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29th CIRP Life Cycle Engineering Conference

From Innovation to Eco-Innovation: Co-Created Training Materials as a Change Driver for Research and Technology Organisations

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Abstract

The concept of the circular economy has been a major driver in establishing new perspectives in innovation, product design and in technology management. Technological innovation in the context of a circular economy has become a factor of competitiveness, of success in national and European calls for projects, as well as a source of attractiveness for employees. A transition management is operating today in worldwide organisations from innovation intended to only provide additional economic incomes, to innovations that are willing to be sustainable by staying under the planetary boundaries limits and by satisfying some targeted societal needs. The term ‘eco-innovation’ is among the most cited design for sustainability methods associated with this transformation. The required paradigm shift is a new challenge that technology-intensive organisations must handle with the companies and industries included in this socio-technical system. Such a paradigm shift cannot be achieved without adapting the innovation processes. Moreover, the concept and implementation of eco-innovation remain unclear, lacks in the validation and the experimentation processes are frequent. The overall approach therefore needs to be supported by practical tools and methods for design engineers and applied researchers.

This article provides feedback on a project collaboration between a large public-funded research organisation (CEA: Alternative Energies and Atomic Energy Commission) and academic researchers from university (Grenoble Institute of Technology), with the aim of formalising an approach needed to conduct eco-innovation R&D projects. One of the levers in this perspective is the dissemination of applied knowledge (know-how) by providing training materials in order to make R&D engineers aware of the importance of innovation within the circular economy framework.

This paper presents the process of development of such educational training conducted in a collaborative way. This training content has the ambition to empower engineers in developing a systemic vision and practical insights in four main topics: sustainability challenges, environmental impact assessment, circular economy vision, and eco-innovation methods. It was tested during pilot workshops and then transformed into an online format.

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Keywords: Circular Economy; Eco-innovation; Education; Training; R&D; Change management; Design for Sustainability

1. Introduction

Circular economy is one of the most important concepts that have made significant advances in product design in order to achieve better resources management and contribute to moving toward sustainability. It has been widely discussed in the

literature regarding its conceptualization and implementation in many industrial sectors [1,2]. It is made up of many processes whose objective is to minimize waste, pollution and to continuously use resources. Those processes are reuse, repair, refurbishment, remanufacturing and recycling and they constitute therefore a closed loop system [3]. Reuse consists of

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using a discarded product in another context, in which the product is still running well and fulfilling its original functions. Repair consists of restoring a product to match its required function, while refurbishment is about restoring an old product, and potentially updating its functionalities. The remanufacturing is about restoring a used product in its end of life with similar performance and warranty period as a new product. Recycling a product destroys its functionalities by the shredding and/or melting material processes, and provides the same quality or lower-grade materials out of it [4]. In Europe, the circular economy is considered, beyond the material recovery loops, as a new economic model to achieve a cleaner and more competitive Europe [5]. The New European Circular Economy Action Plan aims to accelerate the transformational change required by the European Green Deal [6]. The plan presents a set of interrelated initiatives to establish a strong and consistent product policy framework that will make sustainable products, services and business models. The objectives of the plan address the same three pillars of economy, environment, and society established in 1987 by the UN World Commission on Environment and Development in the Brundtland Report. It aims to transform Europe to a climate neutral continent in 2050, providing a competitive and resilient economy, and achieving a fair and inclusive transition.

Driving the transition through research, innovation and digitalization is considered as one important level toward achieving these goals [6,7]. Innovation and technology development are often considered as the drivers of modernity and the economic growth of societies. However, these innovations raise many concerns about the damage to the environment that is increased as well, pollution is growing and natural resources including water and energy are exponentially extracted, used, spoiled (cf. The Club of Rome reports, such as the Planetary Emergency Plan [8]). Relatively new terms such as eco-innovation, green innovation, sustainable innovation, responsible innovation, are commonly used in literature in design topics. Eco-innovation is of growing importance to policy-makers, academics and practitioners [9,10] as the wording to depict sustainable innovation. Schiederig et al. [11] conducted an extensive literature review to identify the most relevant concepts that bridge the gap between innovation and sustainability. Their study showed that the concept of “green innovation” is closely related to three other terms, which are: “sustainable innovation”, “environmental innovation” and “eco-innovation”. Although these four concepts focus on economical and ecological aspects of innovation, Schiederig et al. [11] determined that the societal dimension is what distinguishes the definition of “sustainable innovation” as stated by the Brundtland report [12] from the other three concepts. They also determined that “eco-innovation” seems to be the most precise and well-developed concept, whereas “green innovation” remains rather shallow. According to the UN Environment Programme, “*Eco-innovation is the development and application of an economic model, shaped by a new corporate strategy integrating sustainable development into all operations, based on life cycle thinking and in cooperation with partners all along the value chain*” [13].

To show the increasing interest of researchers on the concept of eco-innovation, a quantitative review of the literature was conducted according to the preferred reporting items for

systematic review and meta-analysis (PRISMA) approach [14]. PRISMA allows conducting a rigorous, systematic literature review based on a four-phase flow diagram (i.e. identification, screening, eligibility and inclusion). The Scopus database was used, and the criteria for inclusion were the use of the term “eco-innovation” in the papers’ titles, abstracts or key words. This analysis determined the number of articles published on the subject over the last 20 years. The results of this analysis are shown in Fig. 1.

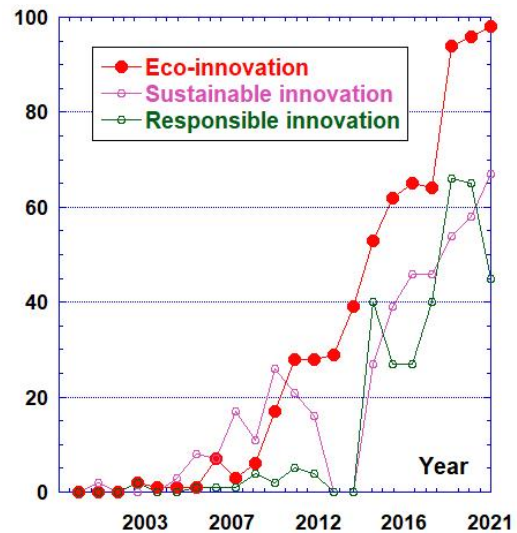


Fig. 1. Evolution of the number of publications about eco-innovation

Over the last 20 years, more than 1,300 papers have been published dealing with the topic of eco-innovation. An analysis according to the subject areas of these papers showed that 20% are in environmental sciences, 20% in business and management and 15% in engineering. The European Commission is the top funding sponsor of these studies.

Education and professional training on environmental challenges are powerful and influential levers to facilitate fundamental changes in the way organisations and companies think their environmental transition process [15]. Training is the most effective way to enable engineers and R&D practitioners to expand their skills while enhancing their motivation and commitment in the medium and long term. This paper shows the case of a collaborative project which involved a large French public-funded research organisation (CEA: Alternative Energies and Atomic Energy Commission) and G-SCOP laboratory (which stands for the Grenoble laboratory dedicated to Design, Optimisation and Production Sciences and is part of Grenoble Institute of Technology) in order to design and implement a training program for CEA engineers about eco-innovation and sustainability topics. The paper has the following outline: section 2 presents the context and objectives that are underlying this training program. Section 3 gives an overview of the training materials content, while section 4 explains the training approach that has been chosen. In conclusion to this paper section 5 concludes the paper and presents the upcoming activities and perspectives to this collaboration project.

2. Context and Approach Development

The following factors motivate this study. First, circular economy and eco-innovation are efficient approaches to reduce environmental and social burden of technology and support the resource efficiency through promoting circular economy in technology development projects. Second, the inflection of Europe towards the circular economy through the “Green Deal” and also by French national policy are major drivers for any technological organisation, including the CEA. The French national circular economy roadmap sets out a path that will enable rapid progress towards France’s target on climate challenges [16]. Therefore, the CEA is committed to orienting its future technological developments within the framework of the circular economy in order to better respond to calls for tender, to its industrial partners in this evolving society context. These factors increase the demand for proposing training materials and content to CEA engineers and managers, in charge of developing and implementing innovative technologies. This training is an opportunity to encourage CEA engineers to think in terms of the global impact of the technologies they develop on the three pillars of the eco-innovation throughout the entire life cycle, while meeting the requirements of the circular economy. This article presents the collaboration between the G-SCOP laboratory and the CEA, which aims to disseminate good practices in eco-design and the circular economy based on the skills and G-SCOP researchers experience. A joint team was created to co-design, test and implement the training content in CEA in 2021.

3. Training Programme Design

The training contains theoretical contributions in slide show format allowing the concepts understanding. In addition, several practical exercises to practice the acquired knowledge are mandatory for learners. The content of the training was designed in a collaborative way, and progress meetings allowed to refine the content according to the educational objectives of the CEA. The pedagogical objectives, as defined by the course design team, are the following:

- To be able to understand the issues and concepts of sustainable development, circular economy and eco-innovation
- Understand the specificity of eco-innovation at CEA
- To be able to identify the application sectors of the circular economy to which the technologies mastered could respond
- Be able to respond to European and national calls for projects
- Better meet the expectations of society and industrial partners

In order to reach these objectives, the content of the training was articulated in seven modules, addressing four main topics: sustainability, environmental impacts, circular economy, and eco-innovation.

3.1. Sustainability and SDGs

The first modules of the training program focus on participants’ understanding of sustainability. Sustainability has gained momentum for product and technology development

actors in many sectors. Sustainable development as defined in the Brundtland report [12] is “a development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. As shown in Fig. 2, it is often presented as three intersecting circles, representing the three development needs of society, the economy and the environment, with sustainability being the intersection of these three circles [17]. Several references are given to learners to analyse this rather old definition, and decontextualize its meanings for today’s sustainability objectives.

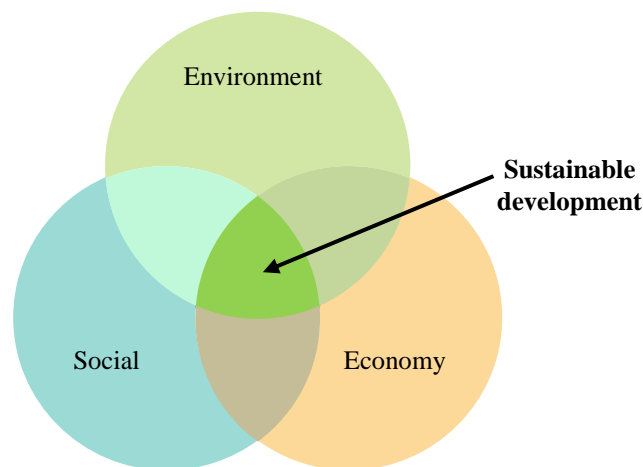


Fig. 2. Three intersecting circles of sustainability

Then, the course content addressed the concepts of the different sustainable development goals SDGs as stated by the UN [18]. The 17 SDGs and their 169 targets internationally agreed by governments, industries and organisations represent a reference for structuring the transition toward sustainable development. Practical examples of the application of these objectives were given with an analysis sheet. The learners also had an exercise to understand and master SDGs by analysing the Fairphone© case study. Based on the documentary resources provided to them, learners have to identify the different SDGs observed in the case study and identify the targets that were implemented by the Fairphone© under each SDG.

3.2. Environmental Impacts

This part of the course highlighted the different environmental challenges the companies, and technology developer need to tackle. The concepts of environmental impacts of human activity were presented. The Life Cycle Engineering (LCE) approach was also explained in order to encourage CEA engineers to integrate ecological and social viewpoints in addition to technological and economic perspectives. A focus is made on the life cycle thinking in order to include the whole product life cycle, including the production, use phase and end of life stages during environmental-impact studies. A very brief introduction is made to LCA method. A closer attention is, however, dedicated to the societal impact during life cycle stages and the rebound effect in LCA. Social Life Cycle Analysis (S-LCA) assesses the sustainability of organisations, products and services, focusing on the society needs [19]. The rebound effect is

generally defined as the difference between the expected and the current environmental savings from efficiency improvements that are overcompensated by the economic growth effect: the products and technologies overconsumption, generating collateral negative environmental impacts [20].

3.3. Circular Economy

In this part of the course, the circular economy is explained, presenting the different definitions that have been given, by Ellen MacArthur Foundation one [7] to the European Union one [5,6,21]. Particular attention is given to the European definition which considers that the circular economy is today a global model that relies on the three pillars of sustainable development. In addition, Europe's shift towards the circular economy through the "Green Deal" is also a strong national issue in France. Innovative technology research and development organisations such as the CEA are therefore rapidly converting to eco-innovation for the circular economy, which is now an essential element of their competitiveness as well as the competitiveness of their industrial partners. The CEA is committed to orienting its future technological developments within the framework of the circular economy in order to better respond to calls for tender, and to its industrial partners, while considering the new expectations of the society. Eco-innovation addresses CEA technologies to make them more virtuous, and technologies specific to the circular economy. Therefore, eco-innovation as depicted throughout the training, and the circular economy promoted by Europe, share the same goals of sustainability supported by the three pillars of sustainable development as defined by the UN. In other terms, eco-innovation is the way to innovate within the frame of the European circular economy plan. The learning materials also include practical examples of circular products or scenarios, in addition to the definitions and the challenges of circular economy. The examples were chosen in order to be aligned to CEA engineers' field of expertise, which includes microelectronics, digital and new energy technologies.

3.4. Eco-Innovation

The Technology Research Department of CEA has chosen the wording of eco-innovation to characterise the innovation process to be adopted within and for the framework of the circular economy. This process starts from an idea of a product or a service with a high potential holistic impact, considered within the three pillars of the Circular Economy. Then, this idea must be evaluated and improved throughout the technological development while ensuring the respect of the use and the satisfaction of the users' needs. The proposed learning material addresses the different definitions of eco-innovation, essentially using the definition given by the UNEP [22]. Then, the CEA's eco-innovation vision is presented. This vision is the result of the cross-analysis of current CEA best practices allowing to efficiently address the objectives of a circular economy for technological activities and the research expertise of G-SCOP in circular economy projects. It can be schematised in Fig. 3. by a process that starts from an idea of a product or service presenting a positive holistic impact on the economy, the environment and the society. This requires the knowledge

of the value chains, which are more complex in the circular economy. Then, engineers can imagine and develop technologies which could respond to the objective.

Technologies should therefore be kept aligned with the principles of sustainability. The formulated ideas are going through the development phase to be further refined, before being transferred to industrial partners. In the CEA's eco-innovation process, during development, the usual technical optimisation of ideas is complemented by an optimisation of the overall impact, i.e. an impact on the three dimensions of sustainable development. Examples of CEA projects achieved through this process are presented as illustrative case studies.

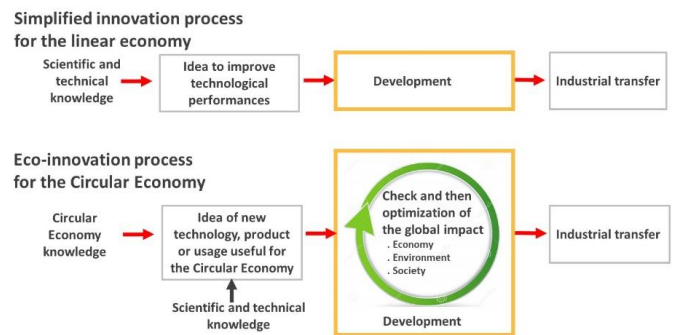


Fig. 3. Graphical representation of eco-innovation process as seen by the CEA

4. Training Approach

The content of the course was presented in the form of seven modules. Each module contains a set of slides to convey the theoretical content of the course. These slides are sometimes accompanied by illustrations in videos format to explain the theoretical concepts associated. Each module included exercises to help learners assimilate the content and test their knowledge. At the beginning of the collaboration project between G-SCOP researchers and CEA, the defined objective was to train CEA engineers in a two-day face-to-face training. Due to the COVID 19 pandemic, the pedagogical approach finally adopted was transformed towards online training on CEA's own e-learning platform. However, a pilot face-to-face workshop was organised with the participation of a dozen CEA engineers and in the presence of the Grenoble Institute of Technology researchers and CEA training team. The objective of this two-day pilot training was to test the course, to validate the proposed content and to check the relevance of the exercises and applications proposed before digitising the course. At the end of the pilot training, a discussion with the participants and an evaluation of the course by distributing questionnaires were organised to collect their opinions on the course. For each part of the course modules, the questionnaires asked the learners to rate the clarity of the content, the quality of the knowledge acquired, the duration, the pace of the content and its relevance to the learner's work. A free comment area was also available in the questionnaire allowing learners to freely express their opinion on a specific concept or to develop a given suggestion in more detail. Several remarks were thus retained for the final version of the course. The need for more practical examples in relation with CEA technologies was mentioned by the learners, for example on life cycle assessment and the implementation

of circular economy scenarios. This feedback allowed the course to be restructured to achieve a better clarity much adapted to the CEA context. Also, learners noted a lack of presentation of the overall context of the course, the challenges for the CEA and the interest of CEA engineers, in addition to a synthetic presentation of the content. Thus, an introductory presentation was added to the course content and some exercises were modified for more clarity. This kind of working process is common for G-SCOP researchers in the field of integrated design in order to ensure that the content of the training is adapted to the context or their use and the users (CEA engineers in this case). This co-design development process is iterative.

Once the content was approved by CEA users, the format was adjusted. The group of designers and trainers moved on to digitising the course and turning it into a “COOC”, or Corporate Online Open Course, as defined by Zhou et al. [23]. A COOC is a private version of MOOC (Massive Online Open Course) that is made available by the CEA to a restricted community of learners and engineers. This training is part of the CEA’s strategic commitment to share a culture of eco-innovation and the circular economy through the training of engineers and CEA employees. The CEA already has a distance-learning platform, that has been used for training in the CEA’s core areas of expertise, and that was made available for this eco-innovation training. The platform interactive format allows alternating theoretical knowledge in the form of slide shows or videos, and also practice with interactive exercises or corrected assignments. It also allows remote tutoring of learners by one or more trainers. In the specific case of the eco-innovation training, the pedagogical approach currently chosen is a self-training, without additional trainers tutoring. The slide shows were therefore made available for the participants, presenting a ten-minute video filmed for each module. Finally, since the theoretical content presents the different concepts, with the key messages to be remembered, the learners have at their disposal for each module an example of applications and exercises. Different forms are displayed such as quizzes, MCQs or exercises to be done as homework. For example, an exercise on the analysis of the SDGs was proposed with an application on the Fairphone© case. For the circular economy module, a case study of circular scenario analysis was proposed for end-of-life electric vehicle batteries. For the eco-innovation module, a case study from CEA was proposed to make the learners think about the degree of successful realisation of sustainability practices during the concrete development of this project by CEA engineers. The course ends with a certification exam to test the learners’ assimilation of the knowledge acquired and to justify their ability to master the basic concepts of eco-innovation and the circular economy. It is also designed in order to check if the learning outcomes defined for the course are being fulfilled. Up to the writing of these lines, around 70 participants are registered and are following for online training, and more than 40% have already completed a successful certification exam. The objective targets at least 300 engineers to train from now. The success in reaching the course objectives can also be measured through the growth in the number of learners for these modules, the expressed needs for more specific modules on the presented concepts (e.g. LCA, eco-design), but also by

the number of projects launched in eco-innovation or the number of responses to national or European calls for projects related to eco-innovation.

5. Conclusion

The increasing focus of development in Europe and France within the framework of the Green Deal and the Circular Economy plan requires different methods of innovation than those usually practiced. When developing very upstream technologies that can have multiple applications, as is the case for the CEA, it is necessary to implement a paradigm shift toward sustainability. This requires transforming innovation processes to eco-innovation which considers not only technological progress but the purpose, usage and global impact of technology on the economy, the environment and society. A strong global impact results in a virtuous innovation, which will make more sense to users, and will meet the new European and national regulations that are increasingly demanding in terms of sustainability. Education and professional training are an important lever to facilitate fundamental shifts in thinking in organisations like CEA. The work presented in this paper to share the experience of the collaboration between CEA and researchers of the Grenoble Institute of Technology for the development of education and training programs for eco-innovation. It is important to highlight the collaborative approach that was followed in order to co-design and co-construct the content of the course. This action is a continuation of previous collaboration between the two partners on topics related to sustainability and impact evaluation of technologies. Previous PhD studies conducted in CEA involving supervisors from Grenoble Institute of Technology researchers were dealing with eco-design of systems for better circularity, mainly in energy systems. The training is also a continuation of previous training about circular economy delivered in CEA for business managers and marketing. Another online training is currently being designed and prepared on the specific topic of environmental impact based on LCA method, still in a collaborative approach between CEA and the G-SCOP laboratory.

With a range of three available training materials on circular economy, eco-innovation and LCA, engineers in different core sectors of CEA will have the required skills to make a paradigm shift towards developing innovative technologies with sustainable value creation in mind. But still a clear formalisation of the process of eco-innovation for CEA case needs to be achieved. One of the perspectives of this work is to define the eco-innovation method best adapted to the R&D activities of the CEA. It needs to be easily understandable by the engineers and researchers so that they adopt it and implement it in their projects. The sustainable quality of achievements should also be verified over the coming years to adjust the course to the evolving society.

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