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27th CIRP Life Cycle Engineering (LCE) Conference

Case study: located pedagogical situations to improve global sustainable skills in engineering education and universities

Lou Grimal[a], Pauline Marty[a], Santiago Perez[a], Nadège Troussier[a], Catherine Perpignan[b], Tatiana Reyes[a]

[a]*ICD, CREIDD, Université de Technologie de Troyes, 12 rue Marie Curie, 10004 Troyes, France*
[b]*Université de Technologie de Compiègne, Sorbonne universités, Laboratoire Roberval FRE UTC-CNRS 2012, Centre de recherches Royallieu, Compiègne Cedex, France*
* Corresponding author. Tel.: +33641612543. *E-mail address: lou.grimal@utt.fr*

Abstract

While the importance of moving towards sustainability rises up in public, the presence of strategies to achieve it, in engineering academic frameworks, hardly increase. In particular, tackling environmental, social and technical aspects in conjunct ways remain difficult to teach in engineering education. The goal of this paper is to offer new engineering pedagogical strategies in order to address sustainable issues with a more global and integrated vision. An experiment of a pedagogical situation anchored into society will be presented and analysed thanks to sustainable skills defined by different institutions.
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Keywords: Design for sustainability; Education; Ecodesign; Territorial Experiment; Participative science

1. Introduction

1.1. General context

Current engineering training courses timidly integrate sustainability issues [1, 2]. The courses offered to future engineers are related to their technological speciality with environmental considerations being taken into account at the very end of their studies. Indeed, according to the Shift Project Report [3], environmental questions are mentioned in 56% of French engineering courses but in 71% of those cases, the courses are attended at a master level, thus at the end of their studies. Moreover, sustainability is taught in a specialized way. According Felgueiras et al [4], “these new degrees have become very specific, with a high level of specialization and a reduced scope. (...) the aforementioned strategy has several disadvantages, such as the reduction of skills in terms of abstraction to deal with more realistic and complex models, the lack of ability to deal with multidisciplinary problems”. Another issue is that teaching of environmental sciences is done under the lens of sustainable development, i.e. weak sustainability approach [5]. Students are not encouraged to change paradigm but are rather oriented towards Corporate Social Responsibility (CSR), industrial ecology, recycling, and so on. Life cycle engineering is studied through projects generally proposed by manufacturers to rethink the design and deployment of their products. These projects lay down strategies of weak sustainability not allowing to leave the context of a capital-intensive socio-economic market. In order to get out of this framework, our team has chosen to launch projects on green field sites in order to experiment more freely. This choice is also motivated by the ever-increasing demand from engineering students to enter into a logic of strong sustainability [6]. This posture integrates considerations around low-techs, the need for degrowth, the resilience of socio-technical systems and territories, and so on. Engineering students and, more generally, higher education students are mobilizing to have access to training to prepare them for future socio-ecological crisis. Indeed, a student Manifesto for a wake up on the environment has been written in 2018 [6] by

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students from different French engineering schools. The Manifesto has been signed by 30,883 students and 27,884 of those are French (from universities and engineering schools). The message of this Manifesto is the following: "As we get closer to our first job, we realize that the system we are part of steers us towards positions that are often incompatible with the result of our reflections. This system traps us in daily contradictions". These sentences express clearly the cognitive dissonance in which a wider part of students is. Another sentence of the Manifesto is essential to understand the motivation of the people who wrote and signed it: "We, future workers, are ready to question our comfort zone in order to achieve a deep social change". It means that part of the students is ready to act and considerably change their way of life to cope with climate change.

These requested changes come at a time when French universities are increasingly having to rethink their economic model, given that the government is gradually reducing its funding and offering universities real autonomy [7]. The strategy of higher education institutions must be rethought and redirected towards local or European objectives. It is in this sense that this change can be an opportunity to propose new learning systems and bring the themes of strong sustainability into engineering curricula (we take here the case of an engineering school but this study could take place in other institutions).

This article describes an experiment of sharing and teaching sustainability knowledge outside the classroom, considering the pressure of students and the university context.

1.2. Hypothesis and scope

The first hypothesis (H1) is that current pedagogical formats are not adapted to provide students with soft sustainability skills. Here soft sustainability skills are understood through the definition given by Quelhas et al, 2019 [8].

The second hypothesis (H2) is that all projects evolve in a constraint and complex environment which is not always reflected in academia (usually not real case studies).

In this article, the aim is to describe and analyse an experimental situation based on those two hypotheses. Thus, the proposal is that pedagogical situations rooted in civil society make possible to better understand how it is difficult to integrate sustainability into a project. Our experiment was conducted in spring of 2019 and will be addressed as "Grand Chambardement" in the following sections.

The purpose here is to define what we mean by "current pedagogical format". Even if pedagogical strategies evolve, teachers have not moved from the classical format that combines lectures, tutorials and practical work across the engineering programmes. Thus, in the context of this paper, pedagogical innovation refers to the process by which students become actors and stakeholders in their learning and do not necessarily learn exclusively within the university's walls. They are placed in complex situations outside of the traditional academic context.

This paper proposes an analysis of a case study of an original pedagogical format for master students (first and second year). Volunteer students were asked to design and manage workshops during a week of interactive activities with the population of a French rural area. The idea is to see if sustainability skills are developed by involved students. Also, we will see if this pedagogical format is more interesting for students than traditional teaching formats to learn soft sustainable skills and to understand product or services life cycles.

Firstly, we will present the competency analysis grid on sustainability. Secondly, we will detail the pedagogical situation rooted in society. Finally, we will show the correlation between the experiment and the sustainable skills they developed. A discussion will follow before starting the conclusion.

2. Methodology

We have chosen to place ourselves within the national reference framework, named the "competence guide on sustainable development and social responsibility", written by members of the Conference of University Presidents and the Conference of Grandes Écoles [9]. This reference framework was written to respond to the question: "in which way should the training of students is capable of responding to societal challenges in their professional and civic lives by going beyond the current constraints of higher education?". This guide presents a methodology for segmentation of specific competencies for the students participating. Indeed, five competencies are identified:

- Change (1)
- Liability (2)
- Forward-looking (3)
- Collectives (4)
- Systems (5)

Each of these competencies has five "dimensions" which are as follows:

- Becoming aware, knowing and learning (A)
- Identify the personal and contextual resources to be mobilized (B)
- Analyse to understand (C)
- Position, propose and arbitrate (D)
- Act, evaluate and readjust (E)

Table 1. Repartition of bricks into the several dimensions of sustainable development guide.

	Becoming aware, knowing and learning	Identify the personal and contextual resources to be mobilized	Analyse to understand	Position, propose and arbitrate	Act, evaluate and readjust
Change	4	6	4	6	6
Liability	4	5	6	3	4
Forward-looking	5	6	5	5	4
Collectives	2	5	5	5	5
Systems	2	3	4	6	3

Each dimension of each competence is composed of constituent elements which are called "bricks" in the guide. In order to validate a skill, it is important to mobilize several

bricks of different dimensions during actions.

The "Grand Chambardement" project can be understood as a set of actions. Indeed, the students were placed in original pedagogical situations. We will therefore see if some actions correspond to sets of "bricks" of several dimensions to validate a skill.

In order to have a better understanding of the overall skills guide, here is a graphical representation in Table 1.

3. Presentation of the case study

This section will be divided into two parts. The first will present the context and philosophy of the project. The second will be a presentation of the general progress of the project.

3.1. Experiment: its context and philosophy

It is important to understand that the project is positioned in a research-intervention context in the sense that the objective is to implement concrete territorial transformations. Research intervention context proposes understanding the functioning of organizations, as researchers go through the process of "entering it, intervening in it and, consequently, modifying it" [10]. Indeed, the academic team will therefore work in the field with the objective of meeting the inhabitants, understanding their daily difficulties and encouraging them to find feasible solutions. We are therefore well positioned in both actions (transformation of our research context) and research (research on a transformed context).

The case study we proposed is located in the Grand Est Region of France, more precisely in the south of the Aube department (a rural department). It concerns more particularly the territory of the Community of Municipalities of the Barséquanais (CMB). The CMB is an administrative structure that comprises aggregation of towns in order to distribute public resources in a more efficient way. The typology of this CMB is particular: the bigger village of the area has an economically deprived population, while the surrounding smaller villages are wealthier. The wealth of the latter is due to its particularly developed vine-growing activity in the region. Indeed, this region is one of the only ones in the Aube to produce a top-of-range and AOP (produit d'appelation protégé) product: Champagne. The CMB is therefore an area where large well-off land holdings (Champagne houses) coexist with more fragile populations (refugees, single-parent families, farmers).

The project was born following the request of the actors of the CMB. Indeed, it is the institutional actors of the territory who came to seek the research team for a long-term action "intervention".

It was in this relatively controlled context that the research team decided to involve students of different levels (undergraduate, master, doctoral levels as well as civic services). The objective proposed by the CMB was to revitalize their territory and make it more socially and environmentally resilient; this was perfectly in line with the pedagogical objectives towards sustainability set by the research team involved.

3.2. Experiment: the project chronology

The project was developed in four Phases.

The first Phase of the project was to define a common vision for it. This project initially had no agreed name or aim. The preliminary phase was a negotiation where each party (the CMB and the researchers) tested its counterpart in order to find out their motivations and objectives. The common and most important objective was to propose a project that generated long-term results. Once, the phase of negotiation was completed, the establishment of a common vision was essential. To this end, a company specialising in project support was brought in to help the project team to define the objectives of the project. The activity proposed and by the company was based on the theory of "golden circles" (to find the reason of living of the project - why - and its materialization - how and then what) [11]. The name of the project thus emerged: the "Grand Chambardement". More than that, the several dimensions of the project emerged and the question of the implementation of concrete actions was also addressed. The mission of the project was therefore defined as "inventing together and now to live better here and elsewhere" (the "why"). The way in which the project leaders chose to implement this sentence for real was to organize "a week of workshops and discovery to initiate change and launch concrete initiatives" (the "what"). This stage was therefore co-constructed between the university research team and the CMB and will be addressed as "stage 1" in this article. At this stage of the project only a few students have been contacted and participated in it.

The second Phase consisted in developing the practical organisation the Grand Chambardement 2019 project, i.e. setting up a week of workshops with the local population. In parallel and based on the objectives of the project, many contacts were made with students. These contacts took several forms: meeting in students in the corridors of the University, in courses, on social networks and during informal meetings. The project team, joined by a few volunteer students, then developed workshops on different themes. It was decided not to presuppose the themes that might be of interest to the local population. Some of the workshops themes proposed were: robotics, computers, handmade cosmetics, board games workshops, fab lab, design thinking workshops, church visits, hiking, group picnic, festive evenings, and conferences. The students were very active in proposing workshops. Thus, two students proposed a workshop on food which will be discussed in the results part and which will be addressed as "stage 2" in the following sections. One student organized a "Do it Yourself" workshop on cosmetics and household products. Finally, four students participated in the development and the delivery of a Participatory Mapping workshop (addressed as "stage 3" in this article) named "Let's draw our territory". In this specific workshop, a team of observers were taking notes to identify keywords during the development of the workshop, they also were in charge of analysing the process of delivery of the workshop.

The third Phase consisted on carrying out the week of workshops. During the week, each member of the research team had an observation logbook to track their exchange with

citizens. These exchanges were numerous and forced the students to leave their comfort zone by facing people from the non-academic world (refugees who had just arrived on the territory, the elderly, some farmers, town majors and so on) (also part of "stage 3"). The fourth Phase of the project methodology concerns the closure of this project and the prospects for the renewal of this type of action in the territory. Indeed, since the team wanted to invest itself in the long term, it was important to propose new formulas for further action, based on what worked well during this first action. A few days after the end of the week of workshops, several members returned to the villages and re-contacted different stakeholders to set up projects between the University and some local institutions in the CMB (hospital, refugee centre, chamber of agriculture, winegrowers). Participation on those projects was proposed to other students (external to the "Grand Chambardement") looking for training opportunities. The question of which students joined the project and why, will be detailed in the discussion section.

4. Results and analysis

In this section the results will be presented through three analysis grids described above in section 2. The analysis will determine to which extends soft sustainable skills have been learned by the volunteer students in our experiment. Also, will a discussion will be opened on other types of pedagogical experimentation leading to acquire other soft sustainable skills.

4.1. Results

The first stage refers to "Stage 1" identified in section 2.2.. Indeed, in this context, the actors of the CMB and the University met during a design thinking workshop and mobilized the following bricks:

- To have a good knowledge of the starting conditions (1A)
- Co-construct for action (1D)
- Know the standards, laws and rules to which we are subject as individuals and members of an organization, and their reasons for being (2A)
- Clarify one's own values, insert them into the cultural context (2B)
- Identify the ethical dimension of discourse and practices (2B)
- Questioning value systems, from the individual to the collective (2C)
- Define and choose the actions(s) to be taken with regard to the issues and align them with the strategy (2D)
- Produce a response that goes beyond the agreed upon (2E)
- Characterize the dynamics of a system, a strategy (3C)
- Recognize biases from your own context (3C)
- Identify the knowledge and skills of individuals and group members (4B)
- Identify the representations and value systems of the group and group members (4B)
- Recognize the contribution of the diversity of subjects in the group (4B)
- Identify collective working methods and technics (4B)
- Share knowledge, information and resources (4C)
- Establish empathic communication (4C)
- Foster an atmosphere of trust (4D)
- Co-construct, nurture and respect a reference framework and a cooperative working language (4D)
- Define collectively the stakes, the aims, the means, and the temporalities of the collective action (4D)
- Analyse all interactions and develop a global vision (5C)
- Reformulate problems in a global vision (5D)
- Setting objectives, implementation: iteration between theory, practice and trade-offs (doing to learn, learning by doing) (5E)

Table 2. Repartition of bricks into the several dimensions of sustainable development guide for "stage 1".

	Becoming aware, knowing and learning	**Identify the personal and contextual resources to be mobilized**	**Analyse to understand**	**Position, propose and arbitrate**	**Act, evaluate and readjust**
Change	1			1	
Liability	1	2	1	1	1
Forward-looking			2		
Collectives		4	2	2	
Systems			1	1	1

The complex and in-depth work that has been produced has forced the actors to embark on a process of reviewing individual knowledge, revealing their values and intentions, with a view to collective action that makes sense for all. This situation therefore makes it possible to address a certain number of bricks and thus to validate certain dimensions of skill specific to sustainability.

"Stage 2" was interesting because it concerns two engineering students who wanted to join the project in order to test a technical solution on the CMB territory. The position of the students was "classic" in the sense that they wanted to bring a technological tool (electronic box for food conservation and exchange) to a population without knowing if this tool was adapted to their local context. Moreover, no particular needs were previously identified among the population. During the project action, the students understood the importance of listening to the local population, raising needs and then initiating changes from within the population (bottom up rather than top-down approach). This change of perspective allowed them to have a broader view of the potential solutions (as well as the product life cycle into the territory) that could be brought to the territory regarding the management of food. They divided their work into two stages:

- A field survey to know the local actors and stakeholders around food (production and distribution) and an analysis of the relationships between them,
- An awareness-raising and solution-finding workshop with local participants.

Table 3. Repartition of bricks into the several dimensions of sustainable development guide for "stage 2".

	Becoming aware, knowing and learning	Identify the personal and contextual resources to be mobilized	Analyse to understand	Position, propose and arbitrate	Act, evaluate and readjust
Change					
Liability					
Forward-looking			2		
Collectives					
Systems		1	1	2	

The pedagogical situation in a territory allowed the students to:

- Take a critical look in your own context (personal and cultural perspectives) (3C)
- Recognize biases from your own context (personal and cultural perspectives) (3C)
- Identify the functional aspects of the system under study (5B)
- Analyse all interactions and develop a global vision (5C)
- Reformulate problems in a global vision (5D)
- Develop a critical analysis of the validity of the models mobilized and the objectives of the actions according to the sustainability of the systems (5D)

Finally, "stage 3" concerns the deployment of a participatory mapping workshop in the presence of people from civil society. This workshop was called "Let's draw our territory". The workshop was delivered by three master students supervised by a PhD student. Also, there was a team of 'observers' during each workshop. There was a process of collection of feedback from the observers and facilitators after each workshop. This Practice-Action Research (PAR) workshop was built using ethnographic methods for the observation and analysis of the activity. Recordings from the observers and facilitators were taking during and after the workshop for further analysis of the expectations, methodology and results of each activity. The workshop travelled to 4 different villages where the same principles were applied. During these workshops, participants were asked to draw the more pleasant and least pleasant places of their village and imagine ways in which they could transform the least pleasant places into desirable ones. The whole was guided by techniques and vocabulary specific to design thinking. From the first session, a gap was observed between the language of the (rather elderly) population and the very English-speaking and business vocabulary of design thinking. Here are the follow bricks this situation concerns:

- Represent the system (5C)
- Analyse all interactions and develop a global vision (5C)
- Develop a critical analysis of the validity of the models mobilized (5D)
- Setting objectives, implementation: iteration between theory, practice and trade-offs (doing to learn, learning by doing) (5E)
- Feedback on the analytical framework (5E)
- Understanding the dynamic and chaotic nature of the future (3B)
- Identify and accept your fears and desires, analyse their (in)compatibility with the scenarios (3B)
- Recognize biases in your own context (3C)
- Act in the present while thinking and preparing medium- and long-term transformative actions (3E)
- Identify the different modalities of attention (2B)
- Clarify one's own values, put them into the cultural context (2B)
- Take a reflexive look at the actions that will be undertaken (2C)
- Integrate the need for emancipation (2C)
- Analyses his psycho-social skills (2C)
- Identify collective work methods and techniques (4B)
- Share knowledge, information, resources (4C)
- Establish empathic communication (4C)
- Stimulate synergies (4C)
- Foster an atmosphere of trust (4D)
- Co-construct, nurture and respect a reference framework and a cooperative working language (4D)
- Implement the project collectively (4E)
- Mobilizing Life Skills to Facilitate Thinking and Acting (4E)
- Evaluate the added value and limitations of collective action (4E)
- Research, propose, and test ways to improve an operation (4E)
- Critique the barriers and levers to change (1C)
- Co-construct for action (1D)
- Agree to act to promote commitment even if the effectiveness of the action cannot be evaluated in the short term (1E)

Table 4. Repartition of bricks into the several dimensions of sustainable development guide for "stage 3".

	Becoming aware, knowing and learning	Identify the personal and contextual resources to be mobilized	Analyse to understand	Position, propose and arbitrate	Act, evaluate and readjust
Change			1	1	1
Liability		2	3		
Forward-looking		2	1		1
Collectives		1	3	3	4
Systems			2	1	2

4.2. Analysis

The interesting difficulty that our team encountered was to train students for the project. From about one hundred students met, the vast majority seemed sceptical about the usefulness of such a project (for the territory and for themselves). The idea

that a course could be entirely conducted outside a classroom seemed absurd to some. Others understood several dimensions of the project but felt that it would take them "too much time of investment compared to normal courses proposed". Certainly, the investment time is much longer in experimental project for several reasons: it is necessary to travel to the place of experiment (rural area in our case), the "stowaway" syndrome is harder to apply, and the personal energy to put in this kind of project is usually higher, among other reasons. In addition, we noted that the students who joined the experimental project did so to obtain European credits (ECTS) and also because they already had social and environmental convictions towards sustainability. We have to note that the ECTS argument was stronger than the conviction one. Thus, it seems that students are highly "formatted" in a traditional educational system where they remain passive and so requires less effort. One of the conclusions is that this experiment didn't caught the attention of enough students. One hypothesis to explain that outcome is that the attractiveness of such kind of project was poor from a student point of view (not enough ECTS credits, too much efforts...). Another hypothesis is that engineers carry a very technical vision of their future work and they don't see the link between technologies and territories and technology and people. This virtual weak link between technological tools and their materiality in territories (extraction, production, use...) blocks engineering students to understand the impact of any product (technology) on a given territory. We can question the efficiency of learning life cycle engineering if those links are not well understood by master level students. This situation could be partly due to the monodisciplinary education given to engineers and the lack of continuity in the teaching of sustainability throughout the higher education system.

We have to notice that once students have made the effort to participate in the pedagogical situation, it's difficult for them to get out (strong dynamics) and they even motivate other students in their dynamics. This is how other alternative pedagogical activities were proposed to the students who participated to the "Grand Chambardement" project. The effort required to participate in the second alternative learning activity was less than when they were asked for the first time. In addition, other students were involved in this atypical learning mode and enrolled in different projects (for the continuation of the "Grand Chambardement" project or in other similar sustainability and resilience projects).

5. Conclusion

Rethinking training means questioning its meaning in relation to current social issues. The socio-ecological stakes are high and rethinking the education system through this lense seems complex. However, this question only the more important as we live in the "Anthropocene", an era characterized by humans controling nature to the point of its destruction [12]. The place of engineers, designers and decision-makers therefore seems even more crucial. It is now up to the team to return to the field in order to acquire "familiarity (…) with time and in interaction" [13] in order to increase the scope of its actions and thus deepen the pedagogical exercises to be offered to future students.

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[a]*ICD, CREIDD, Université de Technologie de Troyes, 12 rue Marie Curie, 10004 Troyes, France*
[b]*Université de Technologie de Compiègne, Sorbonne universités, Laboratoire Roberval FRE UTC-CNRS 2012, Centre de recherches Royallieu, Compiègne Cedex, France*
* Corresponding author. Tel.: +33641612543. *E-mail address: lou.grimal@utt.fr*

Abstract

While the importance of moving towards sustainability rises up in public, the presence of strategies to achieve it, in engineering academic frameworks, hardly increase. In particular, tackling environmental, social and technical aspects in conjunct ways remain difficult to teach in engineering education. The goal of this paper is to offer new engineering pedagogical strategies in order to address sustainable issues with a more global and integrated vision. An experiment of a pedagogical situation anchored into society will be presented and analysed thanks to sustainable skills defined by different institutions.
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1. Introduction

1.1. General context

Current engineering training courses timidly integrate sustainability issues [1, 2]. The courses offered to future engineers are related to their technological speciality with environmental considerations being taken into account at the very end of their studies. Indeed, according to the Shift Project Report [3], environmental questions are mentioned in 56% of French engineering courses but in 71% of those cases, the courses are attended at a master level, thus at the end of their studies. Moreover, sustainability is taught in a specialized way. According Felgueiras et al [4], "these new degrees have become very specific, with a high level of specialization and a reduced scope. (...) the aforementioned strategy has several disadvantages, such as the reduction of skills in terms of abstraction to deal with more realistic and complex models, the lack of ability to deal with multidisciplinary problems". Another issue is that teaching of environmental sciences is done under the lens of sustainable development, i.e. weak sustainability approach [5]. Students are not encouraged to change paradigm but are rather oriented towards Corporate Social Responsibility (CSR), industrial ecology, recycling, and so on. Life cycle engineering is studied through projects generally proposed by manufacturers to rethink the design and deployment of their products. These projects lay down strategies of weak sustainability not allowing to leave the context of a capital-intensive socio-economic market. In order to get out of this framework, our team has chosen to launch projects on green field sites in order to experiment more freely. This choice is also motivated by the ever-increasing demand from engineering students to enter into a logic of strong sustainability [6]. This posture integrates considerations around low-techs, the need for degrowth, the resilience of socio-technical systems and territories, and so on. Engineering students and, more generally, higher education students are mobilizing to have access to training to prepare them for future socio-ecological crisis. Indeed, a student Manifesto for a wake up on the environment has been written in 2018 [6] by

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students from different French engineering schools. The Manifesto has been signed by 30,883 students and 27,884 of those are French (from universities and engineering schools). The message of this Manifesto is the following: "As we get closer to our first job, we realize that the system we are part of steers us towards positions that are often incompatible with the result of our reflections. This system traps us in daily contradictions". These sentences express clearly the cognitive dissonance in which a wider part of students is. Another sentence of the Manifesto is essential to understand the motivation of the people who wrote and signed it: "We, future workers, are ready to question our comfort zone in order to achieve a deep social change". It means that part of the students is ready to act and considerably change their way of life to cope with climate change.

These requested changes come at a time when French universities are increasingly having to rethink their economic model, given that the government is gradually reducing its funding and offering universities real autonomy [7]. The strategy of higher education institutions must be rethought and redirected towards local or European objectives. It is in this sense that this change can be an opportunity to propose new learning systems and bring the themes of strong sustainability into engineering curricula (we take here the case of an engineering school but this study could take place in other institutions).

This article describes an experiment of sharing and teaching sustainability knowledge outside the classroom, considering the pressure of students and the university context.

1.2. Hypothesis and scope

The first hypothesis (H1) is that current pedagogical formats are not adapted to provide students with soft sustainability skills. Here soft sustainability skills are understood through the definition given by Quelhas et al, 2019 [8].

The second hypothesis (H2) is that all projects evolve in a constraint and complex environment which is not always reflected in academia (usually not real case studies).

In this article, the aim is to describe and analyse an experimental situation based on those two hypotheses. Thus, the proposal is that pedagogical situations rooted in civil society make possible to better understand how it is difficult to integrate sustainability into a project. Our experiment was conducted in spring of 2019 and will be addressed as "Grand Chambardement" in the following sections.

The purpose here is to define what we mean by "current pedagogical format". Even if pedagogical strategies evolve, teachers have not moved from the classical format that combines lectures, tutorials and practical work across the engineering programmes. Thus, in the context of this paper, pedagogical innovation refers to the process by which students become actors and stakeholders in their learning and do not necessarily learn exclusively within the university's walls. They are placed in complex situations outside of the traditional academic context.

This paper proposes an analysis of a case study of an original pedagogical format for master students (first and second year). Volunteer students were asked to design and manage workshops during a week of interactive activities with the population of a French rural area. The idea is to see if sustainability skills are developed by involved students. Also, we will see if this pedagogical format is more interesting for students than traditional teaching formats to learn soft sustainable skills and to understand product or services life cycles.

Firstly, we will present the competency analysis grid on sustainability. Secondly, we will detail the pedagogical situation rooted in society. Finally, we will show the correlation between the experiment and the sustainable skills they developed. A discussion will follow before starting the conclusion.

2. Methodology

We have chosen to place ourselves within the national reference framework, named the "competence guide on sustainable development and social responsibility", written by members of the Conference of University Presidents and the Conference of Grandes Écoles [9]. This reference framework was written to respond to the question: "in which way should the training of students is capable of responding to societal challenges in their professional and civic lives by going beyond the current constraints of higher education?". This guide presents a methodology for segmentation of specific competencies for the students participating. Indeed, five competencies are identified:

- Change (1)
- Liability (2)
- Forward-looking (3)
- Collectives (4)
- Systems (5)

Each of these competencies has five "dimensions" which are as follows:

- Becoming aware, knowing and learning (A)
- Identify the personal and contextual resources to be mobilized (B)
- Analyse to understand (C)
- Position, propose and arbitrate (D)
- Act, evaluate and readjust (E)

Table 1. Repartition of bricks into the several dimensions of sustainable development guide.

	Becoming aware, knowing and learning	Identify the personal and contextual resources to be mobilized	Analyse to understand	Position, propose and arbitrate	Act, evaluate and readjust
Change	4	6	4	6	6
Liability	4	5	6	3	4
Forward-looking	5	6	5	5	4
Collectives	2	5	5	5	5
Systems	2	3	4	6	3

Each dimension of each competence is composed of constituent elements which are called "bricks" in the guide. In order to validate a skill, it is important to mobilize several

bricks of different dimensions during actions.

The “Grand Chambardement” project can be understood as a set of actions. Indeed, the students were placed in original pedagogical situations. We will therefore see if some actions correspond to sets of “bricks” of several dimensions to validate a skill.

In order to have a better understanding of the overall skills guide, here is a graphical representation in Table 1.

3. Presentation of the case study

This section will be divided into two parts. The first will present the context and philosophy of the project. The second will be a presentation of the general progress of the project.

3.1. Experiment: its context and philosophy

It is important to understand that the project is positioned in a research-intervention context in the sense that the objective is to implement concrete territorial transformations. Research intervention context proposes understanding the functioning of organizations, as researchers go through the process of “entering it, intervening in it and, consequently, modifying it” [10]. Indeed, the academic team will therefore work in the field with the objective of meeting the inhabitants, understanding their daily difficulties and encouraging them to find feasible solutions. We are therefore well positioned in both actions (transformation of our research context) and research (research on a transformed context).

The case study we proposed is located in the Grand Est Region of France, more precisely in the south of the Aube department (a rural department). It concerns more particularly the territory of the Community of Municipalities of the Barséquanais (CMB). The CMB is an administrative structure that comprises aggregation of towns in order to distribute public resources in a more efficient way. The typology of this CMB is particular: the bigger village of the area has an economically deprived population, while the surrounding smaller villages are wealthier. The wealth of the latter is due to its particularly developed vine-growing activity in the region. Indeed, this region is one of the only ones in the Aube to produce a top-of-range and AOP (produit d’appelation protégé) product: Champagne. The CMB is therefore an area where large well-off land holdings (Champagne houses) coexist with more fragile populations (refugees, single-parent families, farmers).

The project was born following the request of the actors of the CMB. Indeed, it is the institutional actors of the territory who came to seek the research team for a long-term action “intervention”.

It was in this relatively controlled context that the research team decided to involve students of different levels (undergraduate, master, doctoral levels as well as civic services). The objective proposed by the CMB was to revitalize their territory and make it more socially and environmentally resilient; this was perfectly in line with the pedagogical objectives towards sustainability set by the research team involved.

3.2. Experiment: the project chronology

The project was developed in four Phases.

The first Phase of the project was to define a common vision for it. This project initially had no agreed name or aim. The preliminary phase was a negotiation where each party (the CMB and the researchers) tested its counterpart in order to find out their motivations and objectives. The common and most important objective was to propose a project that generated long-term results. Once, the phase of negotiation was completed, the establishment of a common vision was essential. To this end, a company specialising in project support was brought in to help the project team to define the objectives of the project. The activity proposed and by the company was based on the theory of “golden circles” (to find the reason of living of the project - why - and its materialization - how and then what) [11]. The name of the project thus emerged: the “Grand Chambardement”. More than that, the several dimensions of the project emerged and the question of the implementation of concrete actions was also addressed. The mission of the project was therefore defined as “inventing together and now to live better here and elsewhere” (the “why”). The way in which the project leaders chose to implement this sentence for real was to organize “a week of workshops and discovery to initiate change and launch concrete initiatives” (the “what”). This stage was therefore co-constructed between the university research team and the CMB and will be addressed as “stage 1” in this article. At this stage of the project only a few students have been contacted and participated in it.

The second Phase consisted in developing the practical organisation the Grand Chambardement 2019 project, i.e. setting up a week of workshops with the local population. In parallel and based on the objectives of the project, many contacts were made with students. These contacts took several forms: meeting in students in the corridors of the University, in courses, on social networks and during informal meetings. The project team, joined by a few volunteer students, then developed workshops on different themes. It was decided not to presuppose the themes that might be of interest to the local population. Some of the workshops themes proposed were: robotics, computers, handmade cosmetics, board games workshops, fab lab, design thinking workshops, church visits, hiking, group picnic, festive evenings, and conferences. The students were very active in proposing workshops. Thus, two students proposed a workshop on food which will be discussed in the results part and which will be addressed as “stage 2” in the following sections. One student organized a “Do it Yourself” workshop on cosmetics and household products. Finally, four students participated in the development and the delivery of a Participatory Mapping workshop (addressed as “stage 3” in this article) named “Let’s draw our territory”. In this specific workshop, a team of observers were taking notes to identify keywords during the development of the workshop, they also were in charge of analysing the process of delivery of the workshop.

The third Phase consisted on carrying out the week of workshops. During the week, each member of the research team had an observation logbook to track their exchange with

citizens. These exchanges were numerous and forced the students to leave their comfort zone by facing people from the non-academic world (refugees who had just arrived on the territory, the elderly, some farmers, town majors and so on) (also part of "stage 3"). The fourth Phase of the project methodology concerns the closure of this project and the prospects for the renewal of this type of action in the territory. Indeed, since the team wanted to invest itself in the long term, it was important to propose new formulas for further action, based on what worked well during this first action. A few days after the end of the week of workshops, several members returned to the villages and re-contacted different stakeholders to set up projects between the University and some local institutions in the CMB (hospital, refugee centre, chamber of agriculture, winegrowers). Participation on those projects was proposed to other students (external to the "Grand Chambardement") looking for training opportunities. The question of which students joined the project and why, will be detailed in the discussion section.

4. Results and analysis

In this section the results will be presented through three analysis grids described above in section 2. The analysis will determine to which extends soft sustainable skills have been learned by the volunteer students in our experiment. Also, will a discussion will be opened on other types of pedagogical experimentation leading to acquire other soft sustainable skills.

4.1. Results

The first stage refers to "Stage 1" identified in section 2.2.. Indeed, in this context, the actors of the CMB and the University met during a design thinking workshop and mobilized the following bricks:

- To have a good knowledge of the starting conditions (1A)
- Co-construct for action (1D)
- Know the standards, laws and rules to which we are subject as individuals and members of an organization, and their reasons for being (2A)
- Clarify one's own values, insert them into the cultural context (2B)
- Identify the ethical dimension of discourse and practices (2B)
- Questioning value systems, from the individual to the collective (2C)
- Define and choose the actions(s) to be taken with regard to the issues and align them with the strategy (2D)
- Produce a response that goes beyond the agreed upon (2E)
- Characterize the dynamics of a system, a strategy (3C)
- Recognize biases from your own context (3C)
- Identify the knowledge and skills of individuals and group members (4B)
- Identify the representations and value systems of the group and group members (4B)
- Recognize the contribution of the diversity of subjects in the group (4B)
- Identify collective working methods and technics (4B)
- Share knowledge, information and resources (4C)
- Establish empathic communication (4C)
- Foster an atmosphere of trust (4D)
- Co-construct, nurture and respect a reference framework and a cooperative working language (4D)
- Define collectively the stakes, the aims, the means, and the temporalities of the collective action (4D)
- Analyse all interactions and develop a global vision (5C)
- Reformulate problems in a global vision (5D)
- Setting objectives, implementation: iteration between theory, practice and trade-offs (doing to learn, learning by doing) (5E)

Table 2. Repartition of bricks into the several dimensions of sustainable development guide for "stage 1".

	Becoming aware, knowing and learning	Identify the personal and contextual resources to be mobilized	Analyse to understand	Position, propose and arbitrate	Act, evaluate and readjust
Change	1			1	
Liability	1	2	1	1	1
Forward-looking			2		
Collectives		4	2	2	
Systems			1	1	1

The complex and in-depth work that has been produced has forced the actors to embark on a process of reviewing individual knowledge, revealing their values and intentions, with a view to collective action that makes sense for all. This situation therefore makes it possible to address a certain number of bricks and thus to validate certain dimensions of skill specific to sustainability.

"Stage 2" was interesting because it concerns two engineering students who wanted to join the project in order to test a technical solution on the CMB territory. The position of the students was "classic" in the sense that they wanted to bring a technological tool (electronic box for food conservation and exchange) to a population without knowing if this tool was adapted to their local context. Moreover, no particular needs were previously identified among the population. During the project action, the students understood the importance of listening to the local population, raising needs and then initiating changes from within the population (bottom up rather than top-down approach). This change of perspective allowed them to have a broader view of the potential solutions (as well as the product life cycle into the territory) that could be brought to the territory regarding the management of food. They divided their work into two stages:

- A field survey to know the local actors and stakeholders around food (production and distribution) and an analysis of the relationships between them,
- An awareness-raising and solution-finding workshop with local participants.

Table 3. Repartition of bricks into the several dimensions of sustainable development guide for “stage 2”.

	Becoming aware, knowing and learning	Identify the personal and contextual resources to be mobilized	Analyse to understand	Position, propose and arbitrate	Act, evaluate and readjust
Change					
Liability					
Forward-looking			2		
Collectives					
Systems		1	1	2	

The pedagogical situation in a territory allowed the students to:

- Take a critical look in your own context (personal and cultural perspectives) (3C)
- Recognize biases from your own context (personal and cultural perspectives) (3C)
- Identify the functional aspects of the system under study (5B)
- Analyse all interactions and develop a global vision (5C)
- Reformulate problems in a global vision (5D)
- Develop a critical analysis of the validity of the models mobilized and the objectives of the actions according to the sustainability of the systems (5D)

Finally, “stage 3” concerns the deployment of a participatory mapping workshop in the presence of people from civil society. This workshop was called “Let’s draw our territory”. The workshop was delivered by three master students supervised by a PhD student. Also, there was a team of ‘observers’ during each workshop. There was a process of collection of feedback from the observers and facilitators after each workshop. This Practice-Action Research (PAR) workshop was built using ethnographic methods for the observation and analysis of the activity. Recordings from the observers and facilitators were taking during and after the workshop for further analysis of the expectations, methodology and results of each activity. The workshop travelled to 4 different villages where the same principles were applied. During these workshops, participants were asked to draw the more pleasant and least pleasant places of their village and imagine ways in which they could transform the least pleasant places into desirable ones. The whole was guided by techniques and vocabulary specific to design thinking. From the first session, a gap was observed between the language of the (rather elderly) population and the very English-speaking and business vocabulary of design thinking. Here are the follow bricks this situation concerns:

- Represent the system (5C)
- Analyse all interactions and develop a global vision (5C)
- Develop a critical analysis of the validity of the models mobilized (5D)
- Setting objectives, implementation: iteration between theory, practice and trade-offs (doing to learn, learning by doing) (5E)
- Feedback on the analytical framework (5E)
- Understanding the dynamic and chaotic nature of the future (3B)
- Identify and accept your fears and desires, analyse their (in)compatibility with the scenarios (3B)
- Recognize biases in your own context (3C)
- Act in the present while thinking and preparing medium- and long-term transformative actions (3E)
- Identify the different modalities of attention (2B)
- Clarify one’s own values, put them into the cultural context (2B)
- Take a reflexive look at the actions that will be undertaken (2C)
- Integrate the need for emancipation (2C)
- Analyses his psycho-social skills (2C)
- Identify collective work methods and techniques (4B)
- Share knowledge, information, resources (4C)
- Establish empathic communication (4C)
- Stimulate synergies (4C)
- Foster an atmosphere of trust (4D)
- Co-construct, nurture and respect a reference framework and a cooperative working language (4D)
- Implement the project collectively (4E)
- Mobilizing Life Skills to Facilitate Thinking and Acting (4E)
- Evaluate the added value and limitations of collective action (4E)
- Research, propose, and test ways to improve an operation (4E)
- Critique the barriers and levers to change (1C)
- Co-construct for action (1D)
- Agree to act to promote commitment even if the effectiveness of the action cannot be evaluated in the short term (1E)

Table 4. Repartition of bricks into the several dimensions of sustainable development guide for “stage 3”.

	Becoming aware, knowing and learning	Identify the personal and contextual resources to be mobilized	Analyse to understand	Position, propose and arbitrate	Act, evaluate and readjust
Change			1	1	1
Liability		2	3		
Forward-looking		2	1		1
Collectives		1	3	3	4
Systems			2	1	2

4.2. Analysis

The interesting difficulty that our team encountered was to train students for the project. From about one hundred students met, the vast majority seemed sceptical about the usefulness of such a project (for the territory and for themselves). The idea

that a course could be entirely conducted outside a classroom seemed absurd to some. Others understood several dimensions of the project but felt that it would take them “too much time of investment compared to normal courses proposed”. Certainly, the investment time is much longer in experimental project for several reasons: it is necessary to travel to the place of experiment (rural area in our case), the “stowaway” syndrome is harder to apply, and the personal energy to put in this kind of project is usually higher, among other reasons. In addition, we noted that the students who joined the experimental project did so to obtain European credits (ECTS) and also because they already had social and environmental convictions towards sustainability. We have to note that the ECTS argument was stronger than the conviction one. Thus, it seems that students are highly “formatted” in a traditional educational system where they remain passive and so requires less effort. One of the conclusions is that this experiment didn’t caught the attention of enough students. One hypothesis to explain that outcome is that the attractiveness of such kind of project was poor from a student point of view (not enough ECTS credits, too much efforts...). Another hypothesis is that engineers carry a very technical vision of their future work and they don’t see the link between technologies and territories and technology and people. This virtual weak link between technological tools and their materiality in territories (extraction, production, use...) blocks engineering students to understand the impact of any product (technology) on a given territory. We can question the efficiency of learning life cycle engineering if those links are not well understood by master level students. This situation could be partly due to the monodisciplinary education given to engineers and the lack of continuity in the teaching of sustainability throughout the higher education system.

We have to notice that once students have made the effort to participate in the pedagogical situation, it’s difficult for them to get out (strong dynamics) and they even motivate other students in their dynamics. This is how other alternative pedagogical activities were proposed to the students who participated to the “Grand Chambardement” project. The effort required to participate in the second alternative learning activity was less than when they were asked for the first time. In addition, other students were involved in this atypical learning mode and enrolled in different projects (for the continuation of the “Grand Chambardement” project or in other similar sustainability and resilience projects).

5. Conclusion

Rethinking training means questioning its meaning in relation to current social issues. The socio-ecological stakes are high and rethinking the education system through this lense seems complex. However, this question only the more important as we live in the “Anthropocene”, an era characterized by humans controling nature to the point of its destruction [12]. The place of engineers, designers and decision-makers therefore seems even more crucial. It is now up to the team to return to the field in order to acquire “familiarity (…) with time and in interaction” [13] in order to increase the scope of its actions and thus deepen the pedagogical exercises to be offered to future students.

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