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Sustainable development as a driver for educational innovation in engineering school: the case of UniLaSalle.

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Introduction

Since 2000, many studies have dealt with sustainable development and innovation, technological transitions, evolutionary processes, based on the idea that innovation is a key factor for SD (Mulder 2007). Innovation networks could be set up using new methods to search for sustainable technological solutions (Weaver 2000). Innovation or technological transitions could be considered as evolutionary processes (Geels 2002; Geels and Schot 2007; Ziman 2000). Conceptual work has dealt with SD for engineers (Mulder 2006, 2017; Mulder and Francoeur 2009; Mulder, Segalàs, and Ferrer-Balas 2012; Segalàs-Coral 2009). The relationship between sustainable development and innovation has been explored (Hall and Vredenburg 2003; Mulder 2007), and also what should be learnt, in engineering curricula, for sustainability (Segalàs-Coral 2009), with a tension between nature sciences and technology, on the one hand, and public welfare commitment involving *interdisciplinarity* and *transdisciplinarity* education on the other hand (Cech 2014). *Interdisciplinarity* creates dialogue and exchanges between disciplines. It is no longer a fragmented vision but an enrichment from different disciplines. *Transdisciplinarity* works on objects that do not belong to one discipline. It aims to achieve a project through the use of different disciplinary activities.

It appeared necessary to think about the integration of SD in educational programmes as well as innovation for a sustainable educational system (Mulder 2006; Quendler 2017). Moreover, the way SD competences were introduced into technological universities has been studied (Ferrer-Balas, and Mulder 2010); the results show that ‘a more community-oriented and constructive, active learning pedagogical approach increases students’ knowledge of SD’.

Our aim is to keep in mind all these theoretical constructions and observations and to study how to evaluate the integration of SD in a case study of engineering education, and even more how to use this integration as a driver for educational innovation. We define educational innovation¹ as novel practices, tools or technologies used in curricula, course materials and pedagogy.

Following previous research (Fourati-Jamoussi et al. 2015a) this article attempts to answer these questions: i) how has Sustainable Development (SD) been introduced in some curricula? ii) what are the reasons for innovating in an engineer training programme ? iii) can we identify a link or an interaction between the reasons for integrating SD and innovation in training programmes?

The attempt to evaluate the integration of academic SD initiatives in universities suffers from a dual mismatch: i) Most studies only focus on the environmental pillar (Davis and Elliott 2003; Thomas 2004) while they should also take into account the economic and social dimensions (Olszak 2012); ii) We observe an increasing number of scientific works that examines SD initiatives in higher education (teaching and curricula) and research. For instance, Urbanski and Rowland (2014) evaluated academic SD initiatives by using ‘STARS as a multi-purpose tool’ in the campus sustainability movement. This tool was released by the Higher Education Associations Sustainability Consortium (HEASC) in 2006, and ‘would address all the dimensions of sustainability and all the sectors and functions of a university’. In 2009, the use of STARS allowed colleges and universities to measure their ‘sustainability performance’. Rowe and Hiser (2016) consider that ‘effective strategies for blending service learning and sustainability pedagogies are beginning to emerge’.

On the basis of this statement, our hypothesis is that the implementation of SD in its entirety, in a higher education engineering school, should lead to educational innovation, taking into account its relationship with research. We present a case study at ‘Institut Polytechnique UniLaSalle’ focused on the education of engineers (geology, agriculture, and environmental sciences, biomass and food production, food transformation and distribution in relation to health).

For an independent organisation of higher education such as the ‘Institut Polytechnique UniLaSalle’, the challenge of SD is a potential driver for differentiation,

for singularity, and is consequently an innovation process as an answer to this issue. In the French context, with a very strong dominance of public institutions in research and higher education, our hypothesis is that autonomy is not always an advantage neither in terms of legitimacy nor in terms of financial resources. A balanced development, according to economic necessities, social issues and environmental concerns, remains fragile; but precisely this fragility requires a path that must be taken in accordance with Spinozian principle that the order and connection of thoughts should be the same as the order and connection of things. Moreover, we suggest here that an autonomous institution, like UniLaSalle, devoted to teaching and research, in order to be itself sustainable, must also face the three conditions of this sustainability (environment, economic and social), in its own functioning. This autonomy in its development, which is a cause of fragility, is also a condition of its own sustainability. This specific situation increases the need for coherence in terms of SD principles. This case study is not an overview of higher education institutions, although the results could be used in other higher education institutions.

Meeting the challenge of SD by applying it directly to governance, operation teaching and research is of a different nature than teaching SD to students. It is one thing to define the external purpose of organizing training and research, but another to develop methods of internal operation consistent with its purpose. If the purpose of an organisation is to train actors highly concerned by SD, strategic choices should be in coherence with this educational objective. Operations, i.e. courses taught, have to be adapted to this objective. However, the case study of such a transformation is interesting in an Institute which is positioned as a trainer and producer of knowledge in areas at the heart of sustainability: mineral and energy resources, soils, water, biodiversity, adaptation to climate' change, farming systems, food production and food quality (Quendler 2017).

In education, the study of each stage of incremental transformation becomes a strategic priority for the integration of SD (Mulder, Segalàs, and Ferrer-Balas 2012). The change should begin with the educational leaders and then spread to the teaching staff. In addition, reflexivity on the relationship between actions and their purpose, in the short, medium or long term, should

be accessible, since the Institute includes research teams that are able to enforce it. Most of them are well informed about scientific data on climate change, energy resources, biodiversity, etc., but also on economic constraints and social sustainability. The Institute can become, de facto, a 'living Lab' offering the ability to study its evolution towards more SD for its own research team.

The challenge of this work is to study the impact of one Institute's finality as explained by Management, i.e. to train responsible actors for SD, in its operational methods. This particular reflexivity, both from outside and from within, can bring valuable insights in the assistance and support for any organisation that sincerely wishes to reach more social responsibility in its own development.

Finally, the aim of this article is not to describe the sustainability of UniLaSalle only through the campus infrastructure and operational activities, although it is important for educational reasons, but to focus on the sustainability of the teaching itself, that means on its ability to move and to transmit to the students the ability to meet their own needs without compromising the following generations to meet their own. Before any comparison with other peer institutions (engineering schools), it is necessary to understand and modelise the interaction of innovation and sustainability processes in our particular case institution.

The previous paper (Fourati-Jamoussi et al. 2015a) focused on the study of sustainability by using two perspectives: integration and evaluation by the Executive Management team. This paper tends to extend this idea of sustainability through the use of two other perspectives: reflections of the researcher and the perception of Management and educational managers (Lönngren et al. 2016).

The main contributions of this paper are: i) the analysis in UniLaSalle of the staff and curricula managers' educational programmes; ii) The production of a model which describes the interrelationship in a perception and integration perspective. Such a model could then be broadened to students and to other schools.

This study cannot be completely anonymous. In living research approach, 'users' are the concerned people who want to participate to the study. For the recruitment of 'users' according to the context of a 'living Lab' project, we reached the directly concerned people in our network of trust. Paradoxically, it is a question of ethics,

since the model can only be built from a real engagement of the respondents. Subsequently, when the model is used on a larger scale, anonymous methods for recruitment can be used (Dubé, Sarrailh, and Billebaud 2014; Leminen 2013). This aspect, which breaks with the traditional practices of academic research, probably explains the small number, although increasing, of publications on *‘living Labs’*. There are now more than 400 *‘living Labs’* (EnoLL Network) around the world that help to better understand social innovation (Bergvall-Kareborn, Holst, and Stahlbrost 2009; Bergvall-Kareborn and Stahlbrost 2009).

The structure of this article is as follows: section 2 presents a brief literature on SD and innovation; section 3 articulates the relationship between SD and innovation in higher education; presents the research questions and provides the methodology of our empirical study on the dynamic capacity of innovation in UniLaSalle; section 4 presents the results of the study; the discussion and research limits and section 5 concludes this paper.

1. A brief literature review on SD and innovation in education and training

We adopt the traditional definition of SD, from the Brundtland Report (1987) that specifically emphasises the requirement to *‘meet the needs of the present without compromising the ability of future generations to meet their own needs’*. If it is necessary to meet current needs, the important thing is not only to anticipate the needs of the future but to participate in the development of the capacity of future generations to meet their needs. UniLaSalle aims at training young engineers or managers for the very near future, that is to say, those that will meet the needs for a short-term future without compromising the ability of *‘their future children’*. This vision led to teaching methods which, in fact, are both focused on the present – making young people able to meet their needs, but also look to the future – enable them to act while thinking about the effects of their actions on tomorrow’s society.

The *« three pillars of sustainability »* is a metaphoric way to visualise their needs to reach sustain-ability, like three Greek columns carrying the pediment of a temple. Of course, each pillar should be as high and as strong as the others. Another way is to use the Euler diagram generalised by Venn (1880); in this representation, sustainability is achieved

when the three 'pillars' are merged into one. Truly the number of three pillars is a minimum; they are economic, social and environmental issues. A global adapted policy is needed to obtain three pillars of sustainability at an equivalent level. Until now, a clear definition of this equality was not achievable, but it could be shown through pragmatic actions. The major point to understand is that sustainability is a process of perpetual adaptation and that actions should concern the three pillars.

Moldavska and Welo (2016) insist on the fact that the three pillars of SD should be addressed equally. Here, we focus our attention on how teaching could be transformed in order to be in adequacy with the global aim of SD. In accordance with Van Bellen (2006), who explained that the construction of indicators in order to measure sustainability must establish a connection from past to present and from present to future, we defined indicators to follow the evolution of SD teaching practices. These indicators could have a practical utility, as a support for instructional decisions and for evaluating degrees of success in new educational tools.

Lozano, Ceulemans, and Scraff Seatter (2015) presented five main approaches for incorporating SD into higher education curricula: *i) coverage of some environmental issues in an existing course or courses; ii) a specific SD course; iii) SD intertwined as a concept in regular disciplinary courses; iv) SD as a possibility for specialisation within the framework of each faculty; v) SD as an undergraduate or post-graduate programme.*

UniLaSalle has followed the third approach as SD is adapted to the nature of each specific course (Abdul-Wahab, Abdulraheem, and Hutchinson 2003; Ceulemans and De Prins 2010; Kamp 2006; Peet, Mulder, and Bijma 2004; Thomas 2004). No specific courses on SD were defined for one major reason: all the curricula need SD, profoundly, depending on the type of know-how (expertise) the future engineers are trained for. They will work on energy production, in mining or public works, in agriculture and biomass production, in environmental protection, or in the food industry.²

Cros (1997) presented the theoretical works about the concept of innovation in social sciences and asked how this research could encourage reflection on innovation in education and training. She thought that 'this innovation is a relatively recent subject of reflection. It has interested social scientists since 1960 (Bashi and Zass 1992) and often

in operating terms'. Later, she discussed 'innovation in education and training as presented by the works of researchers in education'. She showed the complexity and the difficulties of 'attachment' to academic disciplines. She proposed to conceptualise this specific innovation because this field is one that didn't have theories, models or strategies to improve the work of teachers and researchers.

In the same article, Cros (1997) presented the development of innovation in education and training according to eight entries to, or views on, innovation. In this study, our problematic refers to the fifth and the seventh issues respectively focused on:

- The evaluation of innovations either by a fine analysis of the objectives or by the analysis of teacher's performances and their attitude towards innovation.
- The place and the role of different categories of stakeholders in the educational system: students, teachers, and academic staff.

In the same vein, Huberman and Miles (1984) adopted an empirical approach and analysed the attitudes of teachers through representative case studies, and changes in terms of restriction and effects on students when several innovations were applied in different contexts. This work uses such studies and their results as the basis for an empirical study of the perception of the interrelationship between SD and innovation in education.

2. Methods to analyse and discuss the problem

2.1. Articulating the relationship between SD and innovation in higher education

Operationalisation of SD requires strategic thinking. It is, therefore, necessary to innovate in the content of training courses but also probably in their organisation and their pedagogical modalities. But this relationship is probably not deterministic since it goes through representations of what SD requires.

2.1.1. Theoretical analysis

In France, there are different models of engineering schools; integrating SD approaches

differs from one institution to another because of the importance of Humanities and Social Sciences (HSS) is variable. In her thesis, Roby (2014) presented the communication of Béraud (1996) who proposed three categories of higher education engineering schools: the first group isn't interested in HSS, the trained engineer is a 'one-dimensional' expert whose missions are purely technical. Organisational missions are considered only in connection with their technical aspects; the second group whose archetype is 'Ecole Polytechnique', considered that business techniques are learned after school: HSS are part and parcel of general training as well as fundamental sciences. The third group corresponds to HSS training embedded in professional situations; this group takes into account engineering trades to try to detect the skills needed in their professional practices. Educational research can help to better understand the evolution of engineer training courses. A link can be made between the epistemology of various disciplines and the history of education in their domains (Sonntag et al. 2008).

In agriculture sciences, in France, for the last fifty-six years, training in HSS has been considered as necessary, due to the age and the importance of agricultural law, the recognition of close links between agriculture and society, and the importance of territorial management and development. Agriculture is at the origin of civilisations. All higher education engineering schools in agriculture, even in the seventies, included training courses in humanities and social sciences. Food science engineers also need knowledge on the social and cultural basis of human consumption of food, more and more related to the internationalisation of the food business. Generally speaking, engineers in agriculture and food sciences need some basic knowledge of HSS.

According to Sonntag et al. (2008), a better adaptation of individuals to professional activities and economic realities is due to the increase in teaching of humanities and social sciences. We believe that HSS should be thought as a useful knowledge for students, to acquire skills or 'competencies' and to be able to adapt themselves to work in companies, and/or to be also able to change them. An integrated sustainable approach should involve the evolution of the academic programmes in a transversal way.

2.1.2. Context of UniLaSalle and its choice about SD and innovation

On the campus, the students stay during five years and they often have a behaviour of consumers of campus facilities. To learn that they have to be involved in the sustainability of their Institute is a novelty for them. In addition to engineering degrees, some masters (Management of Urban Food Security, Plant Breeding, Data Management in Agriculture) train future actors, coming from international networks, to work in areas directly engaged with the issues of SD. Insofar, UniLaSalle provides training which is at the heart of SD issues and also specific and applied courses which are answers to SD. It is obvious that the whole Institute has to take the choice of SD at all levels. The context in which the Institute evolves seems favourable: international networks of Lasallian universities; international networks of universities in agriculture/agronomy/geology, accurate insertion in the regional territory and numerous partnerships with industry. After fifteen years of continuous growth, with now more than 2500 students, and about 450 graduated engineers every year, the institute has begun to acquire a new but real recognition in France.

A strategy of development of teaching and research chairs in partnership with companies and territorial institutions has been undertaken on three subjects: Risks in Agriculture, Agro-Equipment & New Technologies, and Plant Breeding. A fourth one is being considered: Entrepreneurship and Innovation. Research areas ('Agroecology' Unit, 'Quality of Agricultural Resources and Processing' Unit, 'Process Innovation, Competitiveness in the Agriculture and Rural Territories' Unit,³ 'Basin, Resources and Tanks' Unit) associated with all the other chairs make it possible to work on many questions induced by the choice of SD. Therefore, the choice to set up a teaching strategy, research, and governance consistent with the imperatives of SD seem 'natural'. In this context, as presented in the previous article (Fourati-Jamoussi et al. 2015a), the question was: how to place an integrated approach of SD in the strategy of UniLaSalle? The Institute implemented many actions at all levels from an evaluation perspective (Lönngren et al. 2016), the first results of the dimensions, or axes of SD, and the choice of strategic variables were published in the cited article above.

We analysed these actions and their new perspectives on management, practices in teaching and research about sustainability in an engineer higher school.

To compare the evolution of UniLaSalle with roughly comparable structures (Lima

et al. 2016) raises many problems, as the chosen indicators can experience biases that are difficult to assess: different financial resources, specific student populations, diverse academic programmes, specific and non-comparable business activities of graduate students.

2.2. *Problematic and research questions*

The question is now the following: does the strategic choice of SD promote innovation in education? We, therefore, undertook a study on the importance of SD as an Innovation vector for higher education, from the teachers' point of view. To the extent that SD requires the acquisition of capacities/skills and to take into account, in education, the necessary capacities/skills of future technical and economic actors, it seemed consistent that SD could be an innovation vector.

Very few studies investigated the ways in which education and SD have evolved or what is the impact of the choice of SD in higher education on the overall content of education and teaching methods (Crofton 2000; Quist et al. 2006). Sterling (2004) argues that 'the sustainability does not simply require an 'add-on' to existing structures and curricula, but implies a change of the fundamental epistemology in our culture and in our educational thinking and practice [...], sustainability is a gateway to a different view of curriculum, of pedagogy, of organisational change ... '. Multiple international declarations (Wright 2002) refer to the need to include SD across the curriculum and to develop *interdisciplinarity* and *transdisciplinarity* research as well as public outreach.

Viegas et al. (2016) identified attributes of sustainability in Higher Education by analysing 2513 studies published between 2000 and 2015; their findings show that 'the *transdisciplinarity* can be considered as an epistemic transgression that relates societal issues with scientific problems'. This study offered 'an alternative approach related to the lack of comprehensive research works on how to organize diverse assets involved in Sustainability in Higher Education'.

We focused more on the last two years of the curricula (Master level), as these are the ones leading to professional practice. The Institute follows the Bologna process, but it follows also the French system for engineer training in five years. The strategic and operational directions of the Institute are underpinned by the integration of a vision of

SD and therefore should bring both opportunities and constraints involving creativity and innovation. In practice, does SD promote or restrict innovation?

Furthermore, for students learning a trade, they must think about it in the framework of SD. Concerning SD, we defend the idea according to which there is a teaching specificity that requires a change in perspective. It seems that integrating SD in higher education, which leads to new useful skills for a professional activity, should be a source of innovation. SD comes from different awareness of our responsibility towards future generations (Brundtland 1987; Jonas 1979; Jonas and Greisch 1999). The reasons which led to the construction of the concept of SD are thus derived from philosophical reflections on human becoming and from our responsibility in the evolution of the biosphere. This is indeed a new ethical dimension. This responsibility, which guides economic decisions, takes the environment into account and should lead to innovations in the structure of education as well as in the content of theoretical courses.

2.3. Methodology

To understand precisely how SD is articulated with educational innovation, both in content and in method, we pursued the examination of Holmberg et al. (2008) about the integration of SD into educational programmes in three universities to show the difference of their activities and to describe the methods used to achieve the embeddedness of sustainability in curricula with teachers and other actors. We chose a qualitative methodology (Wacheux 1996; Yin 1994) based on a single case study of UniLaSalle, in order to place the Institute in its role of '*living Lab*'. This study uses 1 type of non-numerical data that were collected from 27 semi-structured interviews (during 45 min) with 2 groups: the Executive Management Team and the Curricula Management Team. The first one includes the Vice-President, the Director of studies, the student life Director, the Directors of each specialisation pathway, the previous and the new Director of SD, the Manager of the master in management of urban food security, the professional integration Manager, the Information Technology and Communication in Education manager, the Scientific Director and one research unit Manager. The role of this team is to guide the strategic decisions of teaching and research. The second one is composed of 14 Curricula Managers including three academic advisors. Their role is to implement the

programmes of the different courses. As interviewees did not answer the same item for each theme (e.g. Figure 2), we have less than 27 answers for each item.

The interview guide was built on six themes/questions: i) what is the definition of innovation in engineering education?; ii) what are the different types of innovations?; iii) what are the reasons to innovate at UniLaSalle?; iv) what is the definition of SD?; v) what are the reasons for integrating SD in the engineer training?; vi) what is the link between SD and innovation in engineering education? All the answers to the questions were open-ended questions that were recorded. To analyse qualitative data, we used NVivo 9⁴ that allowed us to: i) organise, classify and analyse responses more effectively, ii) examine relationships between data and themes, iii) visualise our project and draw models and charts. We summarised the ‘coding process’ of Philip Adu⁵ to conduct this qualitative analysis with NVivo 9: ‘we identify and code relevant information and put them in their respective nodes’. Figure 1 shows each node that contains the number of relevant information coded; they are called ‘node references’ (code Frequencies). For each new node, ‘we are expected to label and describe it’. We have two kinds of nodes: ‘Parent to represent a theme (defined during the phase of building the survey) and Child to represent a category (the sub-themes were defined after the transcription phase)’. To generate and label nodes/codes, ‘we assigned a word or phrase (a concept) that best represents the relevant information’ (Bazely and Jackson 2013). After reviewing the characteristics of the research questions, ‘we used the answer to code (create a node) and represented the information’ (Kane and Trochim 2007). The processing of the collected data with those discussions (from June 2015 to March 2016) allowed us to better understand the dynamics of the innovation process in Uni- LaSalle for the past two years, and the role of SD in the events of creating new courses, masters and new teaching practices in a specific situation. The following section details the results of these interviews.

3. Results analysis and discussion

3.1. Results

The definitions of innovation in engineer training, as described by the respondents of the interviews, reveal four different types of innovation that could be named as: a) Educational innovation;

b) Content innovation; c) Training Teacher's innovation; d) Social innovation.

Name	Sources	Ref	Create	Creat	Modifie	Modified By
⊕ Pillars of sustainable development integrated	23	56	18/02/	FF	20/04/2	FF
⊕ Reasons of Sustainable development integrated	21	31	19/02/	FF	19/04/2	FF
⊕ Ethical dimension	7	9	19/02/	FF	20/04/2	FF
⊕ European dimension	2	2	19/02/	FF	19/02/2	FF
⊕ Regulatory and environmental dimension	8	9	19/02/	FF	13/12/2	FF
⊕ Responsible engineer dimension	9	10	19/02/	FF	20/04/2	FF
⊕ Reasons to innovate	23	61	18/02/	FF	13/12/2	FF
⊕ Adapt training to the engineer's profile	8	10	19/02/	FF	13/12/2	FF
⊕ Companies' needs	7	7	18/02/	FF	13/12/2	FF
⊕ Constraints of natural and global environment change	9	10	19/02/	FF	13/12/2	FF
⊕ Creation of new courses and masters	2	2	19/02/	FF	19/02/2	FF
⊕ Demands and motivation of the students	8	10	18/02/	FF	13/12/2	FF
⊕ Evolution of Education	4	4	19/02/	FF	13/12/2	FF
⊕ Improve teaching quality	6	7	18/02/	FF	19/04/2	FF
⊕ Linking research and teaching	3	3	18/02/	FF	19/02/2	FF
⊕ Needs and motivation of teachers	4	4	18/02/	FF	22/02/2	FF
⊕ Stimulate the collective effort and favour sharing between teach	4	4	19/02/	FF	13/12/2	FF
⊕ Sustainable development promotes innovation	23	25	18/02/	FF	18/02/2	FF
⊕ Sustainable development restricts innovation	10	10	18/02/	FF	19/02/2	FF
⊕ Types of Innovation	24	37	18/02/	FF	18/02/2	FF
⊕ Content Innovation	4	4	18/02/	FF	13/12/2	FF
⊕ Educational Innovation	24	31	18/02/	FF	13/12/2	FF
⊕ Social Innovation	1	1	18/02/	FF	23/02/2	FF
⊕ Training teacher's Innovation	1	1	18/02/	FF	13/12/2	FF

Figure 1. NVIVO data figure for coding process. All sub themes are not presented in this screen capture (+ in a node means that the sub themes are not visible).

(a) Educational innovation concerns the teaching methods and the new tools involved in teaching. It can be described according to different formalised situations and implies a change in the relationship between students, their involvement, and the teacher: flipped classroom (Bergmann and Sams 2012); project approach, inductive method; tools and materials used to make this type of innovation (Mooc, Videos, boxes, podcast, audio, digital tablets ...); 'reverse professionalization' (It is the used terms for an adapted project training, build on the request of a sponsor, which is interested in a project to be realised by the students. We have no references about such project training courses) and coffee meetings between students and entrepreneurs to share experience stories.

According to the Vice-President of UniLaSalle, 'The curricula innovation is a state of mind, to share with teachers: try and test new practices for the transmission of knowledge, not only through IT tools but also with traditional tools. Innovation in courses may be promoted through *transdisciplinarity*'.

(b) Content innovation for student engineers and the creation of new courses and Master degrees are due to close relationship between research and education and the adaptation to external changes in higher education and the business environment. The innovation in the content is directly connected to the evolution

- of knowledge, know-how, or specific tools developed for engineers.
- (c) Training teacher's innovation: joined in the strategy of the Institute, we can consider that this training helps to maintain optimum consistency between teachers' conceptions and behaviour when engaging in curricula innovation (Bécharde and Grégoire 2005). It is not just more training. It is a radical change in the contents and the ways of training, considering that teachers are adults who can have reflexive thinking on their own practices, their own behaviour, and their own representation about what is teaching. This falls within an all-round personal development approach.
 - (d) Social innovation, seen as a systematic sharing of experiences (monthly) between teachers helps increasing reflexivity. These formal meetings are not merely discussions, but imply sharing teachers' experience.

The most frequently cited innovation by the respondents is the innovation in teaching methods because this type is central to the strategy of the Institute, we must support practices and all innovations ... We are in a systemic approach; we innovate in pedagogy for each teacher. To really get a dynamic approach, we designed a 'support cell'. It is a group designed to offer exchanges between teachers which are presentations and explanations followed by a collective discussion. We can be innovative if we adopt a reflexive posture both personal and collective. (Director of studies). Sonntag (2007) highlighted the dynamism of the teaching in educational programmes. He found a promotion of interactive educational methods (by projects, by problems, simulations) in opposition to traditional pedagogical methods (based on the transmission of knowledge) which is reputed as passive by students.

This categorisation of innovation in engineer training and the definition of SD have been communicated in a paper at the Ingenium Symposium (Fourati-Jamoussi et al. 2015b).

We develop the results of the interviews below, regarding the reasons to innovate in engineering education and the relationship between this innovation and SD.

- (1) What are the main reasons to innovate?

Figure 2 shows the distribution of the answers to the question on the reasons to innovate by executive and management teams (executive managers and managers of Master or research unit ...). The first cited reason refers to *the constraints of natural or global environment change*. Three other reasons are mentioned: *to adapt training to the engineer's profile*; *to stimulate the collective effort and favour sharing between teachers*; *the evolution of education*. This global presentation requires a comparative analysis: see Figures 3 and 4.

Figure 3 shows that the reasons to innovate, as the curricula managers or the academic advisors say, are quite different. The two first answers are focused on *the needs of the manufacturers and companies* and on *the demands and motivation of the students*, meaning the constraints connected with their professional and social environment. The *constraints of the natural or global environment change* come after.

Directors are more concerned with the issue of global environment and education while teachers in charge of final curricula look for the best compromise between companies' needs and students'

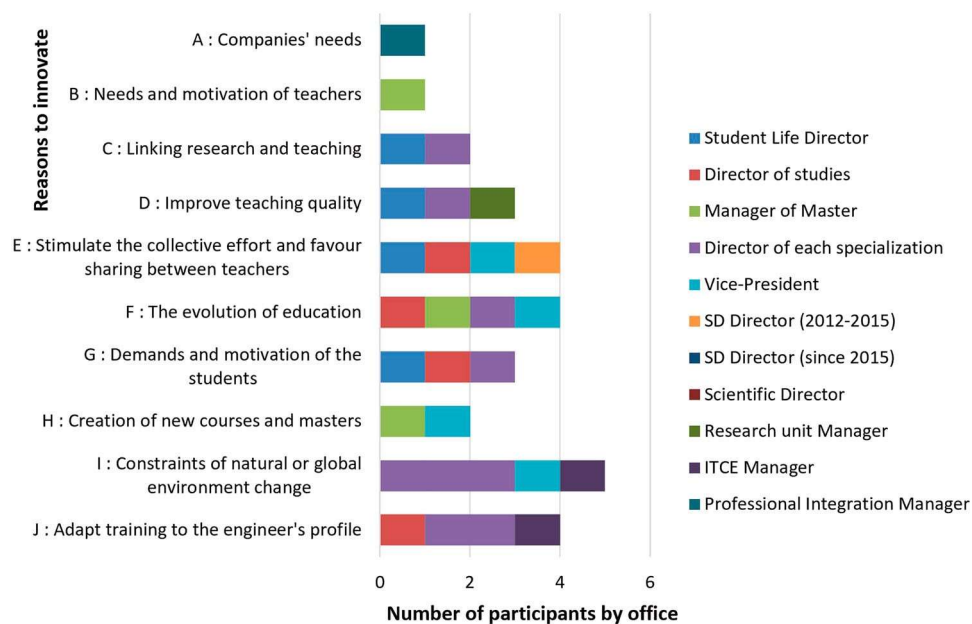


Figure 2. Reasons to innovate for Executive Management Team.

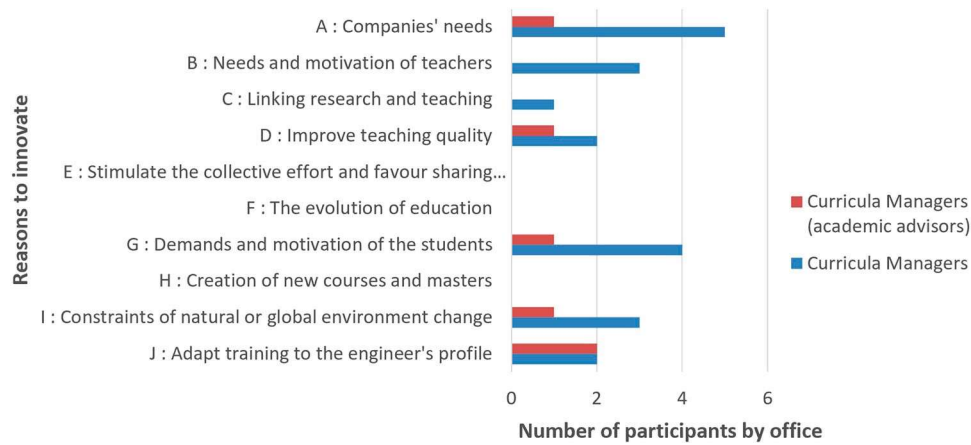


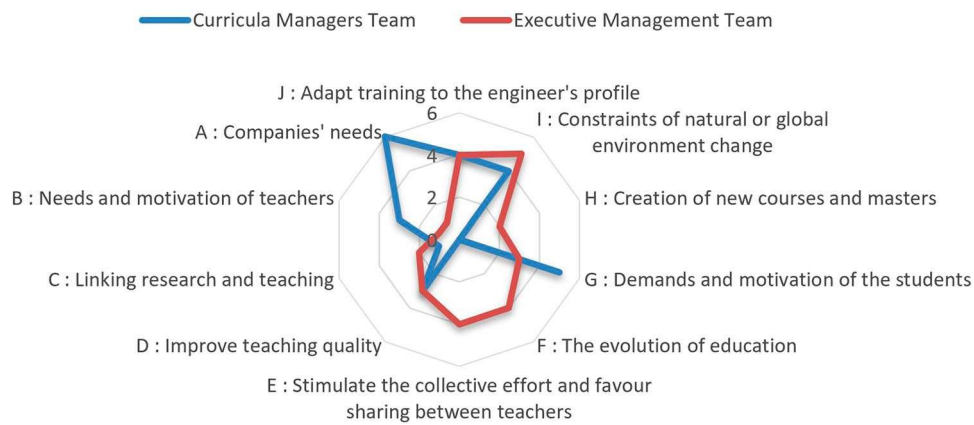
Figure 3. Reasons to innovate by Curricula Managers Team.

needs and wants (Figure 4). For the operational actors, economic problems and companies needs are considered as a priority. This is in tune with their activities; the first group has a strategic view, and the second a tactic one.

(2) Reasons to integrate SD in the courses

Figure 5 clearly shows that for directors, the first reason for integrating SD is to train *Responsible Engineers*. Ethics *per se* seems not to be considered; the meaning of such answers is that Ethics is directly considered as responsibility. Even if they do not mention this, they clearly follow the distinction of Max Weber between the ‘ethics of responsibility’ [in German: Verantwortungsethik] and the ethics of attitude [in German: Gesinnungsethik] through the affirmation: ‘engineers should respond for the consequences of their actions’.

In contrast, as Figure 6 depicts, teachers in charge of professional-qualification curriculum modules and academic advisors, precisely focus on ethics. During interviews, ethics was specifically linked to the rules of the technical profession, which is more connected to ethics of attitude [Gesinnungsethik], according to Max Weber. Regulatory and environmental issues are also important as they establish rules, Responsibility is just evoked. For all of these respondents, the European dimension seems to have nothing to do with the reasons to integrate SD in courses (Figure 7).



3

Figure 4. Radar fusion of Figures 2 and 3

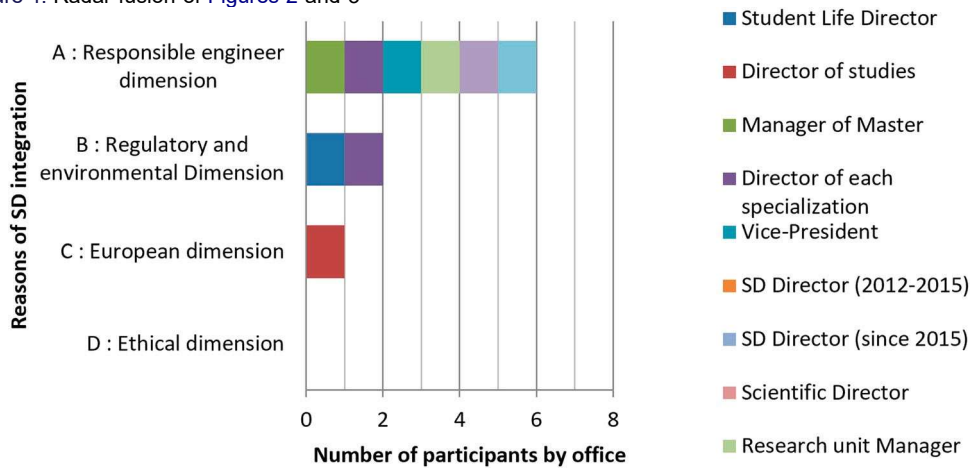


Figure 5. Reasons of SD integration by Executive Management Team.

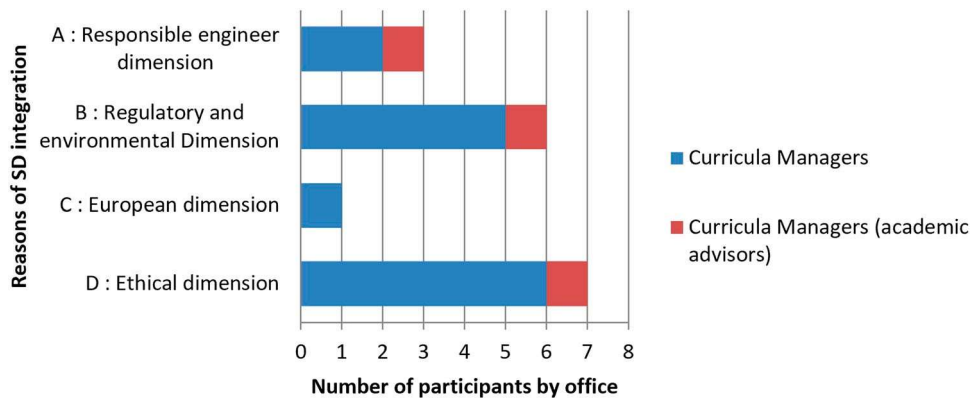


Figure 6. Reasons of SD integration by the Curricula Managers Team.

(3) SD, a three or four pillar concept?

Figure 8 shows that, unsurprisingly, the three pillars of SD are well integrated,

although environmental issues are a little more considered. An important element of our results is the emergence of a fourth pillar. The three respondents who insisted on this fourth dimension came from three different horizons: the previous Director of Agronomy speciality, two curricula managers one is a geologist and the other is an agricultural ecologist. They affirm that the governance of energy and mineral resources is specific and different from environmental issues which are more connected to *the natural living world*. This new pillar is said to describe fundamental technical needs, less connected with the living world but more with minerals and physics, and to involve strong geopolitical components; this is close to Vatin's (2006) point of view: he considers that engineering in agronomy and geology contributed to the genesis of the thought on energy. Environment is globally to be protected, and this protection should be local. Energy and minerals are to be found, extracted, transformed and produced; sources can be local and spread nearly randomly, but the needs are universal and increase with economic development; and it appears that they carry heavy geopolitical stakes. Energy is lost with use, but minerals, metals and their products can be produced and recycled through energy consumption.

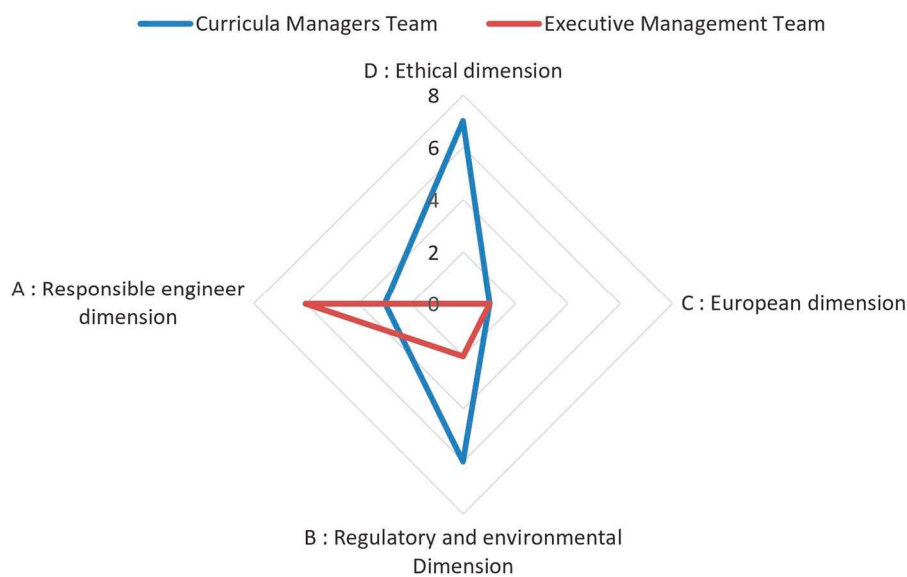


Figure 7. Radar fusion of Figures 5 and 6.

(4) Potential relationships between Innovation and SD

It appears that there is a large consensus that SD is both a restriction and a stimulation for

innovation when analysing Figure 9. But stimulation for innovation is considered to be more important for directors and for curricula managers. This means that, beyond the difference in positioning, the reference to SD is now perceived as a stimulus to innovation for the majority of respondents (85%). This is an important result, because, two years before, there was no real consensus. This change can have occurred as a consequence of the overall commitment of the Institute, but also with the evolution of a collective representation of SD. Nevertheless, it appears that the rate of people who consider SD as both a constraint and a stimulus for innovation is somewhat stronger among managers (no exception). It seems as if they had understood more than the others that ‘contradictory’ could be ‘complementary’, and that the axiom/principle of the ‘excluded middle’, in this case, could not be applied. These two results, as described in Figure 9, indicate an implicit recognition of complexity and that a constraint can be good for innovation, and sometimes can promote it although it could together restrict it. A constraint as SD could be thought as a selective system for innovation; it has a steering effect.

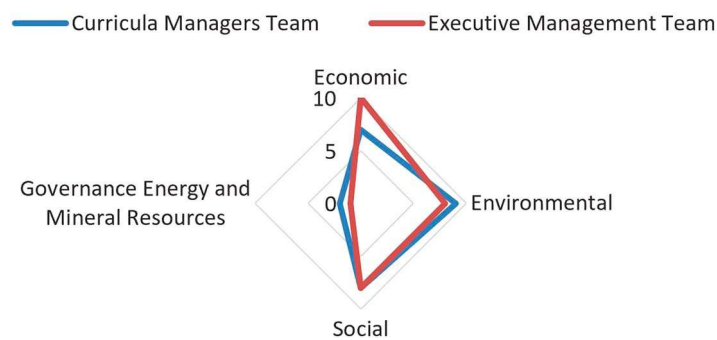


Figure 8. Pillars of SD integration by Executive Management and Curricula Managers Teams.

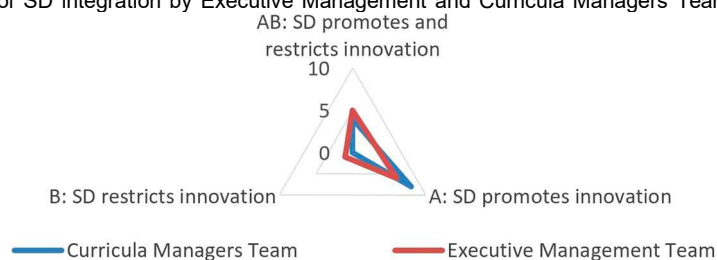


Figure 9. The potential relationship between innovation and SD by Executive Management and Curricula Managers Teams.

Figure 10 presents the model which has been built from the analysis of the answers.

It is not a simple result of the interviews as the answers are open-ended. Some specific and unpredictable items appeared, like the one concerning the European dimension. This is an important element of the strategy of many higher education institutions in Europe. We keep it to check if some evolution could appear in the future and if it can be different when broadening to the students.

After the analysis of all the Figures (2–9), Figure 10 summarises the points raised in this analysis. This model is more oriented in a perspective of perception and integration (Lönngren et al. 2016) than of impact, which could be studied later. The outcomes show that three major reasons are considered when integrating SD. It is interesting to note that very few respondents refer to the European dimension, although most of the regulation originates from European directives (for example, the Energy Performance of Buildings Directive). Our model shows that the reasons to integrate SD in training courses lead to a process of continuous improvement in which promotion and restrictions are mixed, although promotion is stronger (Deardorff and van Gaalen 2012; Geels 2002; Koehn and Uitto 2014).

According to Cros (1997), the process of innovation is more essential than the content. She based herself on the work of Huberman (1973) who identified three types of ‘products’: the ‘materials’, which belong to the textbook; the ‘concepts’, which means the change in programmes or teaching methods; and changes in ‘interpersonal relationships’ which are related to the mutual roles of teachers and students.

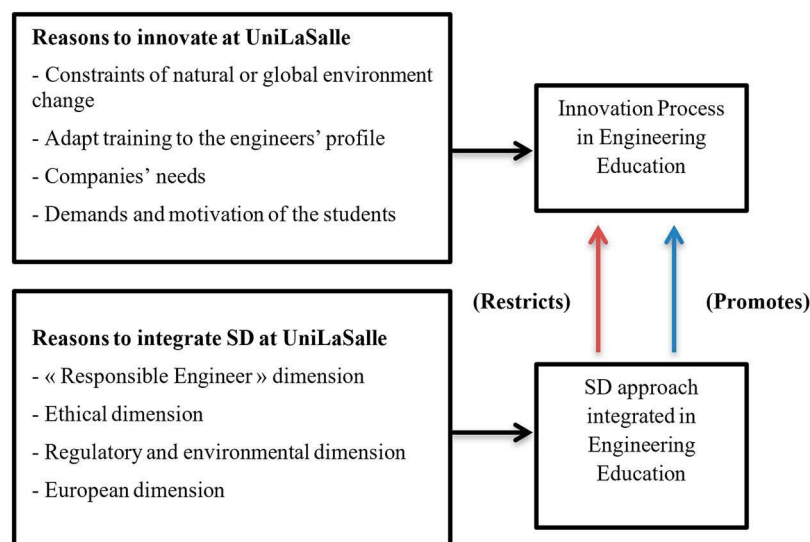


Figure 10. Actual Model of UniLaSalle: Potential relationship between SD integration and innovation process in Engineering Education

Although our study does not aim at distinguishing process innovation and content innovation, these results offer the possibility to distinguish four types of relevant innovations, according to a mix of Huberman's typology (1973). The 'materials' used by teachers have evolved with information and communication technologies that have boosted the potential for teachers to implement new teaching strategies (Bridgland and Whitehead 2005; Konting 2012; Viegas et al. 2016; Wang et al. 2014). The 'concepts' correspond to content innovation about the programme change (integration of SD). But in this study, the innovation in teaching is defined as a specific association of materials and teaching methods; so it is a mix of 'materials' and 'concepts'. Hence, 'interpersonal relationships' correspond to the social innovation that concerns exchanges of experiences between teachers and we can add the roles of teachers who act as students' coaches. Finally, the specificity of SD could have some impact on the nature of innovation, through a higher responsibility of engineers in tomorrow's society (Baillie and Catalano 2009; Bell 2011). Innovation in SD integrates necessarily means and aims in a retroactive loop.

From this analysis, we discovered a real collective awareness, but both some requests for faster progress and some obstacles against progress. SD appeared to be a differentiation strategy with added value for the Institute and for the teaching programme. It is therefore a long-term strategy that depends on continuous involvement. It is necessary to simultaneously modify the contents and the posture, the governance and the behaviour.

3.2. Discussion and research limits

The integration of SD in higher education is of utmost importance to understand how it is taking place and how it could be possible to promote it. Authors have shown that introducing SD requires teaching innovations. But it is far from certain that the educational innovations required are SD' specific. There is a systemic effect between a SD strategic positioning and the content of knowledge. Consequently, there is a need for more consistency in *interdisciplinarity* within the pedagogical methods. For

example, it has been at least 40 years since we know that *interdisciplinarity* is a source of innovation, regardless of the concepts of sustainability. At the UniLaSalle Institute, strategic choices for growth, the implementation of a quality system, the increasing use of digital and video, SD, transformation of teaching content, promotion of innovation and entrepreneurship, work on teaching innovation, have all been taken practically at the same time. It is not certain that the SD choices were the driving forces, because systemic analysis, *interdisciplinarity*, and even flipped classroom were set up independently and often before SD education. In other words, it is not because the incorporation of the SD can transform teaching, that the transformation of the latter cannot take place in the absence of SD teaching. Thus it is important to acknowledge the fact that this hypothesis would necessitate further investigation about the links between SD choices and innovation in teaching. It turns out that the concerns of sustainability in agriculture and living sciences are much older than the political conceptualisation of SD. This research was motivated by the perception that the integration of the SD evolved less quickly than the curricula.

The study of innovation in education and training requires an intersection of disciplines and therefore a *pluridisciplinarity* approach (Cros 1997). *Pluridisciplinarity* addresses an object of study according to the juxtaposition of multiple specialised looks. The problem lies in the fragmentation of approaches, although it is a way of approaching all aspects.

The difficulty is to conceptualise innovation in this field; it is a reflexive research which includes innovation in knowledge contents in permanent interaction with innovation in pedagogy, teaching and learning. These latter were found to be attributes of knowledge assets (Viegas et al. 2016).

Alike Roby (2014), we think that innovation as well as SD could be considered as good opportunities to integrate HSS alongside engineer sciences curricula. The objective of the Institute is to train ‘operating’ engineers in a world of competitive education to enable students to understand the logic and strategies of actors in this context of life sciences, earth and environment. To focus on the

development of young skills at the end of basic training, education should be thought as an action for present needs and also for the development of capabilities or skills (Wiek, Withycombe, and Redman 2011), in the medium and long-term.

Pedagogy can be considered more as a technique than a science; it is a skill that combines objectivity and subjectivity, because its object is the art to transmit knowledge, know-how, methods and also expertise, and so it depends on the field in which knowledge is transmitted. It can be defined also as accompanying somebody for the acquisition of new skills. Mintz and Tal (2013) defined 'pedagogies as teaching strategies to improve students' skills'. This very strong entanglement between science and techniques, so present in 'post-modern' times, can lead to confusion; but innovation itself is a process that is in fact an epistemic transgression, by relating phenomena that refer to different sciences. Even scientists can commit epistemic transgression when they discover something new through an analogy with other concept in another discipline. Discovery, invention, innovation are in general epistemic transgression (Simondon 2014).

Among the research limits we raise, we must mention the following: i) one engineering education school was studied; therefore it could be seen as a case that cannot necessarily be generalised; ii) the perceptions of institutional actors may change and not correspond to the practice of the institution; iii) the opinion of students would also have been interesting to understand how teaching has an impact of their perceptions of SD and SD values. Does teaching change values and students' SD behaviour and attitudes in the future? What is the impact of SD teaching in real life?

4. Conclusion

Integrating SD in engineering education is not only adding material. The task is also to transform teaching, to make students more inclusive and more open to multidimensional issues concerning social and environmental responsibility while meeting economic criteria. It appears that for most teachers, it is really a discovery which should have an important impact, on the medium term, on their activity; they

have to learn by themselves a different language. Comparatively, the students listen to the SD goals and learn some tools, as much new materials. Although higher management is aware of the need to have a holistic and complex approach of SD, curricula managers are even more concerned by economic requirements.

The results of our research suggest that people in charge of the strategic choices consider that the SD is a major reason to innovate, either in the economic action or in the education. Teachers closer to the actual job opportunities of future engineer's place more emphasis on the economic reasons and on motivations of students in situation to be soon engineers. In this case, the SD, as a reason to innovate, is a more strategic than tactical choice. The strategic approach is associated with the ethics of responsibility, while the concern for the professional integration of young people brings them closer to an ethics of attitude.

Executive Management Team is more concerned with the issue of global environment and education while teachers in charge of final curricula look for the best compromise between companies' needs and students' needs and wants (Figure 4). For the Curricula Managers, economic problems and companies needs are considered as a priority. This is in tune with their activities; the first group has a strategic view, and the second a tactic one. This is confirmed by the figure 7; regulation is also directly linked with tactic point of view.

The assessment of a possible fourth pillar in SD should be established and elaborated in a future research project. It would be interesting to validate it by an additional research. A global governance for energy and minerals is really different from climate change and environmental protection issues. The first point to check is the following: is it not already included in Social / Economic / Environmental Pillars? The second point could be to analyse whether if a definition of such a fourth pillar would help geopolitics governance as the distribution and consumption of mineral resources are very specific. European dimension could also be developed. The signal is lower, but is more typical of the Institute' strategic choices'.

The link between research and teaching seems very important. It is possible that the number of publications, reflexive research and teachers/researchers' and managers/directors' attitude towards innovation and SD in UniLaSalle have all had an

impact on SD adoption by teachers and on its integration in the Institute.

This research, although based on previous theoretical analysis (Fourati-Jamoussi et al. 2015a), is an empirical study. We attempt to understand how SD is really implemented into engineering school. This is the reason we used a ‘living Lab’ approach, in order to specify teachers’ and managers’ perception and reflexivity.

Indeed, SD is more a posture, a way of being and living, than a specific discipline such as mathematics, physics or biology. It could be thought as a new designing approach or a new ‘value’: how to act in a global system on which my action has an effect? I am in the system, and whatever I do, I change the system. In this point of view, goals and tools to achieve the goals could be classified as similar categories: something which changes the system. In that case, to be able to listen to the whole environment is a new and important skill to develop. Here is probably the most important innovation to implement in pedagogy, teaching, and training: the ability to listen and to perceive even very weak but persistent signals.

SD challenges reveal some specific stakes, and, as an answer, a posture forcing the Institute to create its own SD model that could be really specific. It is now known that the more complex a system is, the more numerous the possible representations of it could be.

Our model leads to new possibilities to broaden this research at different levels. First, we have to implement this research at the students’ level, and more quantitative results would be useful. This could help to better understand the relationship between Top-down incentives and Bottom-up proposals. We have already designed a first survey for students, in order to validate this model, based on the responses of about 300 students, specifically in master level. Depending on the result, it could be broaden to different situations, e.g. after a six month training course in foreign institutions. Another survey for teachers is underway. Second, it would be insightful to test the model on other peer engineering schools, and then on other academic institutions. Such a methodology could be used to study other relationships between SD and specific educational innovations.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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Notes

1. http://www.sii.soe.umich.edu/newsite_dev/documents/CohenBallScalePaper.pdf.
2. In Geology, Agriculture or Food and Health curricula, the challenge of SD is integrated in specific *pluridisciplinarity* courses which describe the challenges from SD requirements in their discipline.
3. The PICAR-T Research Unit is now called INTERACT (Innovation, Territory, Agriculture and Food-industry, Knowledge and Technology Unit) since 2016.
4. <http://download.qsrinternational.com/Document/NVivo9/NVivo9-Getting-Started-Guide.pdf>.
5. <https://www.slideshare.net/kontorphilip/conducting-qualitative-analysis-using-nvivo-a-quick-reference>.

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