EXPLORATORY RESEARCH TO BETTER UNDERSTAND THE DIFFICULTIES OF TAKING SUSTAINABILITY INTO ACCOUNT IN THE EVOLUTION OF ENGINEERING EDUCATION AND TRAINING

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ABSTRACT (250 WORDS MAX)
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 institutional frameworks can be an obstacle to the production of new 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

1 INTRODUCTION

The entrance of humanity into the Anthropocene [1] requires us to rethink technology by taking into account the impacts technical tools have on the ecosystems. All these techniques used by humanity (our activities in a broad sense) and their impacts can be understood as a whole called « anthroposphere ». This anthroposphere is in constant exchange with the biosphere, which is defined by all ecosystems, living organisms evolving in their living environments. These two spheres interact: people draw their raw materials from the biosphere to meet their needs. This interaction seems one-sided. Indeed, the impact of the anthroposphere on the biosphere is such that the latter is struggling to recover. We can say that the anthroposphere behaves within the biosphere as a linear biophysical flow that extracts resources as inputs [2] (fossil fuels, metals, non-metallic minerals, biomass, land, water) and emits discharges (whether solid, liquid or gas) as outputs. This flow generates ecological pressures: climate change, deterioration of ecosystems services, air pollution, ocean acidification, freshwater depletion, soil degradation, disruption of biogeochemical cycles. The increasing intensity of this flow, which cannot be fully circularized considering the second law of thermodynamics, is not sustainable [3, 4]. Indeed, annually, the rate of extraction of resources exceeds that of their regeneration, while the quantity of emissions exceeds that which the biosphere is capable of absorbing to sustainably ensure our living conditions. In other words, the current metabolism of the anthroposphere within the biosphere is not sustainable and compromise the Earth-system viability [5].

The methods used to design the techniques, therefore, take little account of the biosphere's carrying capacity. In contemporary societies, engineers are applying "scientific principles to solve problems for *the betterment of society*. By definition, engineering is a service profession. Day-to-day engineering, however, is more often focused on technological rather than human concerns" [6]. Engineers are designing a wide part of the technical tools of our world.
The training of engineers in environmental issues is therefore essential in order to develop technologies that respond to societal challenges [6] and to make the links between anthroposphere and biosphere sustainable. Our society seems to develop technologies for only certain categories of the population. Indeed, 80% of engineers design for 10% of the world's population (the richest people) [7]. There is therefore a real challenge in training engineers in environmental and societal issues in order to prepare them for future socio-ecological disasters. The goal of this paper is to question the limitations of the evolution of engineering training in the face of environmental challenges. It presents an analysis of the elements that have favoured or hindered the work during the workshop. In particular, it makes it possible to identify the difficulties posed by institutional training frameworks in order to develop them.

2 RESEARCH METHODOLOGY

2.1 Descriptive study

Our methodology can be positioned in the Design Research Methodology in [8] 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, they collected data to "elaborate the initial description of the existing situation". This paper describes a workshop that tests the capacity of an institutional training framework to integrate societal and environmental issues. Thus, the goal of this experiment is to understand the difficulties of integration of sustainability in the evolution of current engineering programmes.

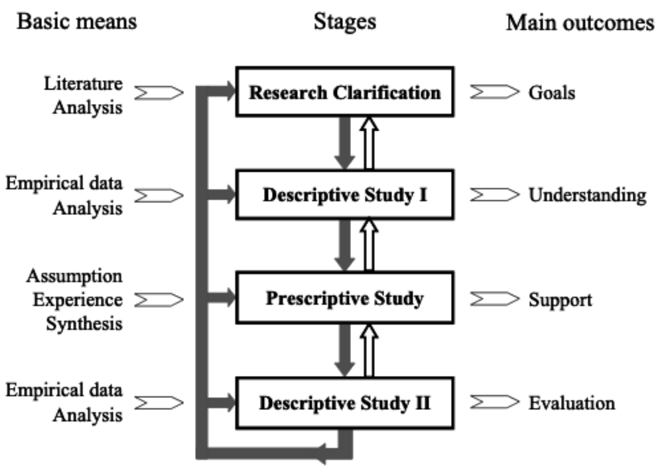

Figure 1. Design Research Methodology

2.2 Details of the study

The exploration work had been done based on a one-day workshop at the University of Technology of Troyes during its 25 years birthday day. The workshop was open to all students

and employees of the university and it was announced as “workshop organized by students on sustainability: perma-engineering and sustainability”, among 7 other workshops.
It was the most successful workshop with 33% of the participants within the 7 workshops. Four students from master’s and engineering curricula were leading the workshop. 15 participants came to the workshop, not all at the same time, and participated in two groups of 6 persons each. At least 11 people were present. This group of participants was composed of students (one of them coming from another European university), employees (administrative and teachers) and direction staff representatives.

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). It seems interesting to make a quick reminder of the history of the engineer in France. At the end of the 18th century, the first French engineers are destined to serve the state in particular by arranging the territory and the military force [9]. By the yardstick of the first industrial revolution engineers are being assigned to the management of the growing industry. In 1934, the CTI institution is created. Its objective is to regulate training in the engineering schools and to supervise private initiative.

The workshop has been led in 4 steps:

- Introduction of the challenges to meet before the end of the century and presentation of the objectives of the workshop
- Choice of a domain from the CTI (French certification institution which delivers the authorization to provide engineering degree) framework
- Mind map of the constraints for the new curricula
- Proposal of topics for contents and modality for new competencies on a “sustainability wheel”

The two groups finished the work. People from undergraduate, research, teaching and direction staff constituted each group. The productions of the groups were kept and analysed after the workshop.

3 RESULTS

Below are the results the participants got following the four steps of the workshop.

3.1 Step 1: literature review presentation

A slide show of about 30 slides has been presented to explain the current environmental challenges. The presentation was made around pictures from an academic literature review and a synthesis of the global stakes.

3.2 Step 2: domain of expertise

The CTI framework is composed of the following dimensions: agriculture, agronomy, agri-food, chemistry, proceeds engineering, medical engineering, earth sciences, materials, civil engineering, building, development, environment, mechanics, energy, electricity, electrical engineering, automation, electronics, telecoms and network, computer science, information systems, mathematics, modelling, industrial engineering, production, logistics. The combination of two dimensions (not more) is possible with defined words “and”, “or”, for”.

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 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 chooses the formation « agriculture, mechanics and energy: training the engineer in sustainable agriculture that considers today's mechanical and energy constraints ».
Both groups took 15 minutes to choose.

3.3 Step 3: mind map of constraints

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

Group 1 identified thirteen constraints that we can group 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 group 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).

3.4 Step 4: sustainable wheel

Each group has elaborated topics on a "sustainability wheel". The two sustainability wheels obtained are very different, both in the content and in their structure.
The first group that chose to build a common foundation for perma-engineering divided its wheel into three categories: skills, content and training cycle. Each category was divided in two "internal" and "external" elements. The internal elements were inside the wheel while the external were outside.
The second group proposed 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 modalities, low tech. Each theme was detailed in subpoints (between 1 and 6 subpoints).

4 ANALYSIS AND DISCUSSION

4.1. Global analysis

This exploratory work carried out in a heuristic approach. Indeed, 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 analyse and use after the event.

All the people who came to the workshop were particularly sensitive to the challenges of sustainability. Despite the strong understanding of these issues, their scientific sources seemed unknown to the participants.

The workshop was time-constrained as it took place over one day (1h30 in the morning and 1h30 in the afternoon). Therefore, no individual spaces for reflection were proposed during the workshop (only moments of collective reflection). During the feedback phase, some of the participants expressed this lack of individual moments of reflection.

4.2 Step 1: literature review presentation

The explanations from the scientific literature 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 a re-explanation by little groups during the workshop's constraint expression phase (phase 3). Thus, despite a certain complexity of the explanations in the introduction, this information given was relevant to the participants' reflections and productions.

4.3 Step 2: domain of expertise

Both groups wished to leave the CTI framework, and this was done in the sense that one of the groups chose to reject the themes proposed by the CTI while the other group broke the rules of themes combination. These choices are significant, and it could be interesting to analyse furthermore why the participants felt « cramped » in the CTI framework.

4.4 Step 3: mind map of constraints

The part on constraints was really complex. The participants returned several times to the sources that had been proposed in the introduction and were able to appropriate them by using them directly within their constraints.

4.5 Step 4: sustainable wheel

The wheel of the 1st group seems very structured and has a very high level of abstraction, so it may seem difficult to build a formation 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.
- 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.

The second group produced a wheel with more content but less structure, 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 their 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.
- The presence of specific experimental sites within the university.

The first group having started from the idea of creating a common foundation, it was much easier for its members to detach themselves from the existing situation in universities. They started to talk about the issues of sustainability and tried to translate them into thematic of action plans. Due to a lack of time, the themes defined remain complex and a bit abstract. However, we can begin to see the emergence of atypical ideas. For instance, the fact of doing a foreign semester stick out in a "context where a carbon budget is to be respected". Ecological rationality will oblige students to travel to a foreign country slower and therefore to manage this journey as an integral part of their whole semester experience. This challenge may seem easy for European countries but will be much less so for countries in Asia or America. Alternative means will, therefore, have to be put in place.

On the contrary, the second group chose to start from the chosen field of expertise (agriculture, mechanics and electronics) 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 both in a strong sustainability perspective and a weak sustainability perspective.

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 on request.

5 CONCLUSION

Based on this exploratory experiment, we can conclude that participants had difficulty 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. Following this workshop, the hypothesis we can make is that the disciplinary approach limits the possibilities of 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 proposed by the French institutional framework CTI, it would be interesting to evaluate the relevance of this framework for designing training courses addressing 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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