



HAL
open science

Engineering education perspective for sustainable development: A maturity assessment of cross-disciplinary and advanced technical skills in eco-design

Catherine Perpignan, Yacine Baouch, Vincent Robin, Benoît Eynard

► To cite this version:

Catherine Perpignan, Yacine Baouch, Vincent Robin, Benoît Eynard. Engineering education perspective for sustainable development: A maturity assessment of cross-disciplinary and advanced technical skills in eco-design. *Procedia CIRP*, 2020, 90, pp.748 - 753. 10.1016/j.procir.2020.02.051 . hal-03491436

HAL Id: hal-03491436

<https://hal.science/hal-03491436>

Submitted on 22 Aug 2022

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution - NonCommercial 4.0 International License



ELSEVIER

ScienceDirect

Procedia CIRP 00 (2020) 000–000



www.elsevier.com/locate/procedia

27th CIRP Life Cycle Engineering (LCE) Conference

Engineering Education perspective for sustainable development: a maturity assessment of cross-disciplinary and advanced technical skills in eco-design

Catherine Perpignan^a, Yacine Baouch^a, Vincent Robin^b, Benoît Eynard^a

^aUniversité de Technologie de Compiègne, 60319 Compiègne Cedex, France

^bUniversité de Bordeaux, 33000 Bordeaux, France

* Corresponding author. E-mail address: catherine.perpignan@utc.fr

Abstract

Nowadays, more and more students feel a lack of teaching development for sustainability topics in their curriculum. In French engineering schools or universities most of training courses do not answer to this challenge because they modestly include the question of sustainability in their curricula. Companies also strongly evolve in their industrial strategy in order to integrate environmental, economic and social perspectives and criteria in their product development process. Thus, they are looking for new skills by recruiting young technicians and engineers.

The question arises how can be improved the integration of basics of sustainable engineering in trainings rooted in technical knowledge. To start addressing such a question, we propose in this paper a skill crossover matrix. Later, this matrix will evolve toward guidelines which may allow combining specific knowledge of eco-design skills and cross-disciplinary competencies.

First, we conduct a systematic review of the literature to identify fundamental skills and knowledge associated to sustainable development approach in engineering and then specifically focusing on ecodesign. Second, we have confronted advanced technical skills from engineer's framework to cross-disciplinary skills in order to identify which connection could be possible. Then, we propose a survey with different academic profiles at different levels of training courses in the French education system. This allow us to clearly define what means eco-design teaching for them to compare expectations with reality on the academic ground. Last, we identified which skills need to be developed.

This maturity assessment will allow us to define basis for guidelines which must help later teachers in engineering and technology to create and define their own fundamental and training content for ecodesign. Furthermore, this tool will also allow students to have a better vision over of their progress in skill growing level.

© 2020 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/3.0/>).

Peer-review under responsibility of the scientific committee of the 27th CIRP Life Cycle Engineering (LCE) Conference.

Keywords: eco-design; cross-disciplinary competencies; sustainable engineering.

1. Introduction

1.1. General context

For several years, the question of sustainable development integration in higher education is discussed. First it appeared in 1972 during the Stockholm conference where it was recognized the necessity of environment education. Then in 1983, World Commission on the Environment and Development report started to encourage a more global approach in curricula with Sustainable Development (SD)

concepts. It was confirmed by the launch of the United Nations Decade for Education for Sustainable Development from 2005 to 2014 which allowed the development of a lot of SD initiatives in higher education. However, even if many researchers agree to say that SD training is a great challenge and is essential [1], there is a gap between what is preconized and what is really done in academic courses [2]. Moreover, industrial practitioners wait for higher knowledge level on SD [3]. So, we can no longer afford to stay in this situation. Future scenarii are more and more disturbing about global warming if people do not change their modes of consumption

2212-8271 © 2020 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/3.0/>).

Peer-review under responsibility of the scientific committee of the 27th CIRP Life Cycle Engineering (LCE) Conference.

doi:10.1016/j.procir.2020.xx.xxx

© 2020 published by Elsevier. This manuscript is made available under the CC BY NC user license <https://creativecommons.org/licenses/by-nc/4.0/>

and production. Thus, future generations are becoming more involved in these issues and do not hesitate to stimulate a reaction. One of their requests is to be correctly train to SD questions in order to have a global vision and to be able to make evolve the situation. In France a draft national law is under review to make compulsory in higher education a training which will take into account, in all academic pathways, the issues related to the preservation of the environment and the biological diversity, and the climatic changes within the framework of the limits of the planet.

1.2. Engineering education context

Our research work focuses on engineering education in France and the main issue comes from nature of competencies and skills to achieve. On the one hand SD education is based on environmental, social and economic knowledges and cross-disciplinary skills such as ethics, systemic thinking, critical thinking and so on [4]. On the other hand, engineering education is primarily focused on technical knowledges [5]. Moreover, we have to pay attention that « *Instead of adding SD to an unsustainable curriculum, we should rebuild curricula by taking the contribution of a field of expertise to SD as the leading principle for curricula* » [6]. In such a context, we have chosen to analyse ecodesign trainings which are in engineering education the most involved with SD questions. Research questions are:

- a. Are these competencies addressed in ecodesign training in France?
- b. How can we really combine cross-disciplinary skills, sustainable skills and technical skills in an ecodesign training?

Our objective is to propose guidelines which can help teachers to develop curricula and courses and cross technical knowledge with more transversal skills in their training pathways. First, we have identified by a literature review which cross-disciplinary skills are necessary in ecodesign trainings. Then we proposed a survey to academics in order to define which competencies are targeted when they offer ecodesign trainings to their students. This first step allows us to understand the gap to fill between what it is expecting and what it is really doing on academic ground. The following section details skills need to be developed and presents a first proposition of links that can be made between these 2 kinds of skills. Finally, we will present a first proposition of a skills assessment tool which embedded cross-disciplinary competencies and technical knowledges.

2. Literature review

2.1. Cross-disciplinary competencies in Engineering Education

Many researchers have written about the necessity to acquire key cross-disciplinary competencies to answer to the global issue of sustainability. All these authors have in common to highlight communicative competence,

interdisciplinarity and a more global vision of the issues with system or systemic thinking methodology (Table 1).

Table 1. State-of-the-art on key competencies for sustainability

Authors	Key competencies for sustainability
De Haan, 2006 [7]	foresighted thinking, working in interdisciplinarity, cosmopolitan perception, transcultural understanding, learning participatory, planning and implementation skills, capacity of empathy, self-motivation and motivating others, distanced reflection
Barth et al, 2007 [8]	Interdisciplinary cooperation, socio-communicative skills, team leading
Segalas et al, 2009 [9]	Self-learning, cooperation and transdisciplinarity, SD problem solving, systemic thinking, critical thinking, social participation
Wiek et al, 2011 [10]	Systemic thinking, anticipatory, normative competence, strategic competence, interpersonal competence
Frisk, Larson, 2011 [11]	System thinking and understanding of interconnectedness, long term foresighted reasoning and strategizing, stakeholder engagement and group collaboration, action-oriented and change-agent skills

Researchers continue to question the identification of non-disciplinary skills in engineering training and in particular for sustainability. Some of these competencies can be acquire during courses which do not deal with sustainable development or ecodesign.

In 2019, Quelhas [12] published a paper focusing on competencies for sustainability in engineering education. This literature review from 22 papers highlighted 8 key competencies and skills (Table.2).

- Critical thinking
- Working in interdisciplinarity
- Ability to solve problems
- Systemic thinking
- Normative competence
- Self-knowledge
- Anticipatory

These 8 competencies structure a synthesis between the proposal of Segalas [9] and Wiek [10] and they are confirmed by other researchers who have recently published on the subject. In this paper, authors have defined each competency. For example, critical thinking: « *can be understood as the ability of questioning standards, practices and opinions* ». This work can be considered as basics to help teachers in order to clearly define skills to achieve with their students. Certainly, more detailed descriptors should be added to specify the level of competency acquisition.

Futhermore, Thürer [13] recently presented a research review on integration of sustainability perspective into engineering curricula. This review demonstrates that it exists an increasing attention for the integration of sustainability into curricula since 2006 but it also highlights new questions. Among these questions, some are about competencies to develop: what kind of competencies? What kind of teaching strategies? How evaluate competencies acquisition? All of these questions are

the core of our research work. Thüerer [13] also concludes that “while there have been several recent literature reviews, these reviews did not focus on engineering, have been limited in scope and did not explicitly discuss implementation”.

So, reviewed papers do not deal with concrete implementation but remain more positioned on a macro level. It’s often very

abstract that do not allow readers to project into a real training situation for integrating the SD in engineering education. Technicians and engineers must acquire this cross-disciplinary skills but they also have to integrate technical skills and knowledges. So, we need to identify a list of engineer technical skills and knowledge.

Table 2. Cross-disciplinary competencies for sustainability (Quelhas et al., 2019)

Critical thinking	Working in an interdisciplinary group (Collaboration)	What are the competencies for sustainability mentioned in the literature?					
		Ability to solve problems (Integrated resolution)	Systemic thinking	Normative competence	Self-knowledge	Contextualization and vision of the future (anticipatory)	Strategic Competence
Korkmaz (2013)	Korkmaz (2013)	Mintz and Tal (2013)	Mintz and Tal (2013)	Mintz and Tal (2013)	Mintz and Tal (2013)	Staniskis and Katiliūtė (2015)	Iyer-Raniga and Andamon (2015)
Iyer-Raniga and Andamon (2015)	Staniskis and Katiliūtė (2015)	Bjornberg and Skogh (2015)	Iyer-Raniga and Andamon (2015)	Thurer et al. (2017)	Thurer et al. (2017)	Iyer-Raniga and Andamon (2015)	Xiangyun et al. (2013)
Thurer et al. (2017)	M.Asce et al. (2015)	Thurer et al. (2017)	Bjornberg and Skogh (2015)	Hedden et al. (2017)	Hedden et al. (2017)	Bjornberg and Skogh (2015)	M.Asce et al. (2015)
Xiangyun et al. (2013)	Kolmos et al. (2016)	Xiangyun et al. (2013)	Watson et al. (2013a, 2013b)	Kolmos et al. (2016)	Kolmos et al. (2016)	Thurer et al. (2017)	Wiek and Kay (2015)
M.Asce et al. (2015)	Mintz and Tal (2013)	M.Asce et al. (2015)	Thurer et al. (2017)			Wiek and Kay (2015)	
Kolmos et al. (2016)	Hedden et al. (2017)	Kolmos et al. (2016)	Xiangyun et al. (2013)				
Hedden et al. (2017)	Wiek and Kay (2015)	Hedden et al. (2017)	M.Asce et al. (2015)				
Guerra (2017)		Guerra (2017)	Kolmos et al. (2016)				
		Wiek and Kay (2015)	Hedden et al. (2017)				
			Guerra (2017)				
			Wiek and Kay (2015)				

2.2. Engineer specific skills

Engineering skills were established by some organizations like ABET [14] (Accreditation Board for Engineering and Technology) in USA, ENAEE [15] (European Network for Accreditation of Engineering Education) or CTI [16] (Commission des Titres d’Ingénieur) in France. All of these organizations have defined some engineering competencies more or less precisely.

ABET defined 11 competencies without categorization and 4 of them can be directly linked to sustainability:

- (c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
- (f) an understanding of professional and ethical responsibility
- (h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
- (j) a knowledge of contemporary issues

CTI defined 14 competencies for engineer’s certification classified into 3 categories: Scientific and technical knowledge; Adaptation to the specific requirements of the company and society; Taking into account the organizational, personal and cultural dimension.

In the second category, 4 competencies are directly linked to sustainability:

- Ability to take into account the company’s challenges: financial dimension, respect for quality, competitiveness

and productivity, business requirements, economic intelligence

- Ability to take into account the issues of workplace relations, ethics, responsibility, safety and health at work
- Ability to take into account the environmental issues, in particular by applying the principles of sustainable development
- Ability to take into account the issues and needs of society

And finally, ENAEE, which have the most detailed framework, defined 22 competencies for the bachelor level and 27 for the master degree level. These competencies are ranked into 8 categories:

- Knowledge and understanding;
 - critical awareness of the wider multidisciplinary context of engineering and of knowledge issues at the interface between different fields.
- Engineering Analysis
 - ability to identify, formulate and solve unfamiliar complex engineering problems that are incompletely defined, have competing specifications, may involve considerations from outside their field of study and non-technical – societal, health and safety, environmental, economic and industrial - constraints...
- Engineering Design
 - ability to develop, to design new and complex products (devices, artefacts, etc.), processes and systems, with specifications incompletely defined and/or competing, that require integration of knowledge from different fields and non-technical – societal, health and safety, environmental, economic and industrial commercial – constraints...

- Investigations
 - ability to conduct bibliographic research, to consult and use scientific databases with a critical thinking
 - ability to design and conduct experimentations
- Engineering Practice
 - knowledge and understanding of the non-technical – societal, health and safety, environmental, economic and industrial – implications of engineering practice;
 - critical awareness of economic, organizational and managerial issues (such as project management, risk and change management)
- Making Judgements
 - ability to integrate knowledge and handle complexity, to formulate judgements with incomplete or limited information, that include reflecting on social and ethical responsibilities linked to the application of their knowledge and judgement;
- Communication and Team-working
- Lifelong Learning

Among these competencies, 6 are linked directly to sustainability, but in this framework others transversal skills are essential in sustainable project. For example, in ENAEE framework Communication and Team working competency is defined as: “ability to use diverse methods to communicate clearly and unambiguously their conclusions, and the knowledge and rationale underpinning these, to specialist and non-specialist audiences in national and international contexts [15]”. In SD project, it is necessary to obtain to agreement and support from all stakeholders. This means that in engineering framework specific technical skills, sustainable technical skills and cross-disciplinary skills are already present.

Now, a first step of diagnosis can be made to assess if cross-disciplinary are achieved when engineering curricula develop their program based on engineer’s specific skills. The three above-mentioned frameworks highlight that different kind of competencies are necessary in engineer training. It means that academics recognize the importance of technical specific skills, cross-disciplinary skills and sustainable skills. They should try to set up these skills and competencies in their curricula but often it looks like a laundry list and the integration is more complex in the real context. « *The engineering community lacks consensus on established methods for infusing sustainability into the curriculum and on verified approaches to assess engineers’ sustainability knowledge* » [17]. Teachers often develop curricula that are addition of courses and obtain a patchwork of not linked competencies and knowledge. To avoid this kind of curricula, we have tried to evaluate if links exist between engineering skills and cross-disciplinary skills. Objective was to use these possible links and to propose structured training modules in a global curriculum allowing at the same time the development of competencies and knowledge. For this work, we have decided to use the European framework edited by the ENAEE.

In table 3, we can see that all cross-disciplinary skills are not targeted in an engineering training. Some are addressed but rarely in a global way. This table gives a global vision of skills crossing. That is why, after identifying skills targeted for engineering training as well as the cross competencies deemed necessary to solve problems that take into account issues related to sustainable development, we chose to limit our study to ecodesign training.

Table 3. Cross skills and engineer skills.

Engineer's skills	Cross-disciplinary skills							
	Critical thinking	Collaboration	Solve a complex problem	Systemic thinking	Normative competence	Self-knowledge	Anticipatory	Strategic competence
Knowledge and understanding	✓		✓	✓				
Engineering Analysis		✓	✓	✓				
Engineering Design			✓					
Investigations	✓		✓		✓	✓		
Engineering Practice	✓		✓		✓			✓
Making Judgements	✓							✓
Communication and Team-working		✓						
Lifelong Learning						✓		

3. Maturity assessment of sustainability in engineering curriculum: a focus on ecodesign teaching

3.1. Technical skills, advanced technical knowledge and cross-disciplinary for ecodesign

Indeed, according to the ISO 14006:2011: "*the goal of ecodesign is to integrate environmental aspects into product design and development so as to reduce the adverse environmental impacts of products throughout their life cycles*". It means that engineers must solve a technological problem while taking into account parameters for which they initially did not receive specific training [18] like economic or environmental issues.

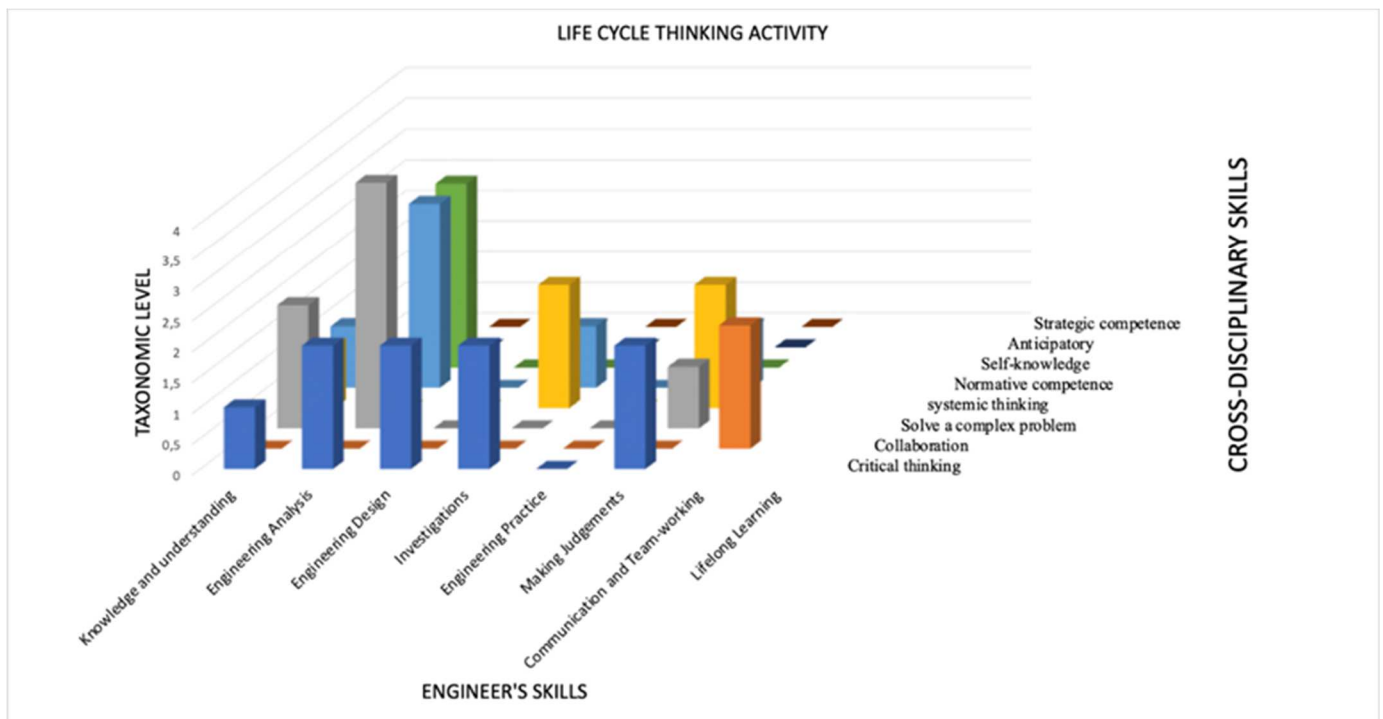
However, this activity allows to acquire all engineering skills and also relies on transversal skills [19]. ISO 14006 gives us the 6 steps to following order to ecodesign. These 6 steps are:

- Step 1, Life cycle thinking
- Step 2, Ecodesign process

- Step 3, Environmental assessment of product
- Step 4, Analysis of interested parties' environmental requirements
- Step 5, Analysis of interested parties' environmental requirements
- Step 6, Ecodesign review

When a teacher develops an ecodesign course, he/she has to evaluate what kind of engineering competencies and cross-disciplinary are essential to transmit. He/she has to identify the level of skill's acquirement by using 6 cognitive processes of the Bloom's taxonomy for instance [20]. With students in bachelor, he/she could target the 3 first processes: remember (level 1), understand (2) and apply (3). Then, these competencies could be re-evaluated during another step of eco-design process in different level of acquirement according to Bloom's revised Taxonomy which is often use in educational system. For example, we propose a possible representation of engineer/cross-disciplinary skills concerning the first step of the ecodesign processes - Life cycle thinking (Fig. 1).

Fig. 1.: Model for engineer/cross-disciplinary skills levels for Step 1



Due to the short length of this paper, the way that the metrics (Fig. 1) are obtained is not detailed. To enrich our proposition and check consistency of our representation, we submitted a survey to a group of teachers (80 and we receive about 30 answers) involved in this kind of engineering training. Survey was also a way to question the current education practices in ecodesign in Higher Education in France and then in order to analyze training content.

3.2. Survey on ecodesign teaching

The survey was submitted in June 2019 to teachers of the higher education in France at the bachelor's and master's degree level. Ecodesign perception evolves over last years. Some of researchers think that ISO 14006 definition does not take into account enough parameters. They are closer from Charter's definition which define sustainable solutions like: "products, services, hybrids or system changes that minimize negative and maximize positive sustainability impacts economic, environmental, social and ethical throughout and beyond the life-cycle of existing products or solutions, while fulfilling acceptable societal demands/needs" [21]. So, to ensure that we "talk about the same thing", the first question in the survey was: "Is the definition of ISO 14006:2001 sufficient according to you?". It is interesting to note that 33% of teachers agree with the considered definition, another 33% have no opinion. It means that either they are not really concerned or something miss but they can not say exactly what. The last 33% consider ISO ecodesign definition is not sufficient. They think that in addition to the environmental impact, ecodesign should also considers aspects such as: economic, marketing, innovation and ethic. So, it seems that ecodesign must evolve toward a more sustainable and global vision of design [22].

Next, we wanted to analyze what kind of knowledge or competencies related to sustainability, teachers target during their training. Fig.2 highlights that teachers mainly work on cleaner production, waste management or pollution prevention. But they not really work on economic and social aspects of sustainable development. There also exists a big place granted to Life Cycle Assessment tool. But companies are looking for new engineering profiles which are able to have a systemic way of thinking for product design and to analyze all the scenarii and the external impacts that could have their decision-making during each step of product development process. So, keeping this teaching way will increase gap between academic curricula and industrial training needs.

Last, even if teachers do not first mention the needs of cross-disciplinary skills, in anyway they take them into account during their training. Teachers agree that cross disciplinary are necessary to have a more global vision of ecodesign. We have interviewed them on six different transversal skills that they think work with their students. These skills are: ethic, complex thinking, collaboration, critical thinking, systemic thinking and agility. In this panel of teachers, critical thinking is the most necessary skill according

to teachers. But they highlight a real difficulty to clearly define what it is and how to assess it during teaching activity.

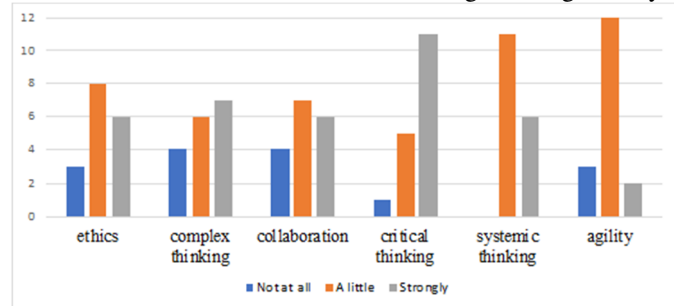


Fig.2.: cross disciplinary skills engaged in ecodesign

3.3. Discussion

The survey allows to identify that ecodesign training are always focus on technical aspects such as choice of materials or energy consumption to reduce environmental impact by using tools (LCA tools for instance) in order to assess product's environmental performance and to propose curative solution. The survey also underlines that teachers are aware their training must include cross-disciplinary skills. Their main difficulties are to correctly define these competencies, to find some detailed descriptors and to cross-check these competencies with specific technical skills. Another challenge is to define training actions allowing students to gradually acquire all the skills related to ecodesign. Then, teachers need guidelines for helping them to create training sessions including these skills but also to quickly visualize the level of skills of their students.

4. Conclusion and future work

The aim of this paper was to define cross-disciplinary skills necessary to include sustainability in engineering curricula with a specific focus on ecodesign expertises and to propose a methodology to help teachers to deal with these skills in such technical context. Literature review allows us to clearly identify competencies and we have crossed-check them with specific technical skills. Our matrix (Fig. 1) must to be refine and to be consolidated. Then we could propose a first version of guidelines which will be available at the end of our work.

In future work, we have to continue our survey nearby teachers and students. Some groups, such as the SEFI's working group on sustainability (European Society for Engineering Education), are also resources which could help us to strengthen our research work at an international level.

References

- [1] Abdul-Wahab, S. A., Abdulraheem, M. Y., & Hutchinson, M. The need for inclusion of environmental education in undergraduate engineering curricula. *International Journal of Sustainability in Higher Education*, 4(2), 2003, 126–137
- [2] Perpignan, Catherine; Robin, Vincent; Eynard, B. From Ecodesign to DFS in engineering education. In DS 93: *Proceedings of the 20th*

- International Conference on Engineering and Product Design Education (E&PDE 2018)*, London, UK. 6th-7th September 2018, 622-627
- [3] Hanning, A., Priem Abelsson, A., Lundqvist, U., & Svanström, M. Are we educating engineers for sustainability? *International Journal of Sustainability in Higher Education*, 13(3), 2012, 305–320.
- [4] Jon-Erik Dahlin, O. L. Attitudes towards curriculum integration of sustainable development among program directors in engineering education. *Proceedings of Engineering Education and Sustainable Development 2018, Glassboro, NJ*, 2018, 198-205.
- [5] Crofton, F. S. Educating for sustainability: Opportunities in undergraduate engineering. *Journal of Cleaner Production*, 8(5), 2000, 397–405.
- [6] Svanström, M., Gröndahl, F., Mulder, K. F., Segalàs, J., & Ferrer-Balas, D. How to educate engineers for/in sustainable development: Ten years of discussion, remaining challenges. *International Journal of Sustainability in Higher Education*, 13(3), 2012, 211–218.
- [7] de Haan, G. The BLK ‘21’ programme in Germany: A ‘Gestaltungskompetenz’-based model for Education for Sustainable Development. *Environmental Education Research*, 12(1), 2006, 19–32.
- [8] Barth, M., Godemann, J., Rieckmann, M., & Stoltenberg, U. Developing key competencies for sustainable development in higher education. *International Journal of Sustainability in Higher Education*, 8(4), 2007, 416–430.
- [9] Segalàs, J., Mulder, K. F., & Ferrer-Balas, D. What do EESD “experts” think sustainability is? Which pedagogy is suitable to learn it?: Results from interviews and Cmaps analysis gathered at EESD 2008. *International Journal of Sustainability in Higher Education*, 13(3), 2012, 293–304.
- [10] Wiek, A., Withycombe, L., & Redman, C. L. Key competencies in sustainability: A reference framework for academic program development. *Sustainability Science*, 6(2), 2011, 203–218.
- [11] Frisk, E., & Larson, K. L. Journal of Sustainability Education Vol. 2, March 2011 ISSN: 2151-7452. *Journal of Sustainability Education*, 2011.
- [12] Quelhas, O. L. G., Lima, G. B. A., Ludolf, N. V. E., Meiriño, M. J., Abreu, C., Anholon, R., ... Rodrigues, L. S. G. Engineering education and the development of competencies for sustainability. *International Journal of Sustainability in Higher Education*, 2019.
- [13] Thüerer, M., Tomašević, I., Stevenson, M., Qu, T., & Huisingh, D. A systematic review of the literature on integrating sustainability into engineering curricula. *Journal of Cleaner Production*, 181, 2018, 608–617.
- [14] <https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2016-2017/>
- [15] <https://www.enace.eu/eur-ace-system/standards-and-guidelines/>
- [16] <https://www.cti-commission.fr/fonds-documentaire/document/25/chapitre/1217>
- [17] Duarte, A. J., Malheiro, B., Arno, E., Perat, I., Silva, M. F., Fuentes-Dura, P., Ferreira, P. Engineering Education for Sustainable Development: The European Project Semester Approach. *IEEE Transactions on Education*, 2019.
- [18] Perpignan, C., Robin, V., Baouch, Y., & Eynard, B. Ecodesign from High School to Bachelor Level: A French Case Study. *Proceedings of the Design Society: International Conference on Engineering Design*, 2019
- [19] Luttikhuis, E.J.O, Toxopeus, M.E.E., & Lutters, E. Effective integration of life cycle engineering in education. *Procedia CIRP*, 2015, vol. 29, p. 550-555.
- [20] Krathwohl, D. R. A revision of Bloom's taxonomy: An overview. Theory into practice, 2002, vol. 41, no 4, p. 212-218.
- [21] Charter, M., Tischner, U.: Sustainable solutions. Greenleaf, Publishing, Sheffield (2001).
- [22] Ceschin, F., & Gaziulusoy, I. Evolution of design for sustainability: From product design to design for system innovations and transitions. *Design Studies*, 47, 2016, 118–163.