Co-designing a curriculum for a sober techno- and eco-responsible engineering: transition to a new professional identity for a sustainable world

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ABSTRACT

In a finite world whose limits now seem obvious, future engineers are wondering what their profession will become tomorrow. To respond to this strong expectation, the PISTE[2] curriculum was opened in September 2021: a full semester in the final year of engineering studies at Grenoble INP-UGA (France). The program was co-designed with the students and the different partners. The objectives are to enable the students to experiment a new posture and to offer them the tools needed to meet the challenges they will face in a world in transition. A systemic, interdisciplinary approach, considering planetary limits and environmental and societal impacts, structures the whole semester.

This paper presents and argues the pedagogical design choices. With a view to continuous improvement, the strengths and areas for improvement are described.

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1 INTRODUCTION

1.1 Context

In a finite world whose limits now seem obvious (as highlighted by the Sixth Assessment Report of the Intergovernmental Panel on Climate Change), future engineers are asking themselves what their role and their job will be tomorrow. And for example, how can they contribute to achieving the UN Sustainable Development Goals? The global challenges are raising questions among young people who would like to give more meaning to their university education [4].

To respond to this strong expectation, this year we opened the PISTE program to a first class of 28 students: a full semester in the final year of engineering studies at Grenoble INP-UGA (France)[3]. The program was entirely co-constructed with the students and the teachers. The objective is to allow students to experiment with a new posture and to offer them the tools they need to meet the challenges they will face in a world in transition. A systemic, interdisciplinary vision, considering planetary limits and environmental and societal impacts, structures the whole semester.

This paper presents and argues the pedagogical design choices, based on empirical findings and elements from the literature: the overall structure of the program, the contents, the pedagogical methods, the assessment of learning outcomes and the specific support for students and teachers in this program.

With a view to continuous improvement and dissemination, the strengths and areas for improvement are described based on feedback from teachers and students, as well as from the program's co-leaders and the educational developer.

1.2 Approach

To train future engineers in the skills needed to resolve the challenges linked to the ecological transition, we have made the following hypothesis

- A systemic (the whole system in which the problem exists), interdisciplinary (without thematic barriers) and global (from needs and uses to the impacts of the proposed solution according to constantly changing contexts) vision is essential for understanding the transition issues [3].
- The pedagogical approach must be adapted to developing a new conception of the engineering profession, i.e. to be able to approach complex problems in a systemic, interdisciplinary and global manner [5].
- The assessment of learning must be aligned with these intentions and methods [1].
- Co-construction of content between teachers and students, and a collective approach to sharing resources (open science), in a climate of collaborative governance, are necessary because the training is intended to be transformative and emancipating [5] for these future engineers: at the levels of their professional

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identity, their behaviour, their conception of the world, their imaginations and their power to act.

2 METHODOLOGY

2.1 Program Design

We have proposed to build on the elements that we believe are essential for a successful transition in the world of tomorrow and to apply them in designing a 6-month program, during the penultimate semester of the engineering curriculum.

Systemic understanding and approach throughout the whole program

- Interdisciplinary, systemic and global learning, both in terms of knowledge and key skills and engineering posture, which enable the projects to meet their challenges.
- Taking advantage of the diversity of the actors, a variety of points of view, reflected in the diversity of speakers and students (open to all Grenoble INP-UGA components).
- The teachers come from different disciplines at Grenoble INP-UGA and Grenoble Alpes University, and local partners working in research centres, companies, and associations. All of them are involved in sustainable development in one way or another and attach particular importance to it [3]. An important part of the contributions is dedicated to human and social issues, which is a departure from the usual engineering curriculum.
- The courses contents cover a variety of subjects: assessment of the environmental state, analysis of planetary limits, sustainable solutions and adaptation solutions, levers for action, integrated resource management, history of industrialisation, sociology (techniques, uses, innovation), digital sobriety, public policy, green taxation, open science, project management, multi-criteria methods to help decision-making, methods centred on the user experience, carbon assessment, life cycle analysis, risk management analysis, energy performance, low-tech and right-tech.

Adapted pedagogy to develop a new conception of the engineering profession

- A framework that stimulates “transformative” [3] and “emancipatory” [5] learning, mutual understanding, empathy, and trust, as well as collaborative governance (sharing of information and ideas, cooperation, benevolence, mutual respect).
- Interactive teaching to include and engage all students [3, 5], and to reinforce learning and reflective assessment.
- The core of the semester is a group project (10 ECTS out of the 30 ECTS of the semester). The projects are concrete, real-world projects [3], starting from the user's needs and breaking away from the 'business as usual' growth model. The objective is to rethink the design and uses of a product, a component, a system, or an organisation.
- The project work is fed throughout the semester by theoretical and methodological contributions, which are scientific, technical, sociological, political, and economic.

The teaching offered is therefore designed around the projects: they provide useful insights for the students throughout the semester.

- The whole program is designed in accordance with the competence strategy of Grenoble INP-UGA [6].

Learning assessment method based on individual reflection

- Project assessment criteria include: reformulation of the specifications, state of the art in relation to the needs, complete free documentation accessible to the greatest number, life cycle analysis and impact assessment, choice of a solution that meets the needs of users and socio-ecological issues, quality of the report and the proposed solution. Particular attention is paid to the prototype (technical or methodological).
- The assessment of learning outcomes is designed with a view to constructive alignment [1]. It is based, for each of the three teaching units, on an individual reflective writing in which each student shows the links between the learning acquired and its reuse in the concrete framework of the project. This written work is then discussed during an oral presentation.
- The students are accompanied in their reflective work throughout the semester: individual feedbacks are provided on demand on draft versions of their written work; at the end of each oral presentation, teachers and students are invited to write together advise for the next session; workshops are offered during the semester about the assessment method and about the emotions lived during the semester.

Co-construction with the students, the teachers and the partners

- Projects are anchored in the territories. Subjects are proposed by three types of partners, reflecting the diversity of society:
  - public partners such as the municipality or a research laboratory
  - private partners such as companies engaged in transition processes or wishing to hire future engineers capable of addressing transition issues
  - partners representing civil society, such as associations directly linked to transition issues or associations wishing to address these issues without having the expertise
- The groups work closely with partners and potential users to co-construct technical or methodological strategies and solutions. Teachers mentor the groups to support them in carrying out the projects (project management and engineering methods).
- The projects address the challenges of transition: they aim to rethink the design and uses of a product, a component, a system, or an organisation, by developing low-impact, sustainable, documented and widely accessible solutions or strategies. These solutions or strategies should be answering a question directly useful for the user, promoting an open science approach, and fitting into a circular economy model, leading to a more convivial society.
- Regular adjustments occur throughout the semester, according to feedback, observations and questions from students, teachers, co-leaders and the educational developer.

2.2 Overall Framework

The teaching activities proposed throughout the semester encourage interaction between students and between students and teachers. Form and content are co-constructed: students and teachers alike can contribute to the construction of learning.

A climate favourable to learning is based on a set of values, mainly stemming from the currents of popular education, collaborative governance, and collective intelligence. This framework was built with and by the students at the beginning of the semester. Tools were proposed to them, and they appropriated them. The different dimensions of this framework are:

- Benevolence, towards oneself and towards others: we do the best we can, with what we have and what we are.
- Respect: each person has a point of view and diversity is a richness; being punctual, doing one's share of the work, being rigorous and demanding about quality, etc. are all part of respecting oneself, others, one's environment, and the work accomplished.
- Sovereignty: I speak as "I"; I am responsible for my words, my actions, my feelings, my choices...
- Co-responsibility: each person is responsible for respecting the framework and for ensuring that it is respected.
- Humility: nobody knows everything about everything (even the experts), everybody can still learn a lot.
- Legitimacy: everyone can contribute. If an idea has not yet been stated, it deserves to be put in the common pot to be discussed and exchange together on its relevance or not. Mistakes allow us to learn, every obstacle overcome is an experience that can help us move forward, every dead end explored deserves to be identified and shared with the community.
- Criticism and self-criticism: reality is complex and needs to consider a range of points of view (vigilance on a miracle solution or an absolute truth); an idea is distinct from the person who states it (vigilance on arguments of authority and debate of ideas rather than debate of people).

3 RESULTS

3.1 Observations and findings

During the semester, we regularly collected informal and formal feedback from students and teachers and this by different means. Informal feedback was collected during pedagogical workshops, through email exchanges and during two meetings organised with the students, the co-leaders of the semester and the educational developer.

An online questionnaire with 130 questions was proposed to students, at the end of the semester: 75 closed questions on a 4-level likert scale plus a "not applicable" option, 46 non-mandatory open questions, 7 yes-no questions, 1 number question and 1 grade question. The questionnaire was built with pre-tested questions mostly used

to assess quality learning and teaching in French speaking Higher Education. It meant to measure the perceived alignment between the aims of the semester and to verify our initial hypothesis (see sections 1.2 and 2.1). 25 out of the 28 students took the time to answer.

In addition, the students spontaneously organised collective feedback, taking the form of a written document worked on in several group sessions.

Systemic Approach

Many comments show the interest of addressing societal issues, planetary limits, putting these questions into perspective, for example through a course on the history of industrialisation, and considering all the stakeholders, in particular with methods from sociology. In their collective spontaneous feedback, the students note in the general feedback paragraph: "The diversity of the courses offers a step back, while developing very technical and practical aspects."

In the questionnaire, all the answers show that the semester has enabled the development of skills related to solving the challenges associated with the ecological transition. Among the skills developed, students cite

- *Having a systemic vision of the issues*
- *Understanding the mechanisms of climate change and the socio-economic mechanisms of the transition*
- *Having a greater capacity for critical analysis of the technical solutions proposed*
- *Be able to assess the social impact of a technique or technology and to measure the environmental impact with rigour (Life Cycle Assessment, carbon footprint, etc.)*
- *Imagine alternative solutions that break with the growth model*
- *Be an actor in the sustainable transition*

Pedagogy Framework

"The interacting pedagogy framework for sustainability education" [5] is built on two axes: one axe "describes a movement from individuality, structure, and predetermined outcomes to collaboration, agency, and self-actualization respectively" and the other axe "describes a movement from content-focused, objective learning resulting in knowledge and skills acquisition to process-focused, subjective learning resulting in novel ways of being and meaning-making" (p.8). These two axes determine four quadrants.

The core projects were perceived as being at the heart of the course (the courses feed into them) by 75% of the students. 84% felt that the project stimulated interest in the course. All of them felt that they could

- use their knowledge and personal skills (responsibility, initiative, autonomy, reflection) well for the project
- learn and develop their skills by doing the core project
- put the technical knowledge in relation to current societal issues in the project.

56% of the students felt that the teachers ensured their involvement in the proposed educational activities (courses, projects, etc.). 92% felt that a significant proportion of the courses offered activities other than listening to lectures. Among the most cited examples are: debates, open discussions, writing and manual workshops, practical work (applications), mini-projects, serious games, creation of common resources. 64% of students believe that teachers leave room for the co-construction of learning: students as well as teachers can contribute to this learning.

According to Papenfuss *et al.* framework [5], we consider that the major part of the teaching is in quadrant 2 (projects and problem solving, application and critical thinking) and quadrant 3 (experiential learning, transformation of the posture and conception of one's role as an engineer). A smaller proportion, consisting of lectures and readings, is more likely to be found in quadrant 1. Another more significant proportion is found in quadrant 4 (reflection, co-responsibility, legitimacy, future professional orientation): the climate that was established at the beginning of the semester and which, according to 84% of the students, lasted throughout the semester.

This climate aimed to change the usual roles in higher education, towards more horizontality between teachers and students. As the authors suggest, this climate remains difficult to maintain because neither teachers nor students are used to quasi-horizontal relationships. Teachers sometimes need to remind (themselves) of the asymmetry that persists (they are the guarantors of the learning framework and responsible for assessment); some students need to be reminded of the overall framework of higher education (they are responsible for their learning and are bound to respect the didactic contract established at the beginning of the semester).

Learning Assessment Methods

76% of the students consider that the assessment method is consistent with the pedagogical intentions of the semester. However, it deserves to be better structured and more harmonised between teachers. The instructions would benefit from being clearer and explained more regularly throughout the semester. Workshops for students and discussions during oral examinations with teachers were insufficient to prepare them to this unusual assessment method. Indeed, students and teachers expressed difficulties in appropriating the method.

Co-construction

The involvement of the students and the effects of this semester far exceeded our expectations: the students' profiles seem slightly different from the standard profile of students at the school, their expectations were undoubtedly high. The possibility of exchanging views with other people who share their values, in an open climate where everyone is legitimate to co-construct knowledge, has visibly shifted their perception of the engineering profession.

The surveys allowed us to better understand the profile of this first class of students. In fact:

- 68% had participated in the "climate mural" before starting the semester and 44% were a facilitator of this mural; 16% participated in the digital mural"
- 60% were coming out of a gap year that was valued in the curriculum
- 96% had made choices in their personal lives, before the start of the semester, related to the issues of transition and climate change (mainly on meat consumption and transport).

These particular profiles show a prior adherence to a set of values, goals and beliefs related to the transition. This adherence can be understood as a strong commitment in the sense of Marcia [2].

The students shared their questions throughout the semester about their future as engineers: a large majority expressed difficulties in finding an end-of-study internship that corresponded to their aspirations, and several questioned the validity of their future profession. In the end, everyone was able to find an internship that suited them (in a company, a research laboratory, or an association), and 76% of the students can now imagine a future that corresponds to them as a future engineer. Some comments in this end-of-semester questionnaire also show that some students have been able to resolve these issues. This resolution can be understood as a state of exploration in the sense of Marcia [2].

Extracts from student's answers to the question "What has changed in me during this semester?" show a turning point in the perception of their career:

- *Today I think I could do a job related to my 5 years of study, which was not the case before.*
- *You can come out of an engineering school and not necessarily do a useless job.*
- *I will be able to make a very informed choice about my future job and the social impact it will have.*
- *I think I'll be a better engineer than I expected and I feel more in tune with the idea of being an engineer.*
- *I have deconstructed my ideal of the engineer and I am readier to have a disruptive job (...) I have more hope about the possibilities for an engineer to be an actor of transitions, to have a job that fits with his values.*
- *A much more serene approach to the professional world.*
- *PISTE has given me back some confidence in the future of the engineering profession.*
- *Above all, it gave me hope: the possibility of changing things.*
- *I had a trigger by telling myself that I would choose why I work and not be subjected to a "classic" engineering job in a company that does not correspond to me totally.*
- *My vision of engineering, my vision of the issues.*
- *My vision of the world, of socio-environmental issues and the role of the engineer.*
- *My vision of the engineering profession: you can break the conventions and still be an engineer.*
- *My vision of the engineer, of the society in which I live and my own desires (...) a change in thinking that I believe will never turn back.*

- *PISTE will be a turning point in my life. I probably would never have had the courage to propose my final internship to the school without this semester.*

Global Consistency

These results also allowed us to draw some key conclusions shared by more than 70% of the respondents:

- a very high overall satisfaction of students, teachers and local partners
- a change in the students' mindset
- confirmation, by students and teachers, that the core project is indeed at the heart of the training and that the courses are engaging and interactive
- effective co-construction in most of the learning activities
- the perception of a systemic and interdisciplinary vision, both in the projects and in the teaching.

Overall satisfaction was evident in all the discussions, the questionnaire and the collective spontaneous feedback written by the students.

3.2 Perspectives

As a result of this feedback, and with a view to continuous improvement, we are considering several developments:

- Clarification of shared documents (assessment grids, semester charter, etc.)
- More in-depth pedagogical support on the methods of assessment of learning, both for students and for teachers.
- Further development of sessions dedicated to welcoming students' feelings and supporting eco-anxiety (present at the beginning for some or developed during the semester for others).
- Opportunities for the teaching team to appropriate the framework and the common tools - e.g. collaborative governance, open science - are planned.
- A greater awareness of the teaching team to the interest of calling upon the educational developer to design the learning activities.
- More explicit sharing of prerequisites within the teaching team, to avoid some redundancies and gaps, mainly within the first teaching unit.
- Some changes in course subjects and contents.
- Opening to a wider public.
- Setting up an alumni network and a network of companies able to host end-of-study projects related to the semester.
- Longer periods of time to work on projects.
- Sharing of the different projects with the whole teaching team via short presentations (video, online document, or another format).

4 CONCLUSIONS

We can consider that this program constitutes a niche [3]. It is a place of experimentation, open to its environment, and the actors are particularly willing to co-construct and widely disseminate the impacts, strengths and weaknesses observed, as well as the avenues of evolution of this program.

The co-construction of the semester with all the actors concerned seems to us to be a factor of success of this type of program. In a quest for congruence between the intentions pursued and the means implemented, it seems obvious to consider the contributions of each person as essential and legitimate, regardless of their status. This approach also applies to courses, projects, etc. Transition issues concern the whole society. Each person can contribute. The diversity of points of view considerably enriches the solutions considered, both at the level of disciplines to provide a systemic vision and at the level of personalities to provide diverse perspectives.

Together, we constructed a framework inspired by popular education, collaborative governance and collective intelligence. This framework changes the place and role of learners and supervisors. It opens up co-construction and requires sharing values such as benevolence, sovereignty, mutual respect, criticism and self-criticism, humility. This framework allowed for collective and individual work on professional posture. This work is essential to reinvest the role of the engineer in a world in transition.

We did not conduct more specific individual interviews to explore the question of identity. In the light of the observations and data collected, we presume that some students are on the threshold of an identity realisation while others may be in phases of foreclosure or moratorium in the sense of Marcia [2]. We do not exclude that the development of professional identity, especially at such a young age, may still show forward and backward steps: it is possible that they may experience times of questioning about engagement and/or exploration.

We also proposed pedagogical activities consistent with the objectives [1], to develop the skills needed to solve the challenges linked to transition and, in particular 'transformative' pedagogy [3,5]. The pedagogical approach - built around real projects and supported by local structures – is designed to develop complex learning. It encouraged teachers and students to weave links between each course and their projects, and to experience innovative pedagogical activities. Pedagogical support for teachers and students in these unusual teaching methods (activities and assessment of learning) has proved necessary but still insufficient.

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