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Exploratory study on the role of institutional frameworks on engineering curricula evolution: A case study on transition towards sustainability

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Abstract
Humanity's entrance into the Anthropocene forces us to question the role of technology because of its impacts on the environment. The stake is the viability of the Earth system for humans. Engineers producing a large part of these impacting techniques are not trained in sustainable issues (environmental, social and economic ones - in a systemic way). An exploratory workshop was held at a French University of Technology to study the development of new engineering training courses on issues of strong sustainability. During this workshop, the participants were placed into the current French institutional framework and were asked to develop a new training within this specific framework. The hypothesis formulated at the end of this experiment is that current institutional frameworks can be an obstacle to the production of new training, especially training adapted to the transition phenomenon to respond to the increasing risk of socio-ecological catastrophes. This experiment was conducted as part of a heuristic approach and opens up new perspectives for the evolution of training as well as institutional frameworks in higher education and research.

Keywords
Ecological catastrophes, engineering studies, education, institutional framework

Introduction
The entrance of humanity into the Anthropocene (Steffen et al., 2015) requires us to rethink technology by considering the impacts technical tools have on the ecosystems. All these techniques used by man (our activities in a broader sense) and their impacts can be understood as the anthroposphere. This anthroposphere is in constant exchange with the biosphere, which is defined by all ecosystems and living organisms evolving in their living environments. These two spheres interact: our industries draw their raw materials from the biosphere to meet all of society's needs (basic and non-basic needs). This interaction seems one-sided. Indeed, the impact of the anthroposphere on the biosphere is such that the latter is struggling to recover. Indeed, each year, the rate of resource extraction exceeds that of resource regeneration (especially fossil ones), while the quantity of emissions exceeds that which the biosphere is capable of absorbing to sustainably ensure our living conditions (especially a stable climate). In other words, the current metabolism of the anthroposphere in the biosphere is unsustainable and compromises the viability of the earth system (Court & Fizaine, 2017; Meadows et al., 1972), at least the continuity of current human productive activities.

The models in the Limits to growth report for the period 1970 – 2000 have been verified (Branderhorst, 2020) and the projections made in the 1972 report are in strong agreement with the historical data (again for the period between 1970 and 2000). It appears that the projections in this report also conclude that there is a possibility of a global collapse before the end of the mid-21st century. « The salient message from the [Limits to Growth] modelling was that continued growth in the global economy would lead to planetary limits being exceeded sometime in the 21st century, most likely resulting in the collapse of the population and economic system, but also that collapse could be avoided with a combination of early changes in behaviour, policy, and technology." (Turner, 2008). In this article we are focusing on those possible changes, and more precisely changes related to technology: how to change technology design by the education of future designers? This paper will take a narrow understanding of design, as we will address engineering design only and engineering education in the French context.

One possible change is to integrate sustainability issues into engineering curricula. Engineers apply "scientific principles to solve problems to improve society. Engineering is a service profession. However, day-to-day engineering is more often focused on technological rather than human concerns" (Chan, Eng, & Fishbein, 2009). The training of engineers in environmental and social issues is therefore essential to develop technologies that respond to societal challenges (Chan et al., 2009) and to make the interaction between anthroposphere and biosphere sustainable. The integration of environmental issues in engineering curricula is not a new thing. Through the 20th century until now, engineering education to sustainability has considerably changed, starting from a very material and environmental-oriented approach to a more holistic understanding of sustainability issues (integrating social issues and multi-scales issues, ethics) (Quist et al., 2006; De Graaff & Ravesteijn, 2001). Nonetheless, this holistic understanding of sustainability is quite a challenge to integrate into current engineering curricula. In 2010, a call to "study engineering in the context of service to society and the need to address complex challenges to the 21st century" (Grasso & Burkins, 2010) asserts that the framework for engineering education is fragmented into disciplines. However, the challenges of the 21st century are multi-dimensional (cultural, political, social, environmental) and it is difficult – unrealistic would be probably more appropriate – to grasp the issues without solid knowledge in other fields. Even, a lot of literature express the need for engineers to develop other competences and other mindset (De Graaff & Ravesteijn 2001; Hsiao 2019; Quist et al. 2006; Vare & Scott, 2007). As said by James Pitt, "advances in the STEM domains of science, technology, engineering and mathematics have given us both the capacity for causing such degradation [of the Earth], the tools for identifying it and understanding its causes, and hopefully for informing genuinely intelligent design decisions in the future" (Pitt, 2009). This last part of the quote on how STEM domains can provide inputs for decision-making resonates with the competences Swedish students on technology need to develop: "identifying problems and finding technological solutions to these problems, as well as critical analysis of modern technology usage and its everyday interaction with people and society" (Schooner et al., 2017).

In the literature about competencies for sustainability in engineering classes, the data revealed that to have a sustainable approach one needs to get specific competences on the interactions between technical systems and its context of production, use and disposal (environmental, cultural, political, normative, social context). Indeed, (Quelhas et al., 2019) defines 8 competences (systemic thinking, ability to solve problems, ability to work in interdisciplinary group, critical thinking, normative competence, self-knowledge competence, strategic competence, contextualization and future vision) and by analyzing those competences, we understand that to have a sustainability approach, an engineer has to understand more than only a technical field. An engineer has to understand how technical systems impact (in a positive and negative way) natural (the environment, earth system sciences) and human (culture, economy, norms, at individual and collective level) systems through all its life cycle stages. This requires a multidisciplinary education which offers a holistic vision of technology. The competences needed to get competencies defined by (Quelhas et al. 2019) are hard to get if disciplines are segmented (Guerra, 2017). Also, a pluri-technic approach gives students a holistic view of technical issues and the mix of different disciplines into a class provides interdisciplinary context. There is therefore a real challenge in training engineers in complex and systemic issues so that they learn how to work and take action in uncertain times, with an increasing risk of socio-ecological disasters.

The state of the art seems to be quite clear that we know what kind of competences are needed to fully integrate sustainability in engineering education. However, little implementation of these competences in training courses is done. In this paper, we express the hypothesis that the institutional frameworks in which engineering education takes place do not allow for the spontaneous implementation of these skills and learning modes.

The goal of this paper is to question the limitations of the evolution of engineering training in the face of complex environmental and social challenges. To do that, the researchers reported the results of an exploratory workshop undertaken in an attempt to formulate an engineering education framework that could better address and integrate sustainability issues. This framework is a French national framework. The goal is not to build a new educational framework on sustainable design but to point out the difficulties posed by the current institutional training frameworks to develop specific ones on sustainable transitions. One of the potential outputs is that competences might be more relevant than disciplines to design global framework for new curricula on sustainable engineering.

Research methodology

Descriptive study through a workshop

Our methodology can be positioned in the Design Research Methodology (Blessing and Chakrabarti 2009) which is represented in Figure 1. This paper can be positioned at the "Descriptive Study I" stage. Indeed, the main goal of the researchers being the integration of sustainable stakes in engineering education, the researchers collected data to "elaborate the initial description of the existing situation". This paper describes a workshop that tests the capacity of an institutional and national training framework to integrate complex environmental and social issues; this framework being the French national accreditation process for engineering curricula. Thus, the goal of this experiment is to understand the difficulties of integration of sustainability in the evolution of current engineering programs. This experiment only allows us to formulate a hypothesis that should be implemented in a prescriptive study in future works. The positioning of our work in the Design Research Methodology helps us defining and structuring the following steps of the study (see 4.5 What is next?).

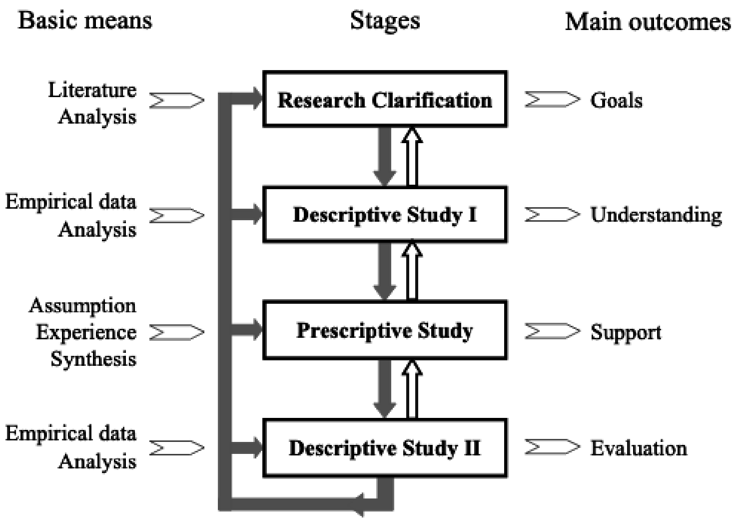

Figure 1: Design Research Methodology

The workshop has been created by the authors from scratch. The different steps are defined in the next section. The format of a workshop allows us "to iterate and thus refine and moderate our research design over time and in different context" (Ørngreen & Levinsen 2017). Even if this paper doesn't present an iteration, the workshop format offers this opportunity to continue the consolidation of this research in future works.

Details of the study

The exploration work has been conducted based on a one-day workshop at the University of Technology of Troyes on its 25th years anniversary celebration. The workshop was open to all members of the university and it was announced as a "workshop organized by students on sustainability: perma-engineering and sustainability". 7 other workshops were conducted that day, organised mainly by teachers.

Figure 2: Photo of both groups working in their sustainable wheel (step 4)

Our workshop was the most successful one, with a participation rate of 33%. 4 students from master's and engineering curricula were leading the workshop. Figure 2 shows participants working on their "sustainable wheel" (step 4 of the workshop). 15 participants joined the workshop at different times (some came just the morning or the afternoon) and were divided in 2 distinct groups of 5-6 individuals each. At least 11 people were present continuously (morning and afternoon sessions). The groups were composed of students (one of them coming from another European university), employees (administrative and teachers) and direction staff representatives, as it can be seen in Table 1.

Table 1: Details on participants

Participant N°	Age category	Nationality	Population type	Main educational background
Participant 1	<25	French	Student	Materials Engineering
Participant 2	<25	French	Student	Materials Engineering
Participant 3	<25	French	Student	Mechanical Engineering
Participant 4	>40	French	Teacher-researcher and administrative staff	Nanotechnology
Participant 5	<25	French	PhD Student	Materials Engineering
Participant 6	>40	French	Teacher-researcher	Mechanical Engineering
Participant 7	<25	Scottish	Student	Mechanical Engineering
Participant 8	<25	Swiss	Student	Ecological Management
Participant 9	<25	French	Student	Materials Engineering
Participant 10	25 – 40	French	Administrative staff	Management
Participant 11	<25	French	Student	Informational systems
Participant 12	<25	French	Student	Materials Engineering
Participant 13	<25	French	Student	Mechanical Engineering
Participant 14	>40	French	Administrative staff	Literature

Information about 1 participant is missing.

Among students, a large majority of them were also linked to the master on sustainability of the school, which is about adding 1 semester on “engineering and management of the environment and sustainable development” to the classic engineering curricula. This information is not added to Table 1 as it doesn’t constitute the main educational background of the participants of the workshop.

Participants related to the master on sustainability:

- 1 student was following the master on sustainability in the same semester where the workshop took place (fall 2019)
- 2 students followed the master on sustainability after the workshop (fall 2020)
- 2 students expressed their strong interest by following the master on sustainability and have done their first internship in a research laboratory on sustainability (spring 2021)

This workshop was meant to be led into the French institutional training frameworks for engineering imposed by the Commission des Titres d’Ingénieurs (CTI, standing for Engineers Titles Commission). The CTI framework structures all the aspects of engineering curricula. To be certified by the CTI, engineering schools have to follow a specific process and provide documents justifying the relevance of their curricula (current and new ones) regarding current jobs and regarding the school’s strategy. The documents are pre-defined and can be found on the website of the commission. For this workshop, we decided to focus on only one specific aspect of the framework which is the name of the provided training and the coherence between the name and the content of the training. There is a specific nomenclature for naming the specialties of engineering titles. The nomenclature is updated frequently, and the last version found is presented in annex 1. Thus, the main goal of the workshop was to create a new engineering training programme, starting from choices in the CTI nomenclature of the name of the new training and then going more deeply in the structure of the new training programme.

The workshop have been segmented into 4 parts (described in Figure 4):

1. Introduction of the challenges to meet before the end of the century and presentation of the objectives of the workshop (scientific content) – 20 minutes.
2. Choice of a domain from the CTI framework (domain of expertise) - 15 minutes.
3. Mind map of the constraints for the new curricula they want to create - 45 minutes.
4. Proposal of topics for contents and modality for new competencies on a “sustainability wheel” – 1 hour.

Figure 3: example of a diagram shown in step 1 (Doughnut economy from Kate Raworth)

For the first step of the workshop, a presentation of approximately 30 slides has been presented to explain to the participants the current environmental challenges. One of the diagrams presented is visible on Figure 3. This presentation has been created around pictures extracted from an academic literature review (diagrams from (Court & Fizaine, 2017) on EROI for global coal, oil, fossil fuels) and a synthesis of the global stakes (planetary boundaries from (Steffen et al., 2015), diagrams showing the evolution of CO_2 emissions until 2100, diagrams from reports on decoupling and its impossibility).

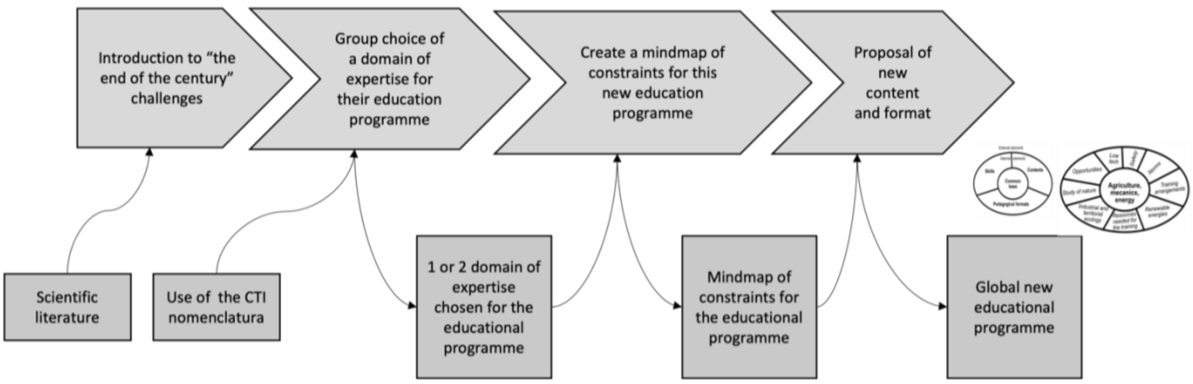

Figure 4: Workshop steps

The two groups went through the entire workshop (the four steps). People from undergraduate, research, teaching and direction staff constituted each group. The productions of the groups were kept and analysed after the workshop.

Results

Below are the results that participants received following the four steps of the workshop. We decided to present the results following the chronology of the workshop. There isn't any subsection for step 1 as no results came out of this phase.

Step 2: domain of expertise

Both groups faced difficulties to choose a domain from this framework and had the willingness to build a pedagogical curriculum out of the framework. One group did so while the second one finally decided to choose to combine three domains of the framework to address a wider scope. The first group chooses to start on a common base of skills: "common foundation of perma-engineering". They decided not to respect the CTI framework because the competences had to be transversal and not be restricted to one engineering domain. The second group chose the formation "agriculture, mechanics and energy: training the engineer in sustainable agriculture that considers today's mechanical and energy constraints".

It took 15 minutes for both groups to choose the domain of expertise. Even if a choice was made, both groups did not respect the CTI framework from the start while it was the only rule the organisers gave them.

Step 3: mind map of constraints

Each group has elaborated a mind map of the constraints. It took 45 minutes for both groups to build the mind map.

Group 1 identified thirteen constraints that we can regroup into three sections:

- Personal commitment of people: personal values, creativity, open-mindedness (addressing everyone, including those with opposing values).
- The complexity of the knowledge to be acquired on sustainability: knowledge of the issues (social, biodiversity, climate and resources), problematized knowledge (intelligibility of knowledge, reticence), global transversality and complexity of the issues.

- The institutional framework: training time (2 or 3 years), training of people, dissemination of the approach, policy, the weight of industrialists, institutional organizations, CTI.

Group 2 identified sixteen constraints that we can also regroup into three sections:

- Personal commitment of people: competence and convictions of teachers/researchers, ethics, consumption.
- Specific knowledge: design (recycling, reuse), technology, land use (deforestation, food waste), water management, biodiversity, eutrophication, resource depletion (biotic resources, abiotic/fossil resources, extraction), soil depletion.
- Structural mechanisms: financing (the current business model requiring partner companies for financing), the need for hiring, regulations, health and safety, working conditions (flexibility).

Step 4: sustainable wheel

Each group has elaborated topics on a "sustainability wheel". The two wheels obtained are very different in terms of content and structure.

The first group chose to build a common foundation for perma-engineering dividing its wheel into three categories: skills, content and training cycle. Each category was divided into two subcategories "internal" and "external" elements. The internal elements were inside the wheel while the external were outside.

The second group suggested a wheel divided into themes: industrial and territorial ecology, means necessary for training, pooling, recycling and reuse, study of climates, permaculture, stakeholders in training, study of climate and geopolitical issues, standards and regulations, health and safety, renewable energies, opportunities, training arrangements, low tech. Each theme was detailed in subpoints (between 1 and 6 subpoints).

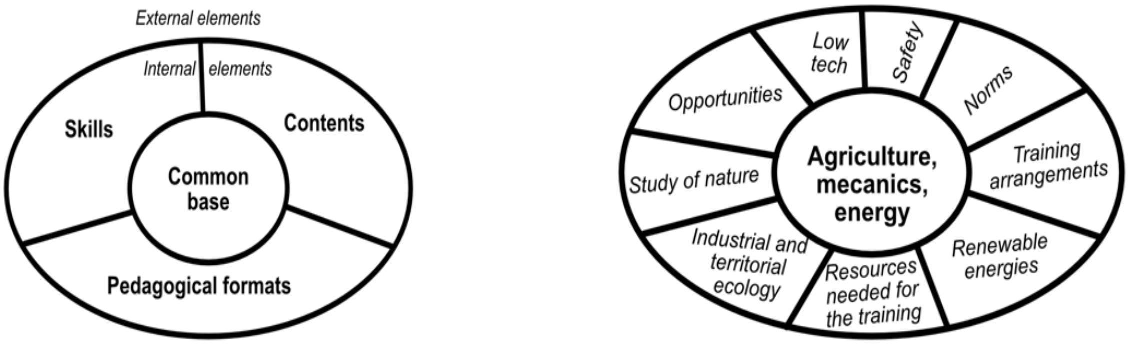

Figure 5: structure of sustainable wheel of group 1 (left) and group 2 (right)

The final "sustainable wheels" in paper format can be found in annex 2 (Figure 6 and 7). They have been represented schematically and translated in English for better understanding. All the results obtained during the workshop (materials created by the participants) as well as details of the participant's profiles have been kept and can be given upon request. The original materials are in French.

Analysis and discussion

The conclusion of the workshop was that both groups wished to leave the CTI framework because they felt “cramped” into it. This framework let at most a disciplinary combination of study fields. This section discusses the possible reasons for this feeling and tend to explain why. The first subpart discusses the results per group and a global discussion on education for sustainable development. The second subpart is focused on the limitations of the experiment which are important to have in mind to understand the outcomes and the possible next steps to follow (3rd subpart).

What are the corresponding characteristics with the literature found in the proposals?

First group analysis

The wheel of the first group seems very structured and has a very high level of abstraction, so it may seem difficult to build a training programme from the rendering. The absence of CTI constraints allowed the group to create a training by detaching itself from what already exists. Strong points emerged from their work such as:

- The need to break the understanding of the university as a « citadel » and to make it become an open place (linked to the imperative of dissemination of universities express in (Lozano et al. 2013)).
- A stronger anchoring in the territory so that the latter benefits from the knowledge produced within the university for its social development (“putting its training and professional future in context”).
- A stronger link between students’ associative activities and “classical” courses.
- A multidisciplinary and multi-stakeholder approach to training (also found in the literature as most of declarations, charters from higher education institutions emphasize on transdisciplinarity and the importance to involve different stakeholders see Part 3 of (Lozano et al., 2013).

The first group developed the idea of creating a common foundation, so it was much easier for its members to detach themselves from the existing situation in universities. They talked about the issues of sustainability and tried to translate them into thematic action plans. Due to a lack of time, the themes defined remain complex and a bit abstract. However, we see the emergence of atypical ideas. For instance, the fact of implementing a semester abroad sticks out in a “context where a carbon budget is to be respected”. Ecological rationality will oblige students to travel to a foreign country by alternative way and therefore to manage this journey as an integral part of their whole semester experience, which can lead to a certain form of new ‘way of life’. This challenge may seem easy for exchanges among European countries but will be much less so for exchanges of students with Asian or American countries. Alternative means will, therefore, have to be put in place.

Furthermore, the link between the territory where engineers are trained seemed to be important for this group. These reflexions can be linked to the work of (Zaluski et al., 2021) on territorial absorptive capacity which is “the interactions and interrelationships between them and several other institutions and public bodies”. The interaction between future engineers from different fields and the territory where they study can be a way to reach the transdisciplinary competence (Tejedor et al., 2018). Indeed, engineers will have to deal with grounded problems and consider how their technology will impact individuals, communities in their territorial context. Also, the multidisciplinary approach to teach technology is seen as essential in the scientific literature but also difficult to put into practice as teachers can lack social support (Aarnio et al., 2021).

Second group analysis

The second group produced a wheel with more content but less structured, where the highly technical content is brought up to the same level as the course format. This lack of structure can be attributed to the lack of time available to both groups to build their wheels. Here are the three areas that stand out for its content:

- The need for immersion in an economic context: the student must be employable at the end of his training course.
- Learning a strong knowledge base on the theme of sustainability (can be found in all the declarations made by higher education institutions through the last 30 years (Lozano et al., 2013).
- The presence of specific experimental sites within the university.

On the contrary, the second group chose to start from the chosen field of expertise (agriculture, mechanics and energy) to go back to the issues of sustainability. The group, therefore, established itself in existing fields of activity (farms, agricultural mechanics) and started from technical needs to try to achieve the challenges of ecological transition. This approach positions itself within the existing system and makes it difficult to detach oneself from it in order to find appropriate modifications to address the issues of ecological transition. This group has therefore made proposals that can be anchored in both a strong and a weak sustainability perspective. Also, this group emphasized on the necessity to be anchored into agricultural practices (not only through projects of 1 semester but through a total immersion). This point is quite linked to the proposal of the Turin Declaration (“Develop partnerships with the private and the non-profit sectors to transfer knowledge and commercialize new technologies that advance sustainable development”).

The areas exposed by group 2 on experimental sites correspond specifically to the competence “problem-solving” exposed by (Quelhas et al., 2019). Indeed, this competence is “the ability to apply engineering design while creating solutions that meet specific needs, still taking into account other dimensions such as public health, safety and well-being, as well as global, cultural, social, environmental and economic factors”. Group emphasized on this need to put into practice in a real context what was learned in theory classes.

Education for sustainable development

- Education for sustainable development (ESD) is categorized into 3 types by (Vare & Scott, 2007) Type 1 approaches assume that the problems humanity faces are essentially environmental and can be understood through science and resolved by appropriate environmental and/or social actions and technologies. It is assumed that learning leads to change once facts have been established and communicated.
- Type 2 approaches assume that our fundamental problems are social and/or political, and that these problems produce environmental symptoms. Such fundamental problems can be understood by means of anything from social-scientific analysis to an appeal to indigenous knowledge.

- Type 3 approaches assume that what is (and can be) known in the present is not adequate; desired 'end-states' cannot be specified. This means that any learning must be open-ended. Type 3 approaches are essential if the uncertainties and complexities inherent in how we live now are to lead to reflective social learning about how we might live in the future"

Types 1 and 2 belongs to ESD1 and corresponds to "the promotion of informed, skilled behaviours and ways of thinking, useful in the short term where the need is clearly identified and agreed". Type 3 belongs to ESD2 which is "building capacity to think critically about what experts say and to test ideas, exploring the dilemmas and contradictions inherent in sustainable living." (Vare & Scott 2007). ESD1 and ESD2 are complementary.

The proposals provided by the 2 groups seem to correspond gather elements from type 1, 2 and 3. In group 1 proposal, most of the content in "internal elements" in "skills" and "contents" are related to ESD1 as skills are oriented towards the mastering of 1 type of discipline each time and on specific knowledge (biodiversity, resources, climate stakes). Nonetheless, the pedagogical formats are more related to ESD2 as critical thinking, operating in an unknown context and collaborating with all stakeholders outside the University. In group 2, the content of the training is also more oriented on ESD1 as it is about putting into practice technical and social tools to improve the sustainability of the agricultural sector. This group emphasized on the importance of being anchored into an economic context (trainingship in agricultural sector). It is quite hard to define if this pedagogical format corresponds to ESD1 or ESD2. Also, as this group focused on the disciplinary area chosen in the CTI nomenclature, they didn't succeed to explicitly to provide elements which could be related to ESD2. It seems that following the nomenclature was a hindrance to the implementation of ESD2 elements. Does this type of nomenclature go against the basic principles of sustainable engineering?

What are the limitations of the experiment?

Context of the experiment

Initially, the conditions under which the workshop takes place are specific. Indeed, this exploratory work was carried out in a heuristic approach. The workshop was planned in order to do some animation (in a festive framework of the 25th anniversary of the University) and not specifically to write a scientific article. The information obtained proved interesting to analyze and use after the event. This results in the non-recording of exchanges and the non-preparation of an analysis grid prior to the workshop. The workshop was carried out in order to have a first intuitive version of what an engineering training on sustainability could be. The CTI framework was given as a constraint due to the French context (as participants had to create a French engineering program). It was the non-respect of the CTI framework by both groups that surprised the workshop organizers.

Participants: few and from the same context

The number of participants was low. For this reason, this study is intended to be exploratory only.

Another specificity is that the participants came from the same university (University of Technology). No one outside this context was present. There was no control over the participants profile present at the workshop, nor was there any specific request to certain parts of the population. The population of participants was therefore heterogeneous. In the end, this was positive in the sense that discussions between stakeholders in a training course could take place. This co-construction seems indispensable to us with regard to the future of sustainability. The limit is the absence of stakeholders outside the University (alumni of the University, education experts outside this context, future employers of the students, citizens) which would have brought a vision less marked by the context of a university of technology (Pritchard & Baillie, 2006).

The question of experts and non-experts

The explanations from the scientific literature (phase 2 of the workshop) seemed too complex in relation to the level of knowledge of the individuals present. Indeed, each slide presented a diagram describing an environmental dysfunction phenomenon (depletion of raw materials, disruption of the carbon cycle, and so on). Participants were unable to understand all the explanations due to their complexity. However, they asked for a re-explanation during the workshop's constraint expression phase (phase 3). The participants returned several times to the sources that had been offered in the introduction and were able to appropriate these contexts by reusing them directly in the mind map of constraints. Thus, despite a certain complexity of the explanations in the introduction, the information given was relevant to the participants' reflections and productions.

Given the participants knowledge disparities, we can question the legitimacy of the work of non-experts in sustainability to discuss the integration of ecological issues in engineering education. Based on the work of (Yesilada et al., 2009) that expertise allows greater precision and accuracy in the choices made than ignorance on a subject. Expertise also increases the robustness of the results. This is of course valid for a large number of disciplines. However, is it valid for the field of sustainability? Would the integration of non-experts be relevant in the end? Some works in the field of environmental planning show that the integration of non-experts allows co-creation and a better matching of results to the expectations of the different stakeholders (Cook, 2011). Can the construction of an engineering education for environmental transition only be done with researchers specializing in the field?

What is next?

An upstream assessment of each participant's level of knowledge on sustainability would be relevant to ensure the relevance of the participants' proposals. Also, a repetition of the workshop in many contexts would make the hypothesis formulated more robust. Additionally, a recording of the interactions between each group would make it possible to understand the pathways and blockages that lead some groups to bypass or dispense with institutional frameworks.

This approach was based solely on the name of the potential training imagined by the participants. In this paper, we chose only 1 aspect of the accreditation process which was the process to define the name of the new curricula. Other elements more complete and complexe are part of the accreditation process, the writing of a synthetic document on the school, a general note of strategic orientation of the school, constitution of a note for the Consultation of the National Directory of Professional Certifications. Other workshops dealing with the other aspects of the certification process could also be analysed to see whether other institutional elements could be used as blockages to the development of engineering education around sustainable transitions.

Conclusion

The workshop detailed in this paper was an exploratory experiment, involving a restricted number of participants. It was divided into 4 parts: an introduction of the challenges from a scientific point of view, the choice of a domain of expertise within the CTI framework, the elaboration of a mind map of constraints for the new curricula each group of participants wanted to create and a final proposal of contents and modality for this new curriculum. Both groups succeeded to path through the 4 steps of the workshop and produced a graphical representation of their proposal.

It can be concluded that participants faced difficulties positioning themselves within the imposed CTI framework because they had the feeling that this framework couldn't let them reach the issues of strong sustainability. The disciplinary approach utilised within this workshop was determined to restrict the evolution of engineering education. This disciplinary approach has been chosen by institutional frameworks. These frameworks can, therefore, constrain thinking for strong evolutions of training. Ecology being a holistic approach involving disciplines other than those offered by the French institutional framework CTI and future work could be conducted to evaluate the relevance of this framework for designing training courses addressing complex environmental and social issues. This heuristic experiment, therefore, opens up new research perspectives in the field of the evolution of engineering education and institutional frameworks accompanying higher education institutions.

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links/5fff872545851553a0417d10/Framework-Conceitual-da-Capacidade-Absortiva-Territorial-e-Desenvolvimento-Sustentavel.pdf).

Appendix 1

Table 2: List of wordings that can be used in the constitution of a speciality title taken from (Commission des titres d'ingénieurs 2018)

1	Aéronautique et espace (ou aérospatiale)	Aerospace engineering
2	Agroalimentaire	Food engineering
3	Agro-industries	Agro-industry
4	Agronomie	Agricultural engineering
5	Automatique	Control engineering
6	Bâtiment	Construction engineering or Building engineering or Civil engineering
7	Bioinformatique	Bioinformatics
8	Biotechnologie	Biotechnology
9	Bois	Wood technology
10	Chimie	Chemistry
11	Électronique	Electronics
12	Emballage et conditionnement	Packaging
13	Environnement (pas seul)	Environment (and…)
14	Ergonomie (pas seul)	Ergonomics
15	Génie biologique	Bioengineering
16	Génie biomédical	Biomedical engineering
17	Génie chimique	Chemical engineering
18	Génie civil	Civil engineering
19	Génie de l'aménagement	Urban planning engineering or Urbanism and spatial planning
20	Génie de l'eau	Water (resources) engineering
21	Génie des procédés	Process engineering
22	Génie électrique	Electrical engineering

23	(Génie) énergétique	Energetics (engineering)
24	Génie hydraulique	Hydraulic engineering
25	Génie industriel	Industrial engineering
26	Génie maritime	Marine engineering
27	Génie mécanique	Mechanical engineering
28	Génie nucléaire	Nuclear engineering
29	Génie physique	Physical engineering
30	Génie urban	Urban planning engineering
31	Géomatique	Geomatics
32	Géosciences	Geosciences
33	Gestion des risques	Risk management
34	Horticulture	Horticulture
35	Informatique	Computer science
36	Informatique industrielle	Computer engineering
37	Logistique	Logistics
38	Matériaux (precision possible du tyme de matériaux : polymères, céramiques, composites, métalliques…)	Materials science or… materials
39	Mathématiques appliquées	Applied mathematics
40	Mécanique	Mechnaical engineering
41	Mécatronique	Mechatronics
42	Microbiologie	Microbiology
43	Microélectronique	Microelectronics
44	Microtechniques	Microtechnology
45	Multimédia	Multimedia engineering
46	Paysage	Landscape engineering
47	Photonique	Photonics
48	Plasturgie	Plastics engineering
49	Production (pas seul)	Production (and… of)
50	Réseaux	IT networks engineering
51	Robotique	Robotics
52	Santé (pas seul)	Health (and…) or… for health
53	Sciences de la Terre	Earth sciences
53	Sécurité (pas seul)	Security (of…)
54	Systèmes () embarqués	Embedded () systems
55	Systèmes d'information	Information systems
56	Systèmes ferroviaires	Railway systems
57	Systèmes numériques	Digital systems
58	Technologies de l'information	Information technology
59	Télécommunications	Telecommunications
60	Textiles (et fibres)	Textiles (and fibres)
61	Topographie	Topography(-surveying)
62	Travaux publics	Public works or Civil engineering

The CTI framework is composed of the dimensions present in the Table 2. « The specialty title of an engineering program must consist of no more than two wordings taken from the list below. In the case of two headings, they may be linked either by a conjunction ("and") or by a preposition ("of", "for", etc.). » (Commission des titres d'ingénieurs 2018)

Appendix 2

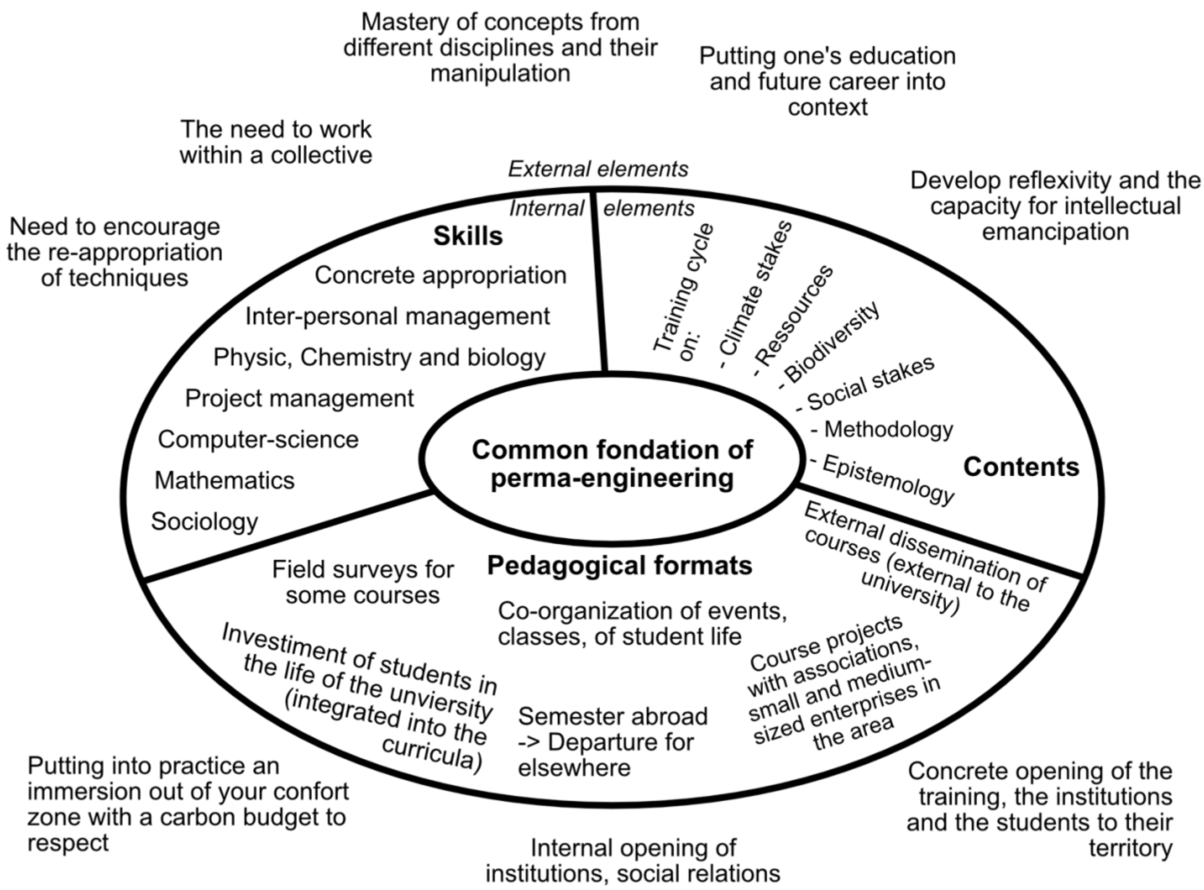

Figure 6: Final production of group 1

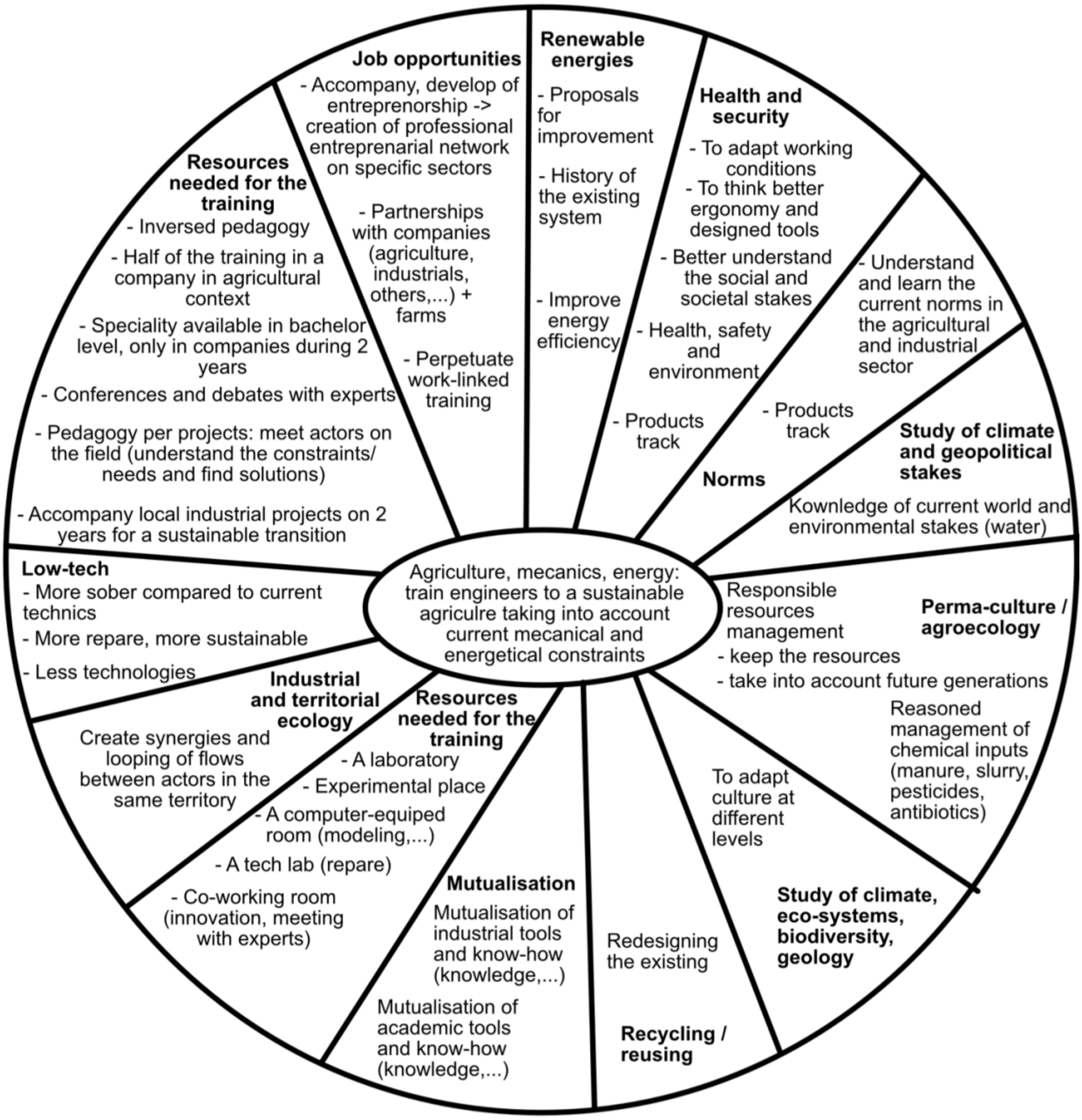

Figure 7: final production of group 2