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Descriptive study of the integration of sustainability through the doughnut in an engineering training material

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Abstract

We need to integrate socioecological issues into our activities. Engineers and designers need to develop competencies in sustainability, but it exists a lack of support in an academic context and for the training of professionals. The aim of this article is to demonstrate that the Doughnut is a support for developing sustainability competencies. In the literature, these competencies are identified and pedagogical experiences on their integration in engineering curricula are reported. We use the doughnut in a workshop as an element of understanding and developing competencies for sustainability.

Keywords: design education, sustainability, design competences, doughnut, training material

1. Introduction

Education for sustainability is an urgent concern. As engineers design technologies and actively engage in industrial activities, their education in sustainable design is crucial (Meyer and Norman, 2020). Furthermore, as products become increasingly interdisciplinary, they will need to have a greater awareness, better understanding, and increased operational knowledge of sustainability and ethical responsibility in the context of design (Isaksson and Eckert, 2022). As briefly described in Grimal *et al.* (2021), there are two different bodies of work: 1) research on the importance of integrating sustainability into design engineering education, as well as the core skills to address (Abd-Elwahed and Al-Bahi, 2021; Perpignan *et al.*, 2020) and 2) a descriptive study of experiences in education for sustainable engineering. We have chosen to be in the second category. Also, as university programmes need to be open to experimenting with unconventional teaching methods capable of providing practical and theoretical knowledge, skills and competences to address sustainable design engineering challenges (Valderrama Pineda and Niero, 2020), our aim is to design and test a training material based on the 'doughnut' model developed by Raworth, which combines environmental issues and social justice. We have built a workshop that connects social thresholds and planetary boundaries with design issues through technical and economic choices to make a product as sustainable as possible, taking into account its complexity. Additionally, we have based our work on the competences described by (Quelhas *et al.*, 2019) to create an analysis framework for the skills developed during this training material provided to students and professionals. We have chosen to address this training material to both students and professionals because, as (Isaksson and Eckert, 2022) argue, we believe that as technology and work practices evolve, engineers must acquire new skills and evolve throughout their careers. Based on the results of the experiment, our article discusses the skills developed by the workshop participants, as well as the limitations we encountered.

2. State of the art

Universities play a significant role in shaping tomorrow's leaders, starting today. As we approach 2030, the importance of realizing the 2030 Agenda has become increasingly paramount for universities emphasizing sustainable development as a key area of focus. This entails stressing the necessity of integrating the Sustainable Development Goals (SDGs) as fundamental values and principles in both education and daily activities. Consequently, we believe that the donut economic model has a role to play in educating students about these issues, as it incorporates the SDGs but goes further by questioning economic growth (Cook and Davíðsdóttir, 2021). Kate Raworth's "Doughnut" refers to an alternative economic model known as "Doughnut Economics" (Raworth, 2012). Kate Raworth, a British economist, developed this approach to rethink the economy in a manner that makes it more sustainable and equitable. The Doughnut model is built on the idea that the economy must evolve while considering:

1. Planetary Boundaries: These boundaries represent environmental limits beyond which human activities cause irreversible damage to the planet. They include elements such as climate change, biodiversity loss, air and water pollution, overuse of natural resources, etc.
2. Basic Human Needs: These needs encompass access to food, clean water, education, healthcare, decent housing, fair working conditions, etc. The goal is to ensure that all humans have access to these fundamental needs.

The Doughnut graphically represents these two boundaries in the form of a donut. Inside the donut are the basic human needs, and outside are the planetary boundaries. The objective is to maintain economic activity at a level that stays within the donut, meaning it meets human needs without exceeding environmental limits (Raworth, 2012). The concept of Doughnut Economics has garnered increasing interest among economists, policymakers, and activists because it offers a holistic perspective on the economy that takes into account both environmental and social aspects of sustainability. However, certain limitations are identified. Biermann and Kim (2020) highlight the limitations of the planetary boundaries approach. Beyond the "calculative" part of the methodology, they emphasize its lack of applicability. Planetary boundaries are, by definition, global, at the scale of the Earth system. However, in daily life, we often think at smaller scales, such as the territorial scale of a country or city, for example. In these cases, indicators must be adapted. This raises questions about the relevance of these global indicators, which may reduce to factors like population (see O'Neill *et al.* (2018) for an application at the country level and Doughnut Economics Action Lab, (2020) for a city-level application, or Parsonsová, (2021) for national-scale methods and indicators). The same problem arises at the business level: Clift *et al.* (2017) identify four key research elements for applying planetary boundaries in business decision-making. The points addressed include the issue of scales: global and local may not always be relevant. In fact, as described by The University of Cambridge Institute for Sustainability Leadership et Kering (2019), reducing planetary boundaries to territorial scales is highly complex. As for social thresholds, they are based on United Nations studies.

Nevertheless, the Doughnut is used in education because it can introduce the concepts of sustainable development (Everett (2022) and social justice (Boehnert, 2018; Hosseini, 2023). Indeed, the donut is a simple and easily understandable image that visualizes the two goals of donut theory (Boehnert, 2018). For example, the donut model provides geography students with a means to explore the links between economic, social, environmental, and physical aspects of geography (Filho and Hemstock, 2019). As they progress, students gain a deeper understanding of how economic activity can influence not only humans but also physical systems. This is achieved through their immersion in a more comprehensive and complex analysis of processes, an approach that differs from more traditional geography programs (Filho and Hemstock, 2019). It can also promote critical thinking. Indeed, the donut can be used to question dominant economic models and propose more sustainable alternatives. Finally, it is used to promote action and inspire students (and others) to act for a fairer and more sustainable world. Kate Raworth's website and the Doughnut Economics Action Lab (DEAL) website offer educational resources, including online courses, activities, and tools (« Doughnut Economics Education: A Teacher's Guide | DEAL » 2020). The donut is used by the Schumacher College, notably in the Ecological Design Thinking (EDT) program (Teglborg Ashworth *et al.*, 2023). Students examine projects from the donut economics lab and how they put theory into practice, especially in a community

context (involvement in a co-design process, facilitation, community empowerment, etc.). DEAL has also created an educational tool called "Doughnut Unrolled." Its purpose is to explore four "perspectives" of the donut, inviting examination of the interaction between local aspirations and global responsibilities in the chosen location, both socially and ecologically, and identifying potential entry points for transformative action. It is notably used in various countries with communities (« Unrolling the Doughnut: Professionals Community | DEAL » 2023). They have also developed a tool tailored for businesses looking to evolve their business models. The competencies developed correspond to those expected to address the issues of sustainability according to (Quelhas et al. 2019). The *Table 1* intitled "**The competencies developed during the workshop**" is available online: <https://zenodo.org/doi/10.5281/zenodo.10667018>. Despite the interest in the Doughnut for design virtuous company (Sahan et al. 2022), as well as the promotion of donut-centred design, which combines service design and ecological design (Golias, 2019), we have not found a pedagogical example where the donut is used as a tool to develop the competences for sustainability of engineers, whether they are students or professionals (column B of the *Table 1*). To make up for this shortcoming, we propose to develop dedicated training material. This will be developed in the third part of this paper.

3. Methodology

3.1. General methodology

To address our research question in this paper, which is whether the donut can serve as a support for developing sustainability competences among engineers, we proceeded by constructing a training material that can be tested on both future engineers and those already in practice. Indeed, we believe that education is an ongoing process throughout the life (Laal and Salamati, 2012). We chose a workshop format because it allowed us to offer it to both students and professionals. The training workshops were designed following (Kirkpatrick and Kirkpatrick, 2014) ten-step systematic process for developing training workshops ((1) identifying needs, (2) setting objectives, (3) determining content, (4) selecting participants, (5) determining the optimum timetable, (6) selecting the necessary equipment and facilities, (7) selecting a qualified trainer, (8) selecting appropriate audio-visual aids, (9) coordinating training workshops, (10) evaluating training workshops). In agreement with Dunberry and Péchard (2007), this process was chosen for its acknowledged reputation in the field of worker training and for its simplicity. The design and content of the workshop is detailed in the following subsection. We ran the workshop with several groups of students and one group of professionals. After the workshops, we evaluated the participants using questionnaires and then, about two months later, we conducted interviews based on these questionnaires to report on what they had learned during the workshop.

3.2. Conception and presentation of the training material

The pedagogical module presented and tested in this article is a training material entitled "understanding the issues of sustainability - introduction to the use of the "doughnut". The aim of this training material is for the learners to appropriate the Doughnut proposed by Raworth (2012) to use it as a design framework to integrate ecological and social dimensions into existing design methods, within a restricted time (3 hours). Therefore, the "doughnut" is one of the key concepts of the workshop.

We are particularly interested in the upstream phases of design, which are not only easier to deal with in a training context ("high level" choices to be made), but also constitute an important lever for introducing sustainability issues (Dewulf and Duflou, 2004; Ibáñez-Forés et al., 2014). We consider through this training workshop that the participants learn to integrate an additional dimension of complexity within the framework of a design which wants to be sustainable. In this upstream design phase, our aim is to get participants to think about the different possible product concepts and their socio-ecological impacts. To do this, we need to compare these different concepts in terms of the different criteria for the doughnut, which are not directly comparable. In this sense, on the one hand, the workshop brings us closer to strong sustainability, which is characterised by the non-substitution of capital, whereas weak sustainability allows substitution (Pelenc et al., 2015). On

the other hand, we come to consider a much broader concept of value than its financial connotation. Indeed, the concept of value is used in many fields and is a polysemous concept (Ben Ahmed and Yannou, 2003). However, it remains a concept connoted as being of a financial nature in the business world. Our framework is value-based management (NF EN 1325:2014-04, 2014). It is defined to compare (balance) the satisfaction of the needs of the stakeholders of a product/system with its cost. The aim of the workshop is to demonstrate the value of taking a broad view of a project's value in relation to the concept of sustainability. Thus, the two combinations of this concept allow us to demonstrate that the technical and financial capital mobilised in a Value Management approach is not sufficient to characterise all the dimensions of Value (need to introduce social and ecological dimensions) in a product/system design project, and that this capital cannot replace the other. This is why strong sustainability and value analysis are part of the initial presentation of the workshop made to address, the competencies listed (column C).

The training workshop took place in French with documents in English. The synchronous format was a choice from the very beginning of the course design: it permits us to understand and evaluate the Sustainability competencies developed. We chose to make groups of 3 to 5 people on average to study their behaviour during the workshop. The proposed workshop conducted:

- An introduction to the workshop and the context (need to integrate Stakeholders and socio-ecological dimensions), 15 minutes.
- A short presentation of the different concepts (Value, Sustainability, Doughnut), 15 minutes.
- Getting to grips with the Donut: how to design a bike that is sustainable? 1.5 hours. The aim is to familiarise the participants with different documents to decide which of the 5 bikes on offer (wood, cardboard, carbon, etc.) to choose to have a sustainable bike. To compare these bikes, we added a common reference, an all-aluminium bike made in China. A definition of the Doughnut and a presentation of the different bikes can be found in a technical file given to the participants. For the bikes, there is a list of stakeholders, a functional analysis, and a financial analysis, as well as a list of technical solutions (materials, country in which the stages of the life cycle take place, design technology) and some estimates for the quantity of CO₂ emitted during the design of the bike. The aim is to determine which bike seems the most sustainable based on these elements and to justify it so that it can be discussed during the exchanges.
- Debriefing and workshop evaluation questionnaires, 1 hour.

3.3. Test of the proposed workshop

Three variables seemed important to us for conducting the workshop evaluation in relation to our objective: (1) learners' perception of the training workshop, (2) learning outcomes achieved, and (3) behavioural changes. Indeed, we choose to design a workshop evaluation questionnaire and to complete it with interviews on the second part (see figure 1). This questionnaire was constructed according to the recommendations of (Dunberry and Péchard, 2007; Lee and Pershing, 1999) which allow us to evaluate not only the content of the workshop, but also the workshop itself. It is also interesting to assess at t+2 months whether these skills are still 'active'. In fact, the literature shows that the assessment of skills should be carried out immediately after the workshop, but also after a certain period (t+2 months) to take into account the real acquisitions made during the workshop, as discussed in (Dunberry and Péchard, 2007; Lecours *et al.*, 2017), based on (Kirkpatrick and Kirkpatrick, 2014) on behavioural change. The document that the participants had to fill in at the end of the workshop consisted in:

- A short summary of the workshop to see what the participants had retained from the workshop.
- Questions on the different key concepts of the workshop.
- Questions about the workshop (time, facilitation, atmosphere, difficulties, etc.).
- A self-assessment of the competences developed during the workshop.

Participants must self-assess the competencies developed through the workshop. This stage, in which participants respond to the questionnaire, corresponds to stage 1 of the assessment (see Fig.1). Stage 2 consists of an interview about the competences developed. We asked participants if they still agreed with their previous answers or if there had been a change and why.

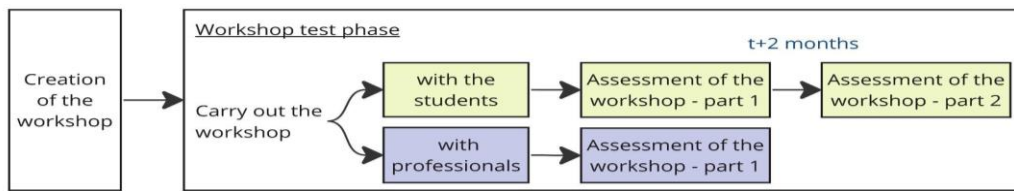


Figure 1. The different steps of workshop design and testing

It should be noted that there were no individual interviews with the professionals. In fact, they were surveyed to plan the interview, but despite several reminders, only one of the 11 people contacted returned a reply. We therefore decided not to schedule an additional interview, which would have been difficult to use (no comparison of feedback).

During the development of the *Table 1*, we identified only 6 of the 8 macro competencies mentioned by Quelhas et al. (2019) as potentially developed (column C) during the training material. These competencies were evaluated by each of the participants through a set of questions and indicators. The questions were “Do you think you developed these competencies during the workshop?” (Q1) and the respondents could answer yes or no, a little, I do not know. For unanswered questions we put “NA” (not applicable). On the one hand, the training workshops were open to the “IMEDD” masters (“Ingénierie et Management de l’Environnement et du Développement Durable”) of the University of Technology de Troyes, with a total of 19 students present (2 sessions of 10 and 9 students divided into groups of 3 or 4 people). These students are interesting because they have a variety of profiles (designers, managers), but they are also students involved in a complete curriculum geared towards sustainability. On the other hand, we have chosen to test this format in other frameworks with professionals of project management: 11 people were divided into 2 groups (2x3 persons) in the first session and the workshop was conducted with all the 5 participants in the other case. The advantage of this test is that it is aimed at people who are either invited (5 people) or obliged (6 people) to take part, and in this context their overall interest in the workshop was limited. We will describe in the next section the results before discussing it.

4. Results

The results described hereafter are based on data: <https://zenodo.org/doi/10.5281/zenodo.10040799>.

4.1. Results of the test on students

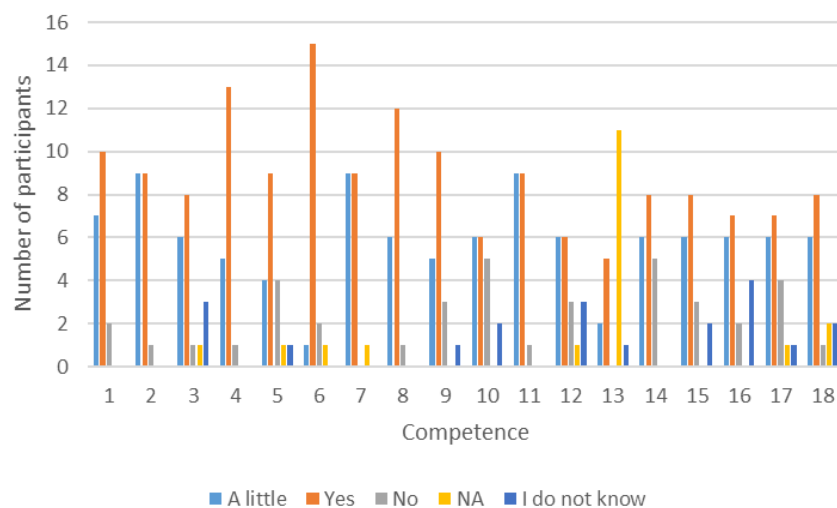


Figure 2. The results for the competencies according to the IMEDD students

In the first group, with 9 respondents (162 responses), we have 23 “no” and 6 “I don’t know” responses to (Q1). It should be noted that for skill 13, the display of the skill was partly erased in the questionnaire, which makes it difficult to use the data concerning it. We therefore excluded this one from our reasoning: it gives 153 responses with 23 “no” and 6 “I don’t know”. We obtained a positive response in 81% of

cases. In the second group, with 10 respondents (= 180 answers), we have 16 "no", 14 "I don't know" and 13 N/A. The response was positive in 76% of cases. We can say that the most developed competencies in this workshop by the students are those that correspond to the macro-competencies: critical thinking, working in an interdisciplinary group, problem-solving, and systemic thinking. Normative competence and self-awareness are the most challenging yet.

4.2. Results of the test on professionals

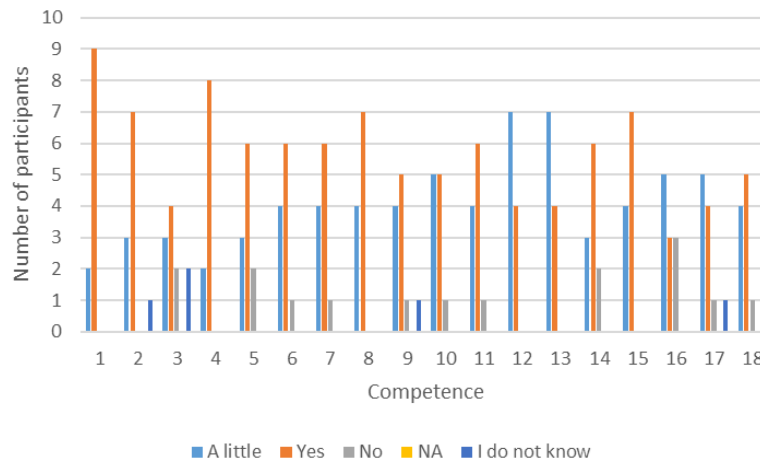


Figure 3. The results for the competences according to the professionals

For the professionals, we can see that the participants consider that the workshop enabled them to develop most of the targeted competences: with 6 respondents, we have only 5 "no" and one "I don't know" to (Q1). The response was positive in 94% of competences. In the other workshop, the participants were in the same frame of mind with 5 respondents (= 90 answers), we have 11 "no" and 5 "I don't know". With these figures, the response was positive in 82% of cases. As with the students, we also observe that the macro-competencies that are most difficult to develop in the workshop are normative competence and self-awareness.

5. Discussions

5.1. The interest of the competence acquisition pathway

In the field of design, sustainability raises challenges today. The aim is to train both engineers and managers to develop common competences and facilitate exchanges between professions and generations. Our workshop is dedicated to future engineers as well as experienced engineers/managers. The training, which takes the form of a workshop designed to enhance understanding of the issues through real-life situations, has helped to develop a significant proportion of the targeted competences for most participants. However, we found that some competences were more difficult to develop than others (normative competence and self-awareness). We are going to focus on these. One of the hypotheses we have on this result is that these competences are less developed in this type of profession and require more time to understand and develop. [Student C] - "I think that at that time, I was telling myself that I hadn't mastered the tool [the framework of the doughnut] yet. As I didn't feel capable of trying to negotiate with people to explain to them why it's interesting, since I didn't fully understand the tool". The students, who were less confident in their responses than the professionals, still felt that they had developed their competences during the workshop. Conducting interviews after two months has confirmed their initial choices and even led to further progress in certain competences. In fact, we have observed that some students tried to apply the doughnut concept to eco-design projects that are part of their curriculum in the IMEDD Masters programme. We have also observed that the Doughnut seems to be a stepping stone for the students rather than an end in itself: [Student A] - "I think it's still relevant [the doughnut]. Even if all the indicators used seem somewhat detached, in a very specific context, it does provide quite a comprehensive view of the social and environmental challenges of our time. So, it

can be quite helpful to have this list, and then consider how and whether the action will have an impact". [Student B] - "I think it does change the way we see things. I find that it does a good job of connecting planetary boundaries with the social aspect. It's something interesting". [Student D] - [What are you using the doughnut for in this course?] "Overall, considering really everything, all aspects, perhaps even social and 'costs,' since we are focusing on ecological aspects, because these are aspects that we tend to overlook when engaged in pure and rigorous design. As engineers, we tend to forget these themes that are present in the Doughnut". The Doughnut serves as a platform for exchange, discussion and exploration of sustainability issues from a particular perspective: [Student C] - "We tried to take the doughnut and see how we could be 'in the middle' for our project: all the ideas we had, making sure they could be both environmentally and socially beneficial". This raises the question of competence acquisition in a professional environment where sustainability is not the core business, and how these essential competencies can be developed in this context. While the professionals appear to have developed their competencies, we were unable to determine whether there was any reactivation of the competencies and knowledge acquired during the workshop. This is one limit identified in this research.

5.2. The adaptation of the indicators from the Doughnut

Adapting the Doughnut indicators (with a territorial input) to a system represents a major challenge. The problem raised by the participants concerns adapting the indicators presented in the Doughnut to the scale of the system: [Student E] - "I find that it really highlighted the difficulty of using it [the doughnut] in practical terms, and I see quite a few challenges. These indicators of planetary boundaries or social thresholds, they are on a global scale. It's quite challenging to focus on a product, a concept, or a system. It's true that we reused it, but we used it somewhat randomly. But since these are quite global indicators, it's challenging to use". In fact, the system is broken down into sub-systems which are localised (country) to allocate a social and ecological impact. This method seems to apply to a bicycle, but we might wonder about it for a system that is not easily localised (or certain phases of its life cycle), such as a plane. We can hypothesise that the logic of framing the needs of the Stakeholders of the project could more explicitly frame the indicators to be used in the Doughnut. Rather than proposing a list, as suggested by some participants, and based on Visentin *et al.* (2020), we suggest working on the interface between the needs and the Doughnut to help the working group determine the indicators to be contextualised and understood. This point seems to be particularly problematic for the professionals, as it was mentioned discussing with them. However, this seems to contradict the scientific literature, which shows that contextualisation is important. Also, the contextualisation is a macro-competence that we do not address in this workshop (see *Table 1*). Maybe it is an essential competence that needs to be developed with another workshop. Another suggestion is the proposition of a contextualised list (by field? by profession?). This proposal, simpler than adding a new workshop, seems problematic because it no longer engages the participants. In other words, the participants are passive and are not encouraged to question this given list, which is necessarily subjective. Besides, this goes against the development of critical thinking competence. This also leads us to another question about the feedback from professionals at the workshop, who, despite having succeeded in co-constructing indicators, would prefer to have an already pre-made list from which to draw indicators. One of our hypotheses, based on the results, is that this can be explained by less developed normalisation competence, but above all by their limited ability to take a step back from their professional activity. We have seen that self-awareness is perceived as the least developed competence. However, considering the feedback from professionals, we believe that the development of this competence is essential for a sustainable design. Another issue we had concerned the relationship between the representation of the results of the workshop (the comparison of the bikes) and the calculation of value. As far as the calculation of value is concerned, the participants were able to see that if they remain within a logic of low Sustainability, i.e., that capital can be substituted, the choice of bicycle can be confined to the reference bicycle, which has a low cost compared with the others. In fact, by using Value Analysis in its original sense, some participants seem to have been tempted to relate all to a vision of "financial cost and functional benefit". However, this vision, which is firmly anchored in a method mastered by one of the professional participants, shows that the development of the competencies targeted

during this workshop is not necessarily uniform and calls into question the capacity of this workshop to challenge experts in specific fields. This echoes our previous point on the self-awareness competence. By taking the different values (social and ecological) separately, the participants were able to reflect on the choices to be made. The question arose as to how these different values should be interpreted and represented (a single ratio or several ratios to retain as much information as possible?). These different ways of calculating and understanding value influence the way in which it is represented and the way in which sustainability is approached. Indeed, if participants tend to want only one indicator, this tends to show that they have not developed certain competencies such as (11) which is the ability to relate planetary boundaries and the social thresholds.

5.3. Limits of the workshop

- The time: The workshop is designed to last 3 hours, including presentation and debriefing (without the questionnaire). This leads us to believe that with a little more time, the Doughnut can be used as a support for co-constructing design indicators for Sustainable Value Analysis.
- Limits related to the workshop facilitation: Workshop facilitation requires adapting to the profile of the participants, their level of knowledge and skills. Despite the decision to have only one facilitator during training sessions, it seems difficult to ensure that the workshop did not vary in content (e.g. in response to participants' questions). Thus, the results obtained in terms of skills development should not be standardised. In other contexts, with other facilitators, other participants or different groups, the results and their interpretation would have been different.

5.4. Limits of the tests made

- A limited sampling: The number of testers, whether professionals or students, is small (a total of 30 people). In fact, it seems difficult to carry out statistical studies. However, a large-scale statistical study could corroborate these initial results, which are positive overall, regarding the use of the Doughnut in the field of design for sustainability. It seems to be interesting prospects.
- Limitations linked to the motivation of participants: The students were obliged to attend the workshop. These students have chosen a course focusing on sustainability issues. This workshop is part of a teaching session on planetary limits. The students' participation was motivated not only by the general aspects of sustainability and their thirst for knowledge, but also by aspects relating to possible evaluations, although the aim was not to evaluate this formally. Some of the professionals (6) were obliged to attend as part of their compulsory training, while the others (5) took part on a voluntary basis. Despite these differences, there was no difference in the responses to the questionnaires. It could be hypothesised that the volunteers were more interested in the subject. However, as there was no feedback on the development of skills in the medium term (t+2 months) or in the long term (no follow-up, few opportunities to use these skills), the contributions are limited to a general understanding of the issues.
- Self-assessment: Self-perception is influenced by actions in an environment and social interactions. Therefore, self-perceived competence can differ from actual capabilities due to the subjective interpretation of results and social experiences (Bandura, 2008). There are also illusions of competence (optimistic perception) and illusions of incompetence (pessimistic perception) (Bouffard and Narciss, 2011). We therefore stress that there may be a bias in the results due to this self-assessment.

6. Conclusion and future works

In conclusion, we can say that the development of competences for sustainability make sense as part of a complete pathway. It is difficult to project medium and long-term results with professionals, even if in the short term it does seem to be of interest. A more in-depth study, with volunteers for example, would provide a better understanding of how to develop the competence of professionals whose core business is not this, but who need to be aware of current issues. The training workshop will be improved based on feedback from participants to become a workshop medium used in both industry and academia.

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