and apply theories to develop new theories of socio-technical relationships, which integrate a SHD perspective.
2. Compare different methodologies for the structuring and framing of problems which allow for a more holistic and multidisciplinary analysis of contemporary engineering practice.
3. Examine the function and culture of traditional business and management practices in the engineering sector in order to identify opportunities for the integration of SHD perspectives.

4. Explain the importance of engaging stakeholders and the public in engineering practice in order to develop a practice more in line with SHD principles.

Block B. Supervising BS/MS thesis with fieldwork

Course B.4: Supervising Engineering Students

1. Apply knowledge of theories and dynamics of student supervision to improve the quality and effectiveness of their own practice.
2. Identify specific skills and competencies required for the supervision of students in a developing-country context.
3. Construct a set of guidelines informing the planning and reporting stages of a research project in a developing-country context, including planning stakeholder feedback and fieldwork preparation.

Course B.5: Knowing the context and partners

1. Describe the relevant criteria to select partnerships in the International cooperation context.
2. Analyse concepts and principles to orient students developing a first broad understanding of the geographical, environmental, social, economic, political and cultural context of the countries where students are going to develop their thesis.
3. Illustrate the basic dynamics and principles governing interaction with and participation of stakeholders in the context of development projects, such as of “active listening” and conflict dynamics tools that can be useful in a specific case.

Course B.6: Knowing International Cooperation

1. Explain the importance of participatory approaches to research, and how these could be implemented to involve stakeholders at all phases of project cycle management.
2. Summarise and explain the basic principles of the logical framework approach applied to development research projects.
3. Develop an independent search of relevant grants and financial support for international cooperation projects, namely including support to engineering students’ thesis.

Block C. Integrating GDE into teaching and research

Course C.7: Integrating GDE into the academia

1. Describe the role of global dimension (GD) in engineering education, and summarise of how GD relates to other educational agendas (sustainability, humanitarian engineering, etc.)
2. Identify and map the GD onto existing educational contexts and practices, including both content and the regulatory frameworks in which the contexts exist.
3. Compare practical understanding of different ways that the GD can manifest in the curriculum, as well as the advantages and disadvantages of each.
4. Identify the regulatory frameworks which operate on a European or in-country level.
5. Analyse the relevance of M & E to the development of new programming and prepare a preliminary M & E programme for curricular interventions.

Course C.8: Integrating GDE into Teaching: Theory and Practice

1. Summarise the key learning theories related to GD, and how these relate to module structure development.
2. Define and document the skills and competencies within GD programming related to their discipline.
3. Construct a set of intended learning outcomes for GD-related programs.
4. Compare appropriate teaching methods and assessment strategies.
5. Identify methods for mapping the GD onto student motivations and prepare innovative practices for engaging with students.

Course C.9: Integrating GDE into Research

1. Identify how the implementation of GD-related programming can be informed through action and applied research.
2. Illustrate how to start adapting research programmes to include more GD-related topics.
3. Compare the application of appropriate research methodology to conduct a research study in topics related to the global dimension in engineering education.
4. Identify sources of funding for GD-related topics.

5. Recognise the importance of collaboration to research stakeholders and open-source as a concept and practical tool.

Appendix C

GDEE courses survey

Questions:

1. () How well did the course meet your expectations and your personal objectives for attending?

- The course met all my objectives
- The course met most of my objectives
- The course met less objectives than expected
- The course did not meet my objectives

2. () Please rate your agreement to the following statement: My interest in cross cutting issues (such as MDG, HD, extreme poverty, climate change, etc.) has increased as a result of this course.

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

3. () Please rate your agreement to the following statement: Overall, this course is useful for integrating cross-cutting issues (MDG, HD, etc.) in teaching activities.

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

4. () Please rate your agreement to the following statement: The course materials provided are relevant and effective for integrating cross-cutting issues (MDG, HD, etc.) in teaching activities.

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

5. () Please rate the overall quality of the course materials

- Excellent
- Very good
- Good
- Fair
- Poor

6. () Which session did you find most useful? Why?

7. () Please rate your level of agreement with the following statement: The course coordinator demonstrated knowledge of the topics.

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

8. () Please rate your level of agreement with the following statement: The course coordinator stimulated interest, participation, debate and exchanges of opinion.

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

9. () If you selected “Disagree” or “Strongly Disagree” in the previous question, please provide details here.

10. () Were there any additional Global Dimension topics that you felt were missing from the course you took?

11. () What could be done to improve this course in the future? Feel free to refer to any aspects of the course: content, direction, facilitation, etc.

APPENDIX D

Detail of the responses on UNESCO nomenclature

Responses to the survey question: ‘With regard to your research activity, could you please indicate up to three codes of UNESCO's international nomenclature?’

Code	Description	Resp.
120600	Numerical Analysis	1
250604	Environmental geology	1
250810	Precipitation	1
250814	Surface waters	1
330300	Chemical technology and Engineering	1
330303	Chemical Processes	1
330306	Combustion technology	1
330500	Construction technology	1
330530	Sewers and water purification	1
330701	Antennae	1
330709	Photo-electric devices	1
330714	Semi-conductor devices	1
330800	Environmental technology	1
330809	Sanitary engineering	1
330810	Sewage technology	2
330890	Food technology	1
330914	Food processing	1
331210	Plastics	1
331212	Testing of materials	1
331499	Medical technology Other	1
332202	Power Generation	3

332205	Unconventional sources of energy	2
332505	Radio communications	1
332818	Mass transfer	1
332905	Regional Development	1
332908	Urban Environment	1
339900	Other technological specialities	1
530407	Production	1
531003	International aid	1
531104	Manpower management	1
531107	Operations research	1
540300	Human geography	1
540306	Social geography	1
580103	Curriculum development	1
580107	Pedagogical Methods	1
580199	Educational theory and methods Others	1
590101	International co-operation	1
620101	Architectural Design	1
620103	Urbanism	2
620308	Photography	1
630700	Social change and development	1
630702	Developing countries	1
631008	Poverty	1
631106	Urban sociology	2
710304	Ethics of science	1

APPENDIX E

Semi-structured survey



GDEE

GLOBAL
DIMENSION IN
ENGINEERING
EDUCATION

Estimada/o,

Le contactamos en calidad de colaborador o participante en las actividades realizadas en el marco del proyecto GDEE.

Estamos realizando una investigación sobre el perfil académico de los docentes e investigadores que han participado en las distintas actividades del proyecto GDEE, con un doble objetivo. Por un lado, queremos mejorar la oferta formativa GDEE con el objetivo de impulsar otras iniciativas dirigidas al profesorado. Por el otro lado, queremos poner en valor los perfiles profesionales de los académicos que trabajan en las temáticas globales. Le pedimos contestar unas preguntas que os llevarán un tiempo aproximado de 15 minutos.

Este tipo de investigación no supone ningún tipo de compromiso para usted. La participación es totalmente voluntaria y los datos obtenidos serán tratados de forma confidencial (Ley 15/1999 de Protección de Datos de Carácter Personal). Cualquier información de carácter personal que pueda ser identificable será conservada y procesada por medios informáticos garantizando el anonimato. Cada participante tiene derecho al acceso de sus datos personales, así como a su rectificación y cancelación. Los resultados de la investigación podrán ser utilizados sólo para fines de carácter científico.

La encuesta está diseñada para que cada invitada/o participe una sola vez, el enlace enviado es personal y válido para ser utilizado una sola vez.

Si desea realizar alguna pregunta sobre la encuesta, envíenos un correo electrónico a: boris.lazzarini@upc.edu

Le agradecemos sinceramente su colaboración.

*** Información necesaria**

page 1

1. Podría indicarnos algunos datos profesionales y de afiliación?
* (a) Genero (indicar H/M)

* (b) Edad

* (c) Titulación (Licenciado, Doctor)

* (d) Universidad

* (e) Facultad/Escuela universitaria

* (f) Departamento

* (g) Categoría profesional

* (h) Número de años acreditados en relación a docencia

* (i) Número de años acreditados en relación a investigación

(j) Correo electrónico (opcional)

2. Por favor conteste a las siguientes preguntas con referencia a los últimos 5 años de actividad académica. Escoja hasta tres asignaturas en las que imparte docencia regularmente. Datos de la Asignatura 1

* (a) Nombre de la Asignatura 1

* (b) Título Universitario

* (c) Enlace a la ficha docente

* (d) Enlace al plan de estudios

* (e) ¿Existen mecanismos de participación activa de los estudiantes? (SÍ/NO)

(f) ¿Si ha contestado afirmativamente a la pregunta anterior podría indicar brevemente cuáles son?

*** 3. ¿Desea aportar información sobre otra asignatura? (Elija una opción)**

Sí No

[Answer this question only if answer to Q#3 is Sí]

4. Datos de la Asignatura 2

5. ¿Desea aportar información sobre otra asignatura? (Elija una opción) [Answer this question only if answer to Q#3 is Sí]

Sí No

[Answer this question only if answer to Q#5 is Sí]

6. Datos de la Asignatura 3

Con relación a cada asignatura indicada anteriormente, ¿podría aportar información sobre cómo avalúa y califica a los estudiantes? indique aproximadamente la importancia relativa de cada uno de los siguientes ítems, puntuando sus respuestas en una escala de 1 a 5 (donde 1 tiene la mínima importancia y 5 la máxima).

7. Asignatura 1					
	Mínimo 1	2	3	4	Máximo 5
* (a) Participación activa en el aula (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
* (b) Trabajo en equipo (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
* (c) Trabajo individual (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
* (d) Control/Examen presencial (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
* (e) Evaluación entre pares (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

8. Asignatura 2					
	Mínimo 1	2	3	4	Máximo 5
(a) Participación activa en el aula (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
(b) Trabajo en equipo (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
(c) Trabajo individual (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
(d) Control/Examen presencial (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
(e) Evaluación entre pares (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

9. Asignatura 3					
	Mínimo 1	2	3	4	Máximo 5
(a) Participación activa en el aula (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
(b) Trabajo en equipo (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
(c) Trabajo individual (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
(d) Control/Examen presencial (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
(e) Evaluación entre pares (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

*** 10. ¿En los planes de estudio de su universidad se han integrado competencias transversales?** (Elija una opción)

Sí No No sé

11. ¿Considera que las competencias transversales adoptadas por su universidad tienen relación con las temáticas globales? (Elija una opción) [Answer this question only if answer to Q#10 is Sí]

Sí No No las conozco

[Answer this question only if answer to Q#11 is Sí]

12. Destaque si personalmente o en los planes de estudio de las asignaturas indicadas anteriormente se trabajan las dimensiones globales a través de las competencias transversales.

	Sí	No	No sé
(a) En algunas de las asignaturas (1,2,3) indicadas anteriormente (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
(b) En los PFC/TFM del mismo plan de estudio (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
(c) En otras asignaturas del mismo plan de estudio (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

¿Promueve o participa en actividades de innovación docente? Puntúe sus respuestas en una escala de 1 a 5 (donde 1 representa la mínima actividad y 5 la máxima). Por favor, indique las temáticas correspondientes a cada uno de los ítems, así como el año de la última actividad realizada.

13. Promoción/Participación

	Mínimo 1	2	3	4	Máximo 5
*(a) Cursos como promotor/a (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
*(b) Cursos como participante (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
*(c) Autor/a de publicaciones/artículos (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

14. Temática
(a) Cursos como promotor/a

(b) Cursos como participante

(c) Autor/a de publicaciones/artículos

15. Año de la última actividad
(a) Cursos como promotor/a

(b) Cursos como participante

(c) Autor/a de publicaciones/artículos

16. ¿Hay otras temáticas relacionadas con innovación docente que le interesaría profundizar, en las que no hay oferta formativa?

17. Con relación a su investigación, ¿podría indicarnos hasta tres códigos de la nomenclatura internacional de la UNESCO? (disponible en http://bit.ly/MFmOT4). Indique códigos de 5 dígitos.
* (a) Código 1

* (b) Código 2

* (c) Código 3

¿En qué nivel su actividad docente se relaciona con sus actividades de investigación? Puntúe sus respuestas en una escala de 1 a 5 (donde 1 es la mínima relación y 5 la máxima) en relación a cada asignatura indicada anteriormente.

18. Asignatura 1

	Mínimo 1	2	3	4	Máximo 5
*(a) Relación docencia/investigación (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

19. Asignatura 2

	Mínimo 1	2	3	4	Máximo 5
(a) Relación docencia/investigación (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

20. Asignatura 3

	Mínimo 1	2	3	4	Máximo 5
(a) Relación docencia/investigación (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

*** 21. ¿Con relación a su actividad académica, considera que la docencia y la investigación se retroalimentan positivamente?**
(Elija una opción)

Sí No

22. Si ha contestado afirmativamente a la respuesta anterior, ¿podría explicar brevemente los aspectos que han favorecido esta situación? Si ha contestado negativamente, ¿podría explicar brevemente las dificultades encontradas?

En septiembre de 2015 se lanzaron los Objetivos de Desarrollo Sostenible (ODS) (más información en <http://bit.ly/1iKD85v>). En la siguiente tabla, los ODS están agrupados en 12 ítems y relacionados respectivamente con 3 bloques en columna.

¿Podría indicar en qué grado integra los ODS en su docencia e investigación? En el caso en que su universidad integre competencias transversales en los estudios, ¿podría indicar el grado de relación de estas competencias con los ODS? Puntúe sus respuestas en una escala de 1 a 5 (donde 1 representa la mínima integración y 5 la máxima).

23. DOCENCIA					
	Mínimo 1	2	3	4	Máximo 5
* (a) Fin de la pobreza y del hambre (ODS 1,2) (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
* (b) Salud y bienestar (ODS 3) (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
* (c) Educación inclusiva, equitativa y de calidad (ODS 4) (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
* (d) Reducción de las desigualdades y igualdad de género (ODS 5, 10) (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
* (e) Agua limpia y saneamiento (ODS 6) (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
* (f) Energía asequible y no contaminante (ODS 7) (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
* (g) Trabajo decente y promoción de una industrialización sostenible (ODS 8 y 9) (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
* (h) Comunidades sostenibles y producción y consumo responsables (ODS 11, 12) (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
* (i) Adaptación al cambio climático (ODS 13) (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
* (j) Conservación y uso sostenible de los ecosistemas (ODS 14, 15) (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
* (k) Promoción de paz, justicia e instituciones sólidas (ODS 16) (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
* (l) Promoción de la cooperación internacional entre estados y organizaciones internacionales (ODS 17) (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

24. COMPETENCIAS TRANSVERSALES						
	Mínimo 0	1	2	3	4	Máximo 5
(a) Fin de la pobreza y del hambre (ODS 1,2) (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
(b) Salud y bienestar (ODS 3) (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
(c) Educación inclusiva, equitativa y de calidad (ODS 4) (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
(d) Reducción de las desigualdades y igualdad de género (ODS 5, 10) (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
(e) Agua limpia y saneamiento (ODS 6) (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
(f) Energía asequible y no contaminante (ODS 7) (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
(g) Trabajo decente y promoción de una industrialización sostenible (ODS 8 y 9) (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
(h) Comunidades sostenibles y producción y consumo responsables (ODS 11, 12) (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
(i) Adaptación al cambio climático (ODS 13) (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
(j) Conservación y uso sostenible de los ecosistemas (ODS 14, 15) (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
(k) Promoción de paz, justicia e instituciones sólidas (ODS 16) (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
(l) Promoción de la cooperación internacional entre estados y organizaciones internacionales (ODS 17) (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

25. INVESTIGACIÓN					
	Mínimo 1	2	3	4	Máximo 5
* (a) Fin de la pobreza y del hambre (ODS 1,2) (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
* (b) Salud y bienestar (ODS 3) (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
* (c) Educación inclusiva, equitativa y de calidad (ODS 4) (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
* (d) Reducción de las desigualdades y igualdad de género (ODS 5, 10) (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
* (e) Agua limpia y saneamiento (ODS 6) (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
* (f) Energía asequible y no contaminante (ODS 7) (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
* (g) Trabajo decente y promoción de una industrialización sostenible (ODS 8 y 9) (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
* (h) Comunidades sostenibles y producción y consumo responsables (ODS 11, 12) (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
* (i) Adaptación al cambio climático (ODS 13) (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
* (j) Conservación y uso sostenible de los ecosistemas (ODS 14, 15) (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
* (k) Promoción de paz, justicia e instituciones sólidas (ODS 16) (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
* (l) Promoción de la cooperación internacional entre estados y organizaciones internacionales (ODS 17) (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

¿Podría indicar con qué tipo de entidades se relaciona habitualmente fuera de la universidad para la difusión de sus actividades académicas? Puntúe sus respuestas en una escala de 1 a 5 (donde 1 representa la mínima relación y 5 la máxima). Seleccione también el tipo de relación mantiene con estas entidades e indique el año de la última actividad.

26. Puntuación

	Mínimo 1	2	3	4	Máximo 5
*(a) Entidades públicas (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
*(b) Empresas nacionales (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
*(c) Pymes (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
*(d) Organizaciones de la sociedad civil/ONGs (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
*(e) Redes/Movimientos sociales (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
*(f) Tercer sector ambiental (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
*(g) Tercer sector social (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
*(h) ONG del sector del desarrollo internacional (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

27. Tipo de relación

	No hay relación	A título personal	Relación formal/institucional	Prácticas de estudiantes	Proyectos con dotación económica
*(a) Entidades públicas (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
*(b) Empresas nacionales (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
*(c) Pymes (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
*(d) Organizaciones de la sociedad civil/ONGs (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
*(e) Redes/Movimientos sociales (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
*(f) Tercer sector ambiental (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
*(g) Tercer sector social (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
*(h) ONG del sector del desarrollo internacional (Elija una opción)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

28. Año de la última actividad	
(a) Entidades públicas	
(b) Empresas nacionales	
(c) Pymes	
(d) Organizaciones de la sociedad civil/ONGs	
(e) Redes/Movimientos sociales	
(f) Tercer sector ambiental	
(g) Tercer sector social	
(h) ONG del sector del desarrollo internacional	

*** 29. Cuando piensa en difundir los resultados de su trabajo, ¿en qué medio piensa? Ordene por importancia los primeros 6 ítems (donde 1 es el más importante y el 5 el menos importante). [Por favor califique 6 opciones.]**

Artículos científicos del primer cuartil indexado	<input type="text"/>
Artículos científicos de todas las bases de datos	<input type="text"/>
Libros	<input type="text"/>
Capítulos de libros	<input type="text"/>
Conferencias internacionales	<input type="text"/>
Conferencias nacionales	<input type="text"/>
Artículos divulgativos	<input type="text"/>
Prensa	<input type="text"/>
Blogs/WEB 2.0	<input type="text"/>

*** 30. ¿El seguimiento que la institución hace de su actividad académica incluye los siguientes aspectos? Seleccione todos los aspectos relevantes.**

- Docencia
- Investigación
- Transferencia de conocimiento
- Innovación docente
- Social Outreach
- Other (Especificar) _____

*** 31. ¿Cómo valora el sistema de evaluación del profesorado de su universidad? Puntúe su respuesta en una escala de 1 a 10 (donde 1 es la valoración más negativa y 10 la más positiva) (Elija una opción)**

1	2	3	4	5	6	7	8	9	10
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

*** 32. En su institución, ¿son públicos los criterios de evaluación de las actividades académicas del profesorado? (Elija una opción)**

- Sí No No sé

33. ¿Podría indicarnos el enlace donde poder consultar esos criterios? [Answer this question only if answer to Q#32 is Si]

*** 34. ¿En qué redunda positiva o negativamente la evaluación del profesorado de su institución?**

*** 35. ¿Ha pasado por procesos de acreditación con agencias de evaluación de la calidad y de acreditación nacional (ANECA) o autonómicas? (Elija una opción)**

- Sí No

36. ¿Podría explicar brevemente cómo valora la experiencia que ha tenido con las agencias de acreditación? [Answer this question only if answer to Q#35 is Sí]

Gracias por su colaboración.

