P/REFERENCES OF DESIGN

SUSTAINABILITY BY DESIGN: A FIVE-YEAR CROSS-CURRICULAR PROGRAMME FOR DESIGN STUDENTS.

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ABSTRACT | The Anthropocene era, marked by unprecedented human impact on the Earth's processes, necessitates a paradigm shift in education, particularly in design disciplines. This article explores the transformation of a five-year design curriculum at a French industrial design school, introducing a proposal for a cross-curricular "Sustainability by design" programme. The central question addressed is how to make ecology an integral pillar, not merely an additional dimension, in the design process. The article outlines the conceptual framework for this shift, emphasising the need for a planet-oriented design that considers Earth as a complex system intertwined with human history and culture. Divided into two sections, the first contextualises the necessity of changing cosmology for education, while the second provides a concrete proposal for the program, addressing challenges in content, methodology, and ethics. This article serves as a case study, aiming to be transposable to other design schools and highlighting the essential skills and knowledge required for designers to embrace a planet-oriented design approach.

1. Introduction

The new paradigms emerging from the Anthropocene (Crutzen and Stoermer, 2000) are challenging our understanding of the influence of human activities on the planet's processes and natural phenomena. A huge number of publications in various disciplines explain the urgent need for a profound shift in human perception and values for a more decentralised and sustainable way of living. So, how, and what to teach for a design adapted to the earth's new bio-geo-chemical regime? How to implement new teaching formats to better equip designers facing increasing challenges?

Future designers have the responsibility to design sustainable artefacts (viable, feasible, long-lasting, and socially desirable) that consider the environment and its limits. More than ever, they must mediate between different stakeholders and collaborate with other production professions (industrialists, engineers, developers, etc.). So, changing cosmology will call for new ways of thinking about design, limits, and leverages of designers in conjunction with the other disciplines. It also raises the question of the responsibility of design schools in preparing designers for the cross-disciplinary environment they will face in their professional path.

This article presents an initiative currently underway to transform the teaching model of a 5-year design curricula of a French industrial design school. The driving force behind the idea of a cross-curricular programme named “Sustainability by design” is the following question: How can we ensure that ecology is not an additional dimension of the design project but rather serves as a fundamental pillar? Therefore, the aim of this article isn’t to present a panorama of course results, but to sketch out the first milestones on the road to transforming the syllabus, so that ecology forms the spine of the curriculum, and consequently of the design process.

Even if this future programme shares many of the core beliefs of the Transition Design Approach developed at Carnegie Mellon University (Irwin, 2015; 2018; 2022), it is important to note that this programme is not intended as a specialization. It aims to add in the design process a holistic understanding of the relationship between humans and the planet, considering the Earth both as a physical entity and a complex system intertwined with human history and culture (Chakrabarty, 2019).
This article is therefore based on our school as a case study but is intended to be transposable to other design schools. It seeks to determine what invariants in terms of skills and knowledge all designers should have in order to move towards a planet-oriented design, i.e., that takes account of the planet as a system of systems, focusing not only on pedagogy—facilitating the acquisition of new skills and knowledge—but also on education, encompassing the execution of projects aligned with the values and ethics inherent to designers. Contents, formats, and ethics are thus the three categories of challenges to be addressed by a design school and constitute what this article seeks to enlighten.

To this end, the article is divided into two sections. The first explains and contextualises the need to change the cosmology of education, and then proposes a conceptual framework specific to design. The second section develops the programme proposal in more concrete terms. It is based on the challenges involved in making these changes in a design school and organized into four sub-categories: (1) new (and adaptable) contents, (2) a proposal of a strategy of implementation of these contents, (3) specific formats for design students’ profile, and (4) ethical positioning of the school through the hierarchization of values and a redefinition of assessment criteria.

2. Changing Cosmology: A Consensus for Education

A holistic understanding of the causes and effects of the Anthropocene (Crutzen and Stoermer, 2000) is necessary to have a multi-perspective overview of the Earth system. Considered as a dynamic network of relationships, an interdisciplinary vision of the planet allows designers to have a cross-scale approach, from the individual experience, passing through intermediary scales and different temporal consequences

to its planetary impact. It is the only way to find relevant answers to complex problems such as those we are facing and support a socio-technical transition.

Changing cosmology is clearly the first priority for students of all disciplines. It's about understanding how a world in which humans have evolved was created and how, as a humanity, we are now reshaping that world leading to uncertain futures. It involves updating educational content to align with the latest scientific discoveries and theories about the origins and evolution of the universe, and consequently the Earth system. This initial awareness enables students to envision a sustainable future for humanity within the Earth system. This involves integrating the science of global warming into existing subjects, taking into account other ecological disasters - biodiversity, pollution, etc. - as well as the principles of sustainability and the social and ethical dimensions of change.

2.1 From International to National Context

Meeting the challenges of the Anthropocene requires well-informed, committed individuals. Yet the complexity of climate change and other ecological challenges is still poorly understood by general population. In response, there is an emerging international consensus regarding the fundamental importance of education in addressing the ecological challenges that are being posed. Universities are intended to offer more space to develop essential knowledge and skills that allow individuals to contribute meaningfully to current challenges (Reimers, 2020; Leal Filho & al. 2021).

This consensus is obviously shared in France, which is moving from recommending to urging the universities to take action. In recent years, several recommendations on the transformation of higher education have been produced by non-governmental organizations or groups of researchers, such as *Campus des transitions* for various disciplines (Renouard & al., 2020) or *The Shift Project* in the field of engineering (The Shift Project & INSA Group, 2022) but also in finance, public administration, culture and health, examining also the issue of teacher training. At the same time, the French Ministry of Higher Education and Research (MESR) set up a working group comprising representatives from higher education, associations, businesses, local authorities and leading scientists in the fields of climate and biodiversity. Their report highlighted the urgent need to radically transform the French higher education system by adapting existing courses and, where necessary, creating new ones. In the short term, 100% of learners should be trained in the ecological transition. These changes must be developed based on a common foundation of five skills: understand the balances and limits of our world through a systems approach, grasping estimates and uncertainties through foresight analysis, elaborating shared diagnoses and solutions, using tools to bring about change and acting responsibly (Jouzel & Abadie, 2022).
Very recently, and based on these reports, the MESR published a set of specifications for all universities on how to integrate climate change education into formal education curricula including pedagogical teams training (MESR, 2023). The key point is that all bachelor's level students must have a knowledge base (of at least 30 hours) based on a scientific consensus with an interdisciplinary approach. It should cover climate change, biodiversity and its preservation, resources and their availability, as well as sustainable transition and social equity. The courses must be structured around action ("hands-on" projects, case studies).

Design schools are even more concerned by these transformations. Indeed, as a skills connector, and claiming the systems approach as part of their DNA, designers will have a crucial role in addressing the Anthropocene challenges. Sustainability has been integrated into design curricula already for several years. But a "subtle paradox" persists. Even if most design professors are fully convinced of the relevance of this issue, the assessment criteria for what makes a good design have not evolved enough in this direction (Ramirez, 2007). So, if "the task thus becomes the designing of the 'object of design' so that it, in turn, can design sustaining 'relations and effects', to which form, and function are subordinate." (Fry, 2009, p.187), what are the prerequisites for designers to adapt their profession?

Sharing the conviction that we need to change cosmology, and before presenting how the "sustainability by design" programme attempts to address this question, we propose to specify the conceptual framework chosen to think about the transformation of design and its teaching.

2.2 Mesology as Conceptual Framework for Design

In the French language, there is a distinction between two translations of the word environment: The first one, "*environnement*" refers to all the physical elements and phenomena that surround a living organism (including sometimes social and cultural conditions that surround the human). The second, "milieu" refers to all the material elements and physical circumstances that surround, influence or condition living organisms. Augustin Berque's concept of mesology is based on the study of "milieux" (in the plural form), which refers to the relations between all the elements that constitute the ecosystem and permit maintaining life (Bergue, 1996). Because it offers a better understanding of interdependencies between beings and the earth system, it is interesting to base the pedagogical programme on a mesological perspective to face the challenges of the Anthropocene. It means shifting our worldview from a world seen as an environment (something external we can change it without being affected) to a world seen as a *milieu* (both external and internal, shaping and shaped by the beings in it).

The philosopher Victor Petit breaks it down into two worldviews, each influencing a different approach to design:

> "In one case, it is possible to design 'ecologically' without compromising the standards of design; in the other, it is impossible. [...] In other words, to change the environment, all you have to do is change it, whereas to change the milieu, you have to change yourself (change your norms)." (Petit, 2015)

This change in norms requires a clear and well-enunciated ethical stance. This means redefining defended values and prioritizing them, and ideally in consultation with the people involved. A section devoted to this aspect, from a design school perspective, will be developed in the following section.

In addition, design practice can be more or less attentive to the living world: design that's indifferent to the living, design at odds with the living, or design in collaboration with the living (Pignier, 2017). So, when we talk about designing for the living, from a mesological perspective, it's not just about coming up with solutions for other living beings (even if it can be a part of this design), but designing for humans considering their "milieu" including natural, social, economic, and political environment. A milieu-oriented design has thus to consider living systems as both a starting and an end point. The concept of milieu also ties in with the principles of deep ecology laid out by Arne Næss. He introduced the idea of "ecosophy," a holistic and ecocentric approach to environmental philosophy that rejects the idea of humans as separate entities within the environment, favouring a relational perspective and recognizing the inherent worth of all living beings and ecosystems. Organisms are thus interdependent nodes in a network, and their identities hinge on their intrinsic relationships (Næss, 2017).

In this vein, milieu-oriented design plays a part in acknowledging the interconnectedness between humans and non-humans. It factors in the inclusion of humans in the living equation. Designing for and with the living is all about a milieu-focused design and requires designers to redefine our existence in this world as humans, redefining the boundaries of our influence and responsibilities.

Changing cosmology and adopting this conceptual framework raises several questions and challenges for design education. The following section presents a proposal of a cross-curricular "sustainability by design" programme incorporating recommendations emerging from scientific literature, various organizations' reports and official French government documents. It aims to initiate addressing the challenges in terms of content, methodology and ethics, corresponding to the three parts of the section.

3. Developing a Cross-Curricular Programme for Design Students

Starting from this conceptual framework, this section presents the three challenges underlying the development of a cross-curricular programme that allow design students learn about the physical constraints of climate change and integrate them in their milieu-oriented design process. First, the pedagogical contents up to date with the scientific research; second, the pedagogical formats which must provide a different learning experience appropriate to the design students profile; and finally values and ethics, which must be clearly formulated by the school and reflected in each project.

This article presents a framework for designing pedagogical progression (Fig.1). It has been thought out to allow design students to answer three questions progressively: (1) Where are we? (2) What can we do? (3) What is desirable versus what is really possible? Each question is paired with an objective to be reached in terms of knowledge (bringing by pedagogical contents) and skills to be developed (through experimenting different pedagogical formats): (1) Develop a sufficient and up-to-date scientific and technical culture, (2) strengthen the systemic approach and consider the global ecosystem (including technology) both as a starting and end point, and (3) Act for a milieu-oriented design (including all dimensions: biological, social, political, cultural, technical, economic, etc.), expressing its own specificity, values and ethical stance as a designer.

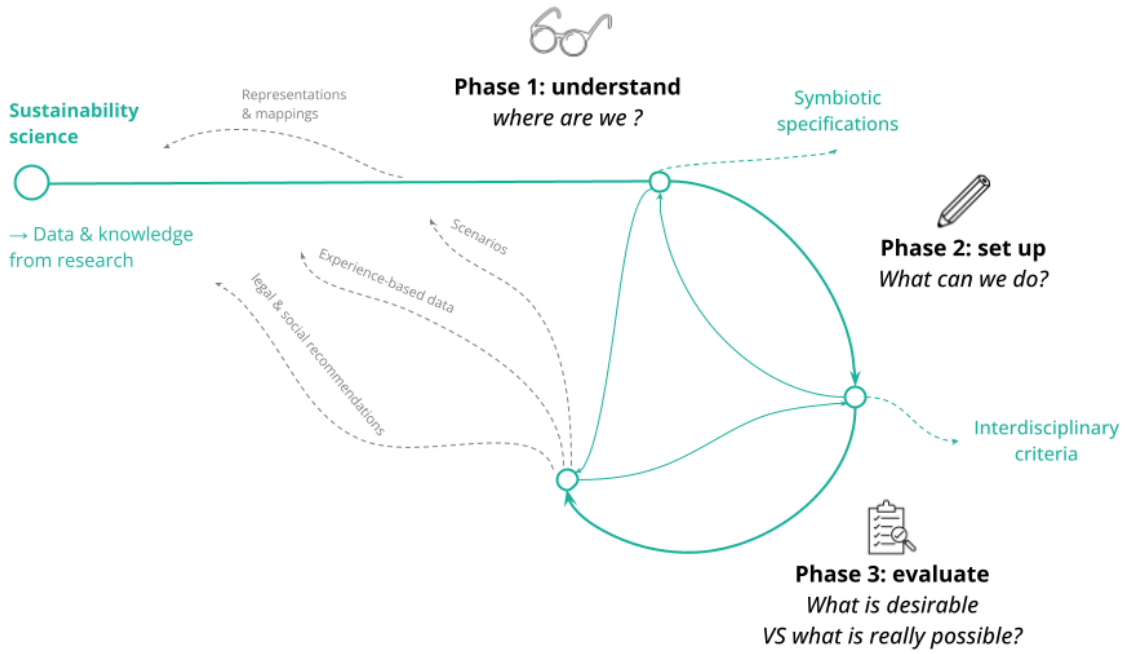

Figure 1. Pedagogical progression framework of the cross-curricular “sustainability by design” programme.

3.1 Pedagogical contents

The pedagogical content is based on inputs from sustainability science that bring together multi-perspective research from natural and social sciences, engineering and medicine (Clark & Harley, 2019). It is organised into three iterative phases: understand, set up and evaluate, which provide some of the answers to the three questions above (Figure 1). These three phases are interrelated and not necessarily chronological. As part of the project, the different inputs from each phase will enable the future designers to confront a reflexive process on several scales. This will develop the ability to zoom in and out, from the micro experience with the design artefact to its implications on a planetary scale, and vice versa, in designing from planetary constraints, helping individuals through the necessary transitions.

"*Where are we?*" Phase 1: Understand

In this first phase, the aim is to build an up-to-date scientific culture, backed up by research to include the latest established knowledge, particularly in the field of Earth System Science (including several disciplines such as chemistry, physics, biology, etc.).

Understanding well what is meant by the Anthropocene is crucial. Students need to know fundamental principles of living organisms (photosynthesis, biological cycles, biodiversity, etc.) and geo-biochemical cycles of the Earth system. Even if the current emergency focuses the debate on CO2 emissions and the measures to be put in place to decarbonise, it is important to have broader and more systemic considerations: criticality of materials, fossil/renewable energies, climatic trends by region, etc. This involves understanding materials, their classification and different potentialities, and the criticality of each material according to its characteristics and availability.

It is also very important to address concepts related to Anthropocene. Discussing several concepts as Planetary Boundaries (Steffen & al., 2015), "Technocene" focusing on the impact of technology on the Earth's systems and ecosystems, and "Capitalocene" highlighting the role of capitalism in ecological destruction (López-Corona & Magallanes-Guijón, 2020; Moore, 2017; Malm & Hornborg, 2014), is a way to understand how complexity of the current situation raises different questions depending on the disciplines and conceptual influences.

Moreover, to understand the planetary scale involved in developing any new product or service, designers need to understand the history that has made human activity the primary threat to the world's habitability for many species, including humans. So, it is essential that designers have a historical approach to technological development and its impact on the modification of individual needs, social organizations (political decisions, economic mouvements) and the Earth system dynamics. This includes a new, more global approach to history, including human civilization and the history of life and the Earth (Chakrabarty, 2019). The historical approach must also include the history of ecological struggles, as it informs about actions taken by various populations to face some climate change problems and the reasons for their success or failure.

"*What can we do?*" Phase 2: Set-Up

The second phase aims to connect knowledge with action. So, the courses should enable design students to circumscribe their limits and levers of action more clearly. With sufficient scientific knowledge to understand how living organisms and technologies work, new specifications that take into account the complexity of the Earth system are needed for the design project. The aim is to move away from technical specifications towards a kind of "symbiotic specifications" that encompasses the project in its "milieu", including material and energy resources, living beings and their (positive and negative) interactions with the socio-economic, legal and political systems in which they are embedded. So, an eco-design approach has to be redefined in the systemic meaning, as "it is not the object that must be 'eco-compatible', but the production-consumption system as a whole" (Petit, 2015).

And because changing the system entirely means coming up against regulations and administrative procedures, it is important training design students to deal with public policy. So, this programme includes a field project in partnership with local authorities, and preferably in collaboration with political science students to promote cross-fertilization of skills and prepare both of them working together.

Moreover, admitting the paradigm of interdependence between species opens up new avenues for designing methods with living organisms. So, the set-up phase therefore comprises two dimensions for reinventing the design process with living systems, to be applied separately or together in the project.

First, by learning from the way living beings use biological strategies to adapt their specific characteristics to an environment. Courses on biomimicry design can be a way to innovate about structures, materials,

energy efficiency…etc. But, using living beings as models and mentors (Stevens & al., 2019) must be coupled with a good scientific knowledge base (from the 'understand' phase) to avoid superficial or naive projects (i.e. that do "like nature" but with unsustainable materials).

Second, by designing for and with living systems. It requires reconsidering the human place in the whole system by building on ecosystem services. This approach aims at reinventing ways of collaborations between species, up to co-design with non-humans (Romani et al., 2022). This approach seeks to design, produce and recycle in a different way by integrating the 'know-how' of certain species (fungi, algae, bacteria, plants, etc.). As researchers work on the "intelligence" of living organism and their application to resolve some complex network problems (Poissonnier & al., 2019), the example of ecoLogicStudio project shows how architects involved a living being into their design process. Indeed, they trained an algorithm to behave as an acellular slime mould organism (commonly known as the blob) to redesign an urban network (ecoLogicStudio, 2021).

In fine, this phase provides skills to navigate complexity and find the way to act with living systems thinking from relationships between systems. Different ways and levels of actions can be experienced: changing trajectories by designing transitioning paths (Irwin, 2018), redirecting (Fry, 2009) or even dismantling and closing activities (Bonnet & al., 2021). Any design intervention needs to develop mediation skills to facilitate common understanding and debates between stakeholders to define the most advantageous, or at least the less harming, design intervention for all stakeholders, including non-human living beings.

"*What is desirable VS what is really possible?*" Phase 3: Evaluate

Recently, the designer Manuel Lima states that designers can no longer presume to deliver solutions without measuring their impact (Lima, 2023). He proposed to add an equally important third step to the double diamond design process theorized by the British Design Council. So, the third block of courses in our programme is a response to this 'third diamond' imperative. Design students need to learn how to assess the relevance of a project within its "milieu" by defining success metrics (impacts on the natural elements, climate, biodiversity and anthropological effects). Also, they do project these impacts over the medium and long term. Evaluation phase courses are obviously related to the knowledge acquired during the understanding phase, as it requires a solid grounding in physical and socio-cultural reality.

In other words, making the right assessment is a question of projecting into different futures and then coming back to the present to iterate on the project.

Moreover, visioning a sustainable world has the power of motivating us to reach this potential future. In 1993, Donella Meadows was already suggesting the use of visioning as a driving force to believe that radical changes are possible, and then to lead it (Meadows, 1994). So, as she said, "children are natural visionaries", design students have to re-learn visioning. In the Transition Design Approach, the ability to project futures from present data is an essential skill to improve for designers. This capacity of having a future vision where the problem is resolved is an important step to imagine a transition pathway with multiple design interventions (Irwin, 2015; 2018). So, to develop their ability to navigate between different timescales of a single problem and to project a multitude of potential scenarios, all designers must be trained with both foresight and design fiction methods. The foresight method enables students to reframe a problem at multiple levels and scales looking at the connections between people, problems and things (Irwin, 2018) while exploring short-, mid- and long-term effects of interrelated solutions. In a complementary way, design fiction allows students to generate a wide range of utopian and dystopian scenarios to hypothesize and ask questions about the transformation of values, beliefs and practices and their consequences. Moreover, the artefacts designed can create a communication situation so as to make people debate about desirability (or not) of future scenarios (Mollon, 2019). Integrating design fiction will therefore develop the mediation skill of designers. This skill is becoming increasingly necessary, as effective transitions are so closely contingent on collective decision-making.

To summarize, table 1 below presents the essential courses in this programme and how they correspond to the skills needed for the ecological transition identified in the two documents from the Ministry of Higher Education and Research (Jouzel & Abbadie, 2022; MESR, 2023). It is important to notify that this table is not a proposal of a pedagogical mockup in itself, but a theorical model that can be used as a guideline for improving, reorienting and implementing courses.

Table 1. Courses and associated skills of the cross-curricular “sustainability by design” programme.

Question to be answered	Where are we?	What can we do?	What is desirable versus what is really possible?
Phase	Understand	Set-Up	Evaluate
Courses	Introduction to Anthropocene and related concepts (technocene, capitalocene, planetary boundaries, etc.) Fundamental principles of living organisms (photosynthesis, biological cycles, biodiversity, etc.) Resources: materials & energy (classification, uses, recyclability, etc.) History of technological development and socio-economic effects History of ecological struggles	Governance models Workshop with local authorities Changing trajectories (transition, redirection, dismantling, closing) Design & biomimicry Design with living organisms	Foresight Fictional writing Design fiction
Associated skills	Consider a systemic approach and be aware of scales (local vs. global)		Developing a forecasting analysis
		Co-building diagnosis and solutions (mediation, facilitation, co-design)	
	Knowing how to implement transitions (realism, technical and organizational feasibility)		

To ensure the success of a transformation, we need to reach a unified agreement on the core elements of sustainability that must be incorporated into the curriculum for training designers. According to literature review and discussions within the school, there is common agreement on the relevance of modifying design education in this way. However, the way in which this material will be shared with students is still under discussion. The following section attempts to address this challenge by identifying emerging initiatives from which to continue building our cross-curricular “sustainability by design” programme and its deployment.

3.2 Implementation Strategies

Based on the theoretical proposal of pedagogical contents and a first overview of pedagogical formats that may be suitable to design students’ profile, the implementation strategy needs to be developed jointly with all the school's pedagogical supervisors. To do so, we have identified a number of key actions to be implemented progressively. Firstly, we need to carry out an analysis of existing courses. Then we need to study the possibility of redirecting the content of certain cross-disciplinary courses (such as storyboarding, writing or human and social sciences) towards ecology-related content. Next, we should experiment with setting up joint projects between these courses and the representation courses (such as sketching or prototyping). Finally, either simultaneously with the previous stage or afterwards, we need to add the necessary new specific courses (such as scientific culture or historical approach of ecological struggles).

So as a first step, an inventory of existing courses dealing wholly or partly with sustainability issues was conducted (see table 2). To compile this inventory, a 30-minute interview was held with each pedagogical supervisors (common core first years, product design, interior design, brand design, ux design, transportation design). As well as a design project, it's essential to determine what content had already been introduced, to explore the desire for new pedagogical developments, as well as the gaps and difficulties in deploying specific content or formats. It is also useful to start involving the pedagogical supervisors to co-build the strategy of deployment of this programme.

Table 2. Inventory of existing courses dealing wholly or partly with sustainability issues.

Year	Courses dedicated to ecological issues	Courses partially addressing ecological issues
First year	"Climate Fresk" workshop	Biomechanics Upcycling (or) make mycelium (or) experimental cooking Workshop*
Second year	Design & naturalistic immersion	Biomechanics Mapping Tools
Third year	Eco-design (systemic approach) Eco-construction/Eco-production (introduction to materials, carbon footprint, reparability, assembly & disassembly) Neo-industrial workshop Technical culture	Human and social sciences Lighting
Fourth year	Eco-design (systemic approach) Eco-construction /Eco-production Design in territories Industrial upcycling	Human and social sciences Projects in partnership with an organization
Fifth year		Projects in partnership with an organization

*These workshops are optional, so will only involve some of the students.

Table 2 aggregates all courses in the school. It should be noted that there are still disparities regarding courses and hours, depending on the design discipline. Moreover, from the fourth year, a major part of the courses is project-based, usually in partnership with organizations. So, the ratio of pedagogical time devoted to ecological issues is hard to measure as the content depends on the brief of the partner companies. Questions raised by this model of teaching through partnerships will be addressed in the section relating to the ethical challenge. Some other identified limitations relate to problems beyond the teacher or the school's scope. Interviews revealed frustrations linked to the limited levers of designers, such as infrastructures, business imperatives, outdated regulations, and too restrictive norms about some materials. Such restrictions sometimes inhibit alternative solutions deployment as reuse-based design, for example. This highlights the fact that technical skills alone are not enough to deal with complexity and confirms the need to train all designers in political issues so that they can anticipate, support, or take part in the transformation of public policies.

The initial actions to prepare for the implementation of the cross-curricular "sustainability by design" programme has also raised a number of issues in terms of the school's ethical positioning and its influence on the speed of deployment. This will be discussed in the "ethics challenge" section trying to address some of these questions but above all, its aim is to initiate a discussion that concerns design as much as other disciplines.

Following the inventory, the second stage of the implementation strategy is underway. We have therefore identified certain course formats to be adapted to the theoretical content (table 1) and investigated innovative formats that might be worth deploying. The following section presents several pedagogical formats that need to be supported, developed, and used as inspiration for other courses.

3.3 Pedagogical Formats

According to the UNESCO report on climate change education (2019), cognitive learning is favored over social and emotional or behavioral learning. However, it has been shown that in order to influence attitudes and behaviors, climate change education should be based on deeper learning because didactic approaches focused principally on the transmission of scientific knowledge do not (Reimers, 2020). This is even more important for disciplines such as design, where knowledge is based on practice. Indeed, it is important to adapt scientific content, which is sometimes highly technical, to pedagogy based on practice and projects. How can we preserve the specific characteristics of designers while providing them with the scientific knowledge they need to practice their profession in a constrained future?

In the beginning of their first year, students take part in a *Climate Fresk* workshop, a collaborative and science-based workshop, mostly from the IPCC reports (climatefresk.org). Its methodology is based on mapping the causes and effects of climate change about a specific object or problem to enable participants to have an open and positive conversation about climate change and imagine some solutions. It's generally animated by older students trained as facilitators by the organization that creates this workshop. This first step is seen as an introduction and an awareness-raising exercise rather than a course. Adding the *2tonnes* workshop (en.2tonnes.org) to the "sustainability by design" programme is also planned. This workshop, designed as a serious game, will provide an understanding of the individual, collective and influential levers for achieving concrete reductions in CO2 emissions, on the individual and the national level. It will help first year students move on from mapping problems and potential solutions (experienced in the *Climate Fresk* workshop) to taking decisions on concrete actions to implement.

In 2023, another experiment at the start of the academic year involved the whole school. All the students took part in a design fiction workshop, in partnership with a reference consultancy firm regarding energy and climate challenges. Each group dealt with a use (clothing, food, housing, transport, healthcare, transport, information, entertainment) that was constrained by a model of society, a trajectory for global warming (from 1.5° to 3°) and a state of biodiversity. The aim was to imagine what life could be like in 2060, informed by several scientific studies.

Another example of a course to consider for its format. In response to the need to combat "environmental amnesia" (Kahn, 2007), the "*design & naturalistic immersion*" course offers an off-campus format that immerses second-year students in a direct relationship with living things. Combining knowledge of biology and design tools, the teacher takes advantage of a walk in the forest to explain the fundamentals of photosynthesis and the biological cycle. The students are invited to take notes by sketching, collecting elements and creating maps. This methodology permits a concrete and powerful insight into the 'others' who inhabit the world and on whom we depend. Similar initiatives are in the process of co-design with some professors before being implemented.

Understanding how we reached the Anthropocene also involves learning the tools for diagnosing a complex situation. As well, in addition to the courses to be incorporated (for phase 1 understand, Table 1) a large part of the courses focusing on developing reading and writing skills will be devoted to ecology-related themes. So, courses such as sketching, storyboarding or narrative writing are meant to be reoriented to address sustainability topics. During those courses, design representation skills will be used to extract and organize data from scientific papers and reports. For example, in the reading course, students will have to read the latest IPCC report and extract data that will be used during both narrative writing and sketch courses to describe the process of a research project and represent its results using more easily accessible media. It implies a new kind of coordination between teachers of different disciplines.

Once the contributions of scientific disciplines to the teaching of design have been discussed, it is important to note that design methodologies can also provide valuable contributions to the scientific community (see figure 1). Indeed, in their process of understanding, designers do not reproduce knowledge in the same way as researchers, science journalists or popularisation specialists, but provide their own expertise through their sensitive interpretation of the world. Formalised into models, visualisations or maps, these contributions can enrich scientific productions by making data tangible. This helps first in making complexity legible and apprehensible. Creative media used by designers are useful for researchers to popularise and spread knowledge that can be understood by a wide audience. Secondly, the designers' methods of fieldwork provide an enrichment of the research with sensitive data derived from narratives and illustrations of real-life experiences. Ultimately, this can shed light on blind areas or highlighting links that were previously undetected due to the hyper-specialisation of research disciplines, thus inspiring the exploration of new fields of research. Design can consequently play a role and be one of the disciplines contributing to sustainability science.

3.4 Ethics Challenge

If the question of sustainability is limited to the preservation or restoration of conditions favorable to human life, to a matter of subsistence (Fry, 2009), then design should only be assessed through the materialistic prism of what it produces and destroys. Yet the symbolic dimension is just as vital to human life, as it conditions our being-in-the-world, and therefore our use of its resources. Thus, we need to change preconceptions about what comprises good design including all those dimensions of habitability: physical, psychological, socio-economic and spiritual (Findeli, 2022).

One of the major challenges in terms of ethics is therefore to reconsider the project evaluation system and redefine what comprises good design. If we consider a new framework for assessing projects, what balance should be made between criteria that are strictly material and criteria linked to experiential benefits?

Currently the evaluation criteria focus more on the acquisition of skills and respect of the design process steps. Sustainability can have almost a similar value to form, functionality, user-friendliness and other criteria (Ramirez, 2007). Instead, a new multidisciplinary evaluation grid must be established. The physical aspects of the project should be systematically assessed, i.e., the level to which the project has addressed the impacts of the entire value chain (supply & production chain). In addition, the social implications of this physical aspect also need to be considered, i.e., the social effects of the potential extraction of natural resources or the waste management involved. Thus, the courses in the evaluation phase will also contribute to this ethical positioning of the school visible through a project-wide scale. This aligns with the idea of introducing the third diamond in the design process (Lima, 2023). In this case, students will then have to present, with each project, a mapping of all these aspects, similar to what they do regarding business issues, for example.

The school's values are also reflected in the collaboration model it establishes with organizations for pedagogical projects. Training models based on partnerships with companies, like that of our school, is highly beneficial for both companies and students. But, in a world where dominant industrial paradigms are no longer sustainable, it raises several new questions about ethical stance: as a school, should we assess the maturity of companies on this topic before setting up a partnership? Should we select only those that are clearly committed to the ecological transition? Or should we decide to redirect the briefs so that the projects provide a deeper understanding of the sciences of sustainability?
Those questions are still discussed between pedagogical staff and students.

4. Conclusion

"The designer of the future is a mix of psychologist and anthropologist, sociologist and ecologist, system theorist and futurist, activist and reformer" (Lima, 2023, p.197). In the conclusion of his latest book, the designer Manuel Lima came to the same conclusions as many of us. As a design school, we therefore have a responsibility to cultivate all these facets of the designer of the future, in addition to provide a scientific knowledge to understand Earth system and technologies on which humanity depends.

The cross-curricular programme "sustainability by design" presented in this article has been designed accordingly. Drawing on the etymological definition of ecology as the study of relationships between living organisms and their physical environment, this programme is aimed at making ecology the driving principle behind the design process. It is based on three iterative phases: understand, set up and evaluate, enabling future designers to link knowledge to action.

To get started, based on the recommendations of the scientific literature, as well as those of government institutions or teachers, the most urgent thing is to strengthen the foundations of fundamental knowledge in the first three years, so that design students can then put their knowledge into practice and experiment as early and as much as possible during their studies. The main objective is to provide them with operational skills to address different levels of change (behavioral, organizational and political). The "sustainability by design" programme outlined in this article is a proposal of the pedagogical progression over a five-year curriculum. However, even if it has been conceived as a cross-curricular programme, it must be adapted according to the specific needs of each design specialization (product design, interior design, brand design, UX design, transportation design…).

This contribution has three aims. Firstly, to join the international scientific community in emphasising the urgency and necessity of changing cosmology, which implies changing content and methods of transmitting information. Knowing that this knowledge is recent and growing, and that some of it remains unknown, raises new questions in scientific research and can enable design to contribute concretely to research into sustainability science.

Secondly, to propose a framework for building a cross-curricular programme meeting the challenges of transforming design education in a French Industrial Design School. This framework is associated with a proposal of a strategy of implementation that would allow this framework to be generalized to other design schools. As a perspective, it would also be interesting to test its adaptation to other disciplines.
In fine, if we follow the principles of living systems, collaboration is one of the strategies that can ensure the survival and evolution of a system. This contribution is thus intended as a way of initiating a dialogue to connect design schools and share best practices on implementation strategies and ethical positioning.

Let's remember that the human origin of the alarming situation we are collectively experiencing can be seen as good news, because we still have the power to change it. The near future can therefore be seen as an enthusiastic period because there are so many things to reinvent, and designers have an important role to play in supporting these multi-level transformations.

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