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Co-Creation as the Solution to Sustainability Challenges in the Greenhouse Horticultural Industry: The Importance of a Structured Innovation Management Process

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Abstract: Sustainable innovations try to resolve complex challenges related to climate change. Co-creation with diverse stakeholders in innovation networks opens opportunities to successfully develop and implement sustainable innovations. However, collaboration between heterogeneous partners poses challenges at the level of stakeholder relationship management that affect the progress of innovation development. This study's purpose is to investigate how co-creation processes that develop sustainable and climate-neutral high-tech innovations in the greenhouse horticultural industry should be structured and how stakeholder relationship management affects the progress of innovation development. Design methodology is linked with innovation management literature. A case study observed seven innovation trajectories that developed energy saving and climate-neutral growing techniques in the greenhouse horticultural industry in Flanders (Belgium) and The Netherlands over a period of three years. In-depth interviews (n = 13) were conducted to have the partners reflect on the co-creation process. Results show that co-creation management should focus on team composition, partner alignment and transparent communication about intentions, expectations and role division throughout the process. The initial stages of a co-creation process are crucial for context mapping and creation of team cohesion and do affect the subsequent stages in the process. Besides, in sustainable high-tech contexts, co-creation facilitators are faced with the need for technical knowledge and skills.

Keywords: co-creation; innovation; multi-stakeholder network; sustainable innovations; high-tech context; stakeholder relationship management; greenhouse horticulture

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1. Introduction

Greenhouses play an increasing role in the food supply needed for a growing world population. However, their promising impact to deal with food shortage also comes with a negative environmental impact [1]. Therefore, one of the main challenges is to keep this competitive industry in line with the sustainable development goals that policymakers set in line with the EU guidelines [2]. The European horticultural industry aims to be climate neutral by 2050, with 2030 as an important milestone [3]. The border region Flanders (Belgium)/The Netherlands, a region where the horticultural industry is considered as leading and innovative, is also home to a strong high-tech industry [4,5]. This creates possibilities towards developing sustainable high-tech solutions to cope with the complex tension between the demand for food and the unwanted environmental impact of producing it. However, past research reports that a lot of high-tech does not yet meet the needs of horticulturists due to a lack of market potential, competitiveness, and environmental efficiency [6]. Therefore, a project was created to examine possibilities and to develop sustainable high-tech innovations that support the industry in attaining energy-efficient and climate-neutral goals, while at the same time taking optimal greenhouse micro-climate conditions into consideration, such as temperature, humidity, light, and CO_2 [7]. Within this research project funded by the European Union, seven sustainable innovation trajectories were started and resulted in promising and feasible crop-specific design interventions.

This paper concentrates on the development process of these sustainable high-tech innovations. From the front end onwards, the innovation challenge is set up as a co-creation between diverse and heterogeneous stakeholders, which is in line with recommendations from previous research [8–12]. Indeed, due to the complexity of sustainable challenges such as climate change, co-creation is considered an appropriate approach to develop innovative solutions [13–17]. It is often used in the context of sustainable innovations [18,19], in which knowledge, resources, (cap)abilities, and value are shared between different stakeholders who participate together in innovation networks.

This paper draws on insights from design sciences and the tools and models used in this discipline to structure product innovation processes (e.g., Double Diamond Model [20]). It uses the approach of design thinking as a co-creation methodology [19,21]. Moreover, it is embedded in the innovation management literature and stakeholder relationship management in particular [22,23].

Although the combination of diverse collaborating partners is a basic premise in co-creation processes, the diversity itself can be interpreted as a double-edged sword [10]. Creativity might emerge from interdisciplinary teams, but it can also lead to team conflicts and might affect the team members' relationship and the progress of the innovation process [10,11,14,15,24]. Consequently, it has become important to study co-creative innovation management and stakeholder's heterogeneity in multi-stakeholder co-creation networks and the effect the collaboration between diverse stakeholders has on the co-creation process.

This study's goal is to examine how co-creation processes that develop sustainable high-tech innovations should be structured and how stakeholder relationship management affects the progress of innovation development. The research questions we aim to answer are:

(1) How to structure co-creation processes that develop sustainable high-tech innovations with multiple stakeholders?
(2) How to manage stakeholders' relationships in co-creation processes that develop sustainable high-tech innovations in multi-stakeholder networks?

The study's novelty lies in the interdisciplinary approach that investigates stakeholder relationship management in the context of sustainable innovation development using a model originating from design literature to structure the process [25]. This process-based approach aligns the different stages in a co-creation process with management challenges such as the relationship between diverse stakeholders. The context of this study relates to achieving the sustainability goals set for the horticultural industry by improving growing techniques and technologies [26]. This study contributes to theory as earlier studies advocate the use of co-creation and open innovation in high-tech contexts and ask for more research [27–29]. The practical contributions of the paper are the useful insights and hands-on information drawn from empirical data regarding the management of co-creation processes for facilitators and future co-creators. Earlier research highlights the role of facilitators [9] that guide the team members through co-creation processes by organising co-creation interventions such as workshops, observations, and team meetings. The results describe challenges the co-creation partners might get confronted with and provide tools to overcome these challenges and provides managerial directives for facilitators.

2. Literature Review

2.1. Innovation via Co-Creation in Multi-Stakeholder Networks

Innovation is the driver behind value creation and knowledge creation and, as a consequence, it is often seen as a solution for complex challenges (e.g., climate change) in business, science, and society [13–15,30]. In earlier decades, innovations were developed relying on internal resources only [27,31]. Despite the feasibility of the developed innovations, they did not always guarantee success in the market [31]. As a consequence, organisations realised that external resources were needed to stay competitive.

Scientific literature has witnessed a boost of research with a focus on the concept of (value) co-creation at the crossroads of three different literature streams. Besides consumer behaviour, insights from innovation management and services design are crucial in understanding (value) co-creation [32–34]. From a managerial angle, Von Hippel [35] focussed on the input of user experience and knowledge. Chesbrough et al. [36] introduced open innovation, whereas Prahalad and Ramaswamy [37] emphasized the co-option of customer experiences to develop successful innovations. Matthyssens and Vandenbempt [38] studied a value-driven management approach. Multi-stakeholder co-creation and co-creation management were further elaborated among others by Reypens, Lievens, and Blazevic [9], Kazadi et al. [39], and Roosens, Lievens, and Dens [14]. From a designer's point of view, Norman [40] stressed the importance of user-centred design; Ehrenfeld [41] reflected on customer's needs, and Manzini [42,43] triggers researchers by positing that everyone is a designer. Aguirre et al. [44] studied design facilitation through co-creation in multi-stakeholder events. Sanders and Stappers (2008) [21] emphasized that the evolution in design research from a user-centred approach to co-designing is changing the innovation process and the roles of the designer, the researcher, and the end-user.

The multidisciplinary background has resulted in a variety of definitions of the concept of value co-creation [45,46]. In the scope of this paper, (value) co-creation is defined in line with Frow et al. [47] according to the definition provided by Perks et al. [48]: "the joint creation of value by the firm and its network of various entities (such as customers, suppliers and distributors) termed here actors. Innovations are thus the outcomes of behaviours and interactions between individuals and organizations" (p. 935). Besides, co-creation is often used as an iterative technique (which originates from design thinking) to initiate innovations [18,49]. This paper applies this approach in a high-tech and sustainable context.

2.2. The Structure of the Co-Creation Process

In our study, we rely on an iterative innovation approach that describes a co-creation process in different stages starting from idea generation to innovation development, using the Double Diamond design model (see Figure 1) [20].

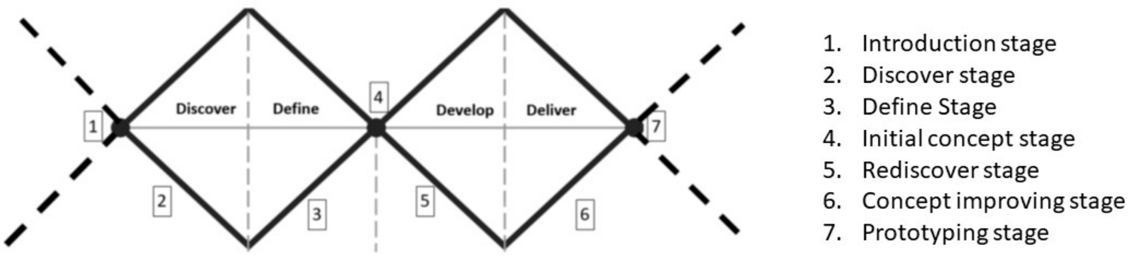

Figure 1. The Double Diamond Model [20]/adapted from [50].

This structured model originates from Design Thinking and is often used to manage design and innovation processes in marketing and management [21,25,49,51–53]. The two diamonds in the model represent both a divergent phase ('discover' and 'develop') in which different ideas are generated and explored, followed by a convergent phase ('define' and 'deliver'), in which the idea(s)/concept(s) is/are defined [20]. The problem definition phase (what should be developed, often referred to as 'designing the right thing') is represented in the first diamond. The second diamond represents the exploration of potential solutions (designing the thing right) by means of a traditional design process in which concepts and prototypes are refined based on stakeholders' feedback [18,21]. Based on previous research [50], this process was further divided into seven manageable stages.

Roosens, Lievens, and Dens [14] show that the initial stages of a co-creation process are the most crucial ones and that these stages determine the process to a large extent. At the **introduction stage**, the core co-creation team is composed based on compatible skills and resources, and the different team 'roles' and the innovation goal are defined. To ensure a smooth process, the goals and expectations of the different collaborating partners are discussed and mapped. Ideally, a project timeline is created which highlights the milestones at each stage of the process. The **'discover' stage** (stage two) aims to collect a wide spectrum of ideas and information related to the innovation's challenge [20]. The core co-creation team is extended with end-users and key partners who collaborate on idea formation and evaluation of the gathered information and ideas [39,54]. **The 'define' stage** (stage three) analyses the input obtained from the 'discovery' stage [55]. These insights are then used to shape an **initial concept** (stage four) of the innovation aimed for [47]. Based on the concept(s) developed in stage four, additional exploration regarding the developed solution is **rediscovered** (stage five) [56]. The convergent phase (stage six) **improves** the innovation concept and makes a synthesis of the concept(s) [57]. The final stage consists of **prototype** development (stage seven) of the innovative solution [58]. Given that the co-creation process is iterative, the sequence of the stages can be repeated as many times as necessary to develop a testable prototype.

Dividing the co-creation process into smaller stages aims to make the process more manageable. As suggested by Reypens, Lievens, and Blazevic [15], the effectiveness of activities on both the network and the stakeholder level, as well as on the pursuit of the concrete innovation goal should be managed in every stage of the innovation process to detect potential gaps in actual and expected outcomes. Co-creation takes an innovation strategy to a further level by systematically engaging a diversity of stakeholders in this structured stage-based process. Especially in the context of (high-)technological and sustainable innovations, a diverse innovation network that consists of heterogeneous team members is required [10–12,15,16,30,59]. Initiating co-creation with diverse stakeholders ensures that the developed innovations are indeed in compliance with end-user's needs and desires, and the possibilities in terms of technology, skills, resources, etc., of the partners involved [14–16]. Stakeholder diversity is crucial in co-creation processes, but it can cause friction as well [10]. Therefore, the process should be managed well from the beginning onwards.

2.3. Managing the Co-Creation Process

As the early stages of the co-creation process are crucial for the pursuit of a feasible innovation, the composition and the alignment of a co-creation team is an important scope of this study. Diversity of co-creation partners is a basic need that results in the ability to develop innovations that serve the needs and preferences of various stakeholders who operate in diverse contexts. A lack of stakeholder diversity usually results in unilaterally developed innovations that take the viewpoint of limited stakeholders or the own organisation into account. As a consequence, unilateral innovations face the risk of market failure [60]. Therefore, innovation development should strive to include all stakeholders that might either affect or being affected by the innovation. As a result, value is offered to all co-creating partners. On the one hand, co-creation generates an advantage since knowledge and skills are shared between heterogeneous partners and creativity might emerge from interdisciplinary teams [10,11]. However, on the other hand, the co-creating partner's diversity might increase the complexity of the co-creation process, resulting in team conflicts that might affect the relationship between the team members and refrain team performance [10,14,61].

The role each team member takes on should be considered thoroughly. Belbin [62,63] distinguished nine team roles that need to be present in a team (resource investigator, shaper, implementer, completer finisher, coordinator, team worker, monitor-evaluator, specialist, plant). Role definition is a key issue and should be aligned with one's personality, communication style, and skills [14]. Facilitators of co-creation processes have a special role and should be provided with insights into how co-creation with multiple stakeholders can be managed to ensure an optimal sustainable innovation [15].

Pera, Occhiocupo, and Clarke [61] identify trust, inclusiveness, and openness as enablers of multi-stakeholders value creation. They mention that one of the key enablers of co-creation is that the diverse partners share a common purpose. A co-creation process does not only need to take the development of the innovation into account but should also be able to cope with different expectations, different backgrounds, and different expertise [11,14,15].

Partner alignment is essential to manage team conflict and tension between team members. Given the differences between individual expectations and goals, it remains complex to reach the common team's goal [14]. Katz [64] showed the importance of communication among group members on positive project performance and reports that apart from formal communications like reports, publications, and other written documentation, interpersonal communication is essential in idea generation and information sharing between team members. It is crucial since it is a means to openly express the expectations and goals of team members and it enables the anticipation of differences, tensions, and conflicts [14]. Moreover, especially in technological and sustainability contexts, jargon and knowledge are highly specialised. Therefore, a language should be used that all co-creating partners understand [10,64].

3. Materials and Methods

3.1. Research Context

The paper describes a case study, the aim of which was to co-create sustainable high-tech innovations to contribute to an energy-friendly and climate-neutral horticultural industry in the border region Flanders (Belgium)/The Netherlands. The project was observed during a period of three years (between 2018 and 2021). In total, the project consortium consisted of 13 partner organisations from both public and private sectors in Flanders (Belgium) and The Netherlands. The key partners' diversity is illustrated by their expertise and the specific context in which they operate. The partners' diversity ranged from greenhouse horticultural research centres, universities, knowledge institutions, a greenhouse construction firm to commercial companies. The partners' expertise covered a wide range of topics such as plant physiology, energy expertise, technical and engineering expertise, expertise in the construction of greenhouses, marketing and communication strategy expertise, and co-creation management expertise. In total, 59 individual members from 13 organisations participated in the project. Throughout the seven stages of the co-creation process, the team interacted with additional external (potential) partners, experts, and end-users.

3.2. Data Collection

The different co-creation interventions and their results that were observed ranged from crop-based research results, technical performance results, sustainable performance results, meeting documents, workshops output, group discussions, to surveys and in-depth interviews with end-users and consortium members. These data were used both as input to describe the co-creation process as well as to provide insights into the performance of the developed innovation concepts. The data indicated which (elements of the) innovations needed further improvement and which (elements) gave promising results.

During the last eight months of the project, ten in-depth interviews (seven individual and three panel interviews) with 13 consortium members (see Table 1) were conducted to grasp their reflections on the co-creation process.

Table 1. Overview sample characteristics.

ID	Interview	Organisation Type	Job Function	Role in the Consortium
1	Individual	Research centre	Bio engineer/Researcher	Project-coordinator
2	Individual	Private company on Marketing and innovation strategy	Marketing Manager	Work-package leader communication
3	Individual	Research centre	Researcher/team leader/plant physiologist	Work-package leader energy-efficient innovations
4	Individual	Research centre	Bio engineer/Researcher cucumber	Researcher cucumber
5	Individual	Research centre	Bio engineer/Researcher lettuce	Researcher lettuce
6	Individual	Research centre	Bio engineer/Researcher tomato	Researcher tomato
7	Individual	Research centre	Researcher strawberry	Researcher strawberry
8	Group interview No. 1	Knowledge centre/university college	Bio engineer/Researcher energy	Researcher energy
9	Group interview No. 1	Knowledge centre/university college	Researcher energy	Researcher energy
10	Group interview No. 2	Research centre	Bio engineer/Researcher bell pepper	Researcher bell pepper
11	Group interview No. 2	Research centre	Bio engineer/Researcher tomato	Researcher tomato
12	Group interview No. 3	Knowledge centre/research centre/university	Bio engineer, researcher and lecturer with expertise in physics of screens	Work-package leader energy-efficient innovations
13	Group interview No. 3	Knowledge centre/research centre	Engineer and researcher physics of screens	Researcher physics screens

The interview guide was structured around the Double Diamond Model (Figure 1) and based on the observation as well as on work from Roosens, Lievens, and Dens [14] and Reypens, Lievens, and Blazevic [9] regarding stakeholder collaboration in innovation processes through co-creation. The majority of the questions concerned the experience with and reflection on the seven stages of the co-creation process. Questions about the partners' role, their relationship with other partners, possible tensions, the communication processes, the co-creation interventions, the flow of the process and project management were asked additionally. The interviews took place online due to the corona pandemic. The interviews were audio and video recorded after obtaining the respondent's approval and transcribed anonymously, which added up to 110 pages of single-spaced transcripts. The interviews lasted between 28 and 82 min, with an average interview time of 54 min.

3.3. Data Analysis

The qualitative text analysis software NVivo 12 was used to analyse the interview data via a coding process that consists of three consecutive coding steps; open coding, axial coding, and selective coding [65]. An a priori codebook was created based on the project observation, the literature, and the Double Diamond framework. In the open coding process, sentences and paragraphs were labelled with codes from the codebook or new codes that emerged from the data itself. In the stage of axial coding, the codes were grouped under the constructs they represented. In the selective coding stage, the hierarchy between the different constructs and the relationship between the constructs was mapped. In different stages of the co-creation process, different concerns seem to be relevant. The constructs that appeared from the data were: project management, team composition, partner alignment, tension at the expertise level, and communication. The coding tree is given in Figure 2.

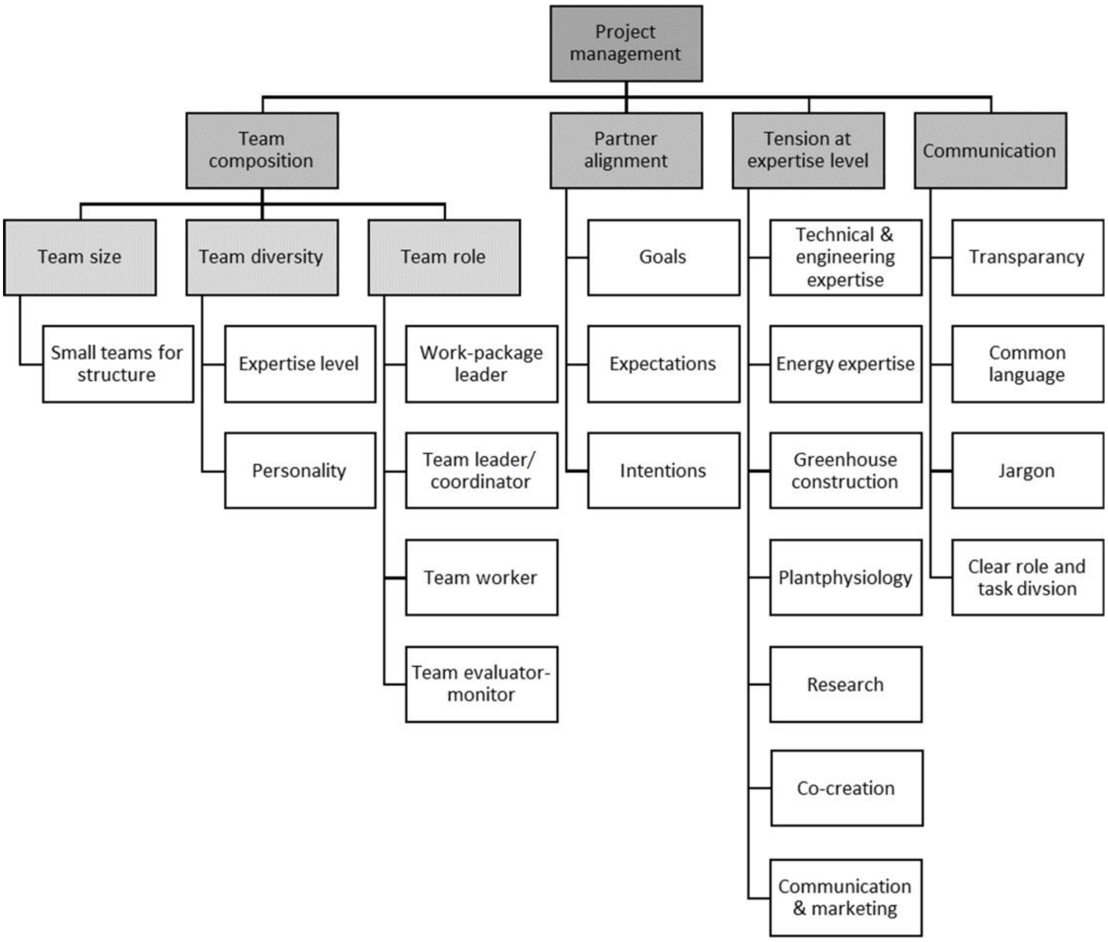

Figure 2. Coding tree.

4. Results

The results section follows the structure of the seven stages of the co-creation process (Figure 1). For every stage, results are presented based on the interview data and main insights obtained from the three-year case observation. The relevant constructs emerging in each stage are illustrated with quotes from the in-depth interviews.

4.1. Introduction Stage

The project team consisted of 59 members aiming at one overall goal: developing innovative solutions to achieve a more sustainable and energy-friendly horticultural industry. The concrete goals of team members and the organisation they represent were, however, diverse, ranging from reducing the use of fossil fuels to improving the greenhouse climate through optimal isolation and humidity. ("In the beginning, it was a challenge to align all partners. The project contains several subthemes that can all be placed under the umbrella of 'energy'. However, the different subthemes themselves are very diverse. This makes that the project consisted of several small subprojects. As such it was a challenge to keep everyone informed and involved in the overall project.")

As high-tech innovations are rather complex and demand an extensive time investment, observations of the first team meetings showed that it was not workable to collaborate in one comprehensive team (including all 59 members). For instance, we observed that it took a while before all parties got to know each other and were able to retrieve the expertise they needed from the partners. Although several meetings were organized, communication between the team members was not efficient. For instance, a lot of emails were sent to everyone, which discouraged the follow-up of all these conversations that were sometimes irrelevant for individual team members. This resulted in a slow start. Most of the interviewees acknowledged that the initial number of participants (59) made the project complex. Some of the members were even involved in more than one innovation trajectory, which made it difficult for them to distinguish between the different innovations. ("The most difficult challenge for me personally was to be able to keep everything apart.")

To keep a structured overview and to make the project manageable, a first intervention took place by dividing the project into two innovation topics: energy efficiency and climate-neutrality. Moreover, subdivisions were made regarding the specific innovation goals, resulting in seven smaller work packages and teams:

1. Reducing energy use by implementing optimal LED lighting in the cultivation of tomato, lettuce, and cucumber;
2. Reducing land use and energy use by implementing a four-layer cultivation system in the cultivation of strawberry;
3. Reducing energy by installing low-grade heat systems;
4. Reducing needed nitrogen and CO_2 nutrients transportation by implementing Plasma Technology;
5. Isolating and optimizing the climate conditions using energy balancing day screens in the cultivation of bell pepper and tomato;
6. Isolating and optimizing the climate conditions using energy balancing night screens in the cultivation of bell pepper and tomato;
7. Keeping control over the humidity by implementing a climate-neutral vapour heat pump.

A core co-creation team was created for every innovation trajectory. The core teams consisted of four to six members (project partners). Each team consisted of partners with complementary knowledge, skills, competencies, and the following expertise: plant physiology, technology and engineering, energy, research capacities, and co-creation. The interviews (n = 13) reflect a positive evaluation of this decision. Besides these smaller core co-creative teams, the overall team (n = 59) kept in touch and met regularly (every six months).

The co-creation interventions helped the partners to get to know each other and to attain team cohesion. However, results showed that the time needed to adapt to the other partners and to start working in close collaboration should not be underestimated. For some teams, this took more than a year. (" ... However, I would have assumed that after one year this would have evolved more smoothly, but this was not always the case ... ") ("It became clear that the team leaders had to push this more to shape the collaboration in such a way that different parties were able to find each other.")

During the initial stage, we observed that the team members were not spontaneously aligning their expectations, intentions, and goals. ("If two parties embark on a project with different intentions and the disagreements remain present throughout the project, this will hamper the collaboration between those parties. In part, this can lead to irritation ... "). To align goals and expectations within each team, and to a get grip on value creation, workshops were organized. (" ... the partners are not aligned. This a good reason to start a discussion, but you just feel that those collaborations and even the initiatives to collaborate are limited in contrasts to partners that are aligned and have similar intentions.") Diverse co-creative techniques were used both on a more strategic as on a more tactical level, such as the Business Model Canvas (BMC) [66], goal mapping, value mapping, stakeholder mapping, and creation of end-users' personas. After this intervention, the teams were more cohesive and started to collaborate more intensively.

Moreover, we observed that, in the introduction stage, the roles the team members could take on were not clear. This created some ambiguity concerning the tasks one should perform. Tools were implemented to assign these basic roles and to bring them in line with tasks. As a co-creation intervention, a team leader was assigned to each team, as well as a team 'worker' and a team 'evaluator-monitor'. The 'worker' had 'performing tasks' to fulfil (e.g., phone calls to potential partners, setting up an experiment...). The 'evaluator-monitor' had to fill out documents, check the results etc. One of the most crucial roles is that of 'coordinator/facilitator' whose task it is to keep the process going.

In the beginning, some frustrations were observed. Results from the interviews confirm that these were partly initiated by the expectations of the team members that were not made explicit. ("I think that during the project description the expectations were not formulated explicitly enough between the partners involved and what would be realistic in that type of project implementation. During the preliminary conversations, too little attention has been given to these expectations. The decision to make this technique part of the project was made too quickly while actually too many things were still unclear.") Therefore, as a co-creation intervention, result-oriented, relation-oriented, and progress-oriented tools were provided to map team members' expectations in a structured way.

Tension was noticed between team members who are mainly result-driven versus members who behave according to their relational expectations about team collaboration. Therefore, it is advised to map team personalities, communication styles, and expectations from the beginning of the process and repetitively during the co-creation process. In this manner, the partners can anticipate when a mismatch between intentions and goals are noticed.

Additionally, time schedules and milestones were plotted for every stage. This was welcomed warmly by team members with explicit result related expectations.

4.2. Discovery Stage

During the discovery stage, the co-creation team gained insights into the innovation context from different perspectives. As the success of a co-created innovation depends on the perception of end-users and the abilities of external partners, various co-creation tools, activities, and interventions were used to enrich the team with useful information. Information from end-users (in this context growers) and external partners (e.g., greenhouse builders, folio producers, led light producers . . .) was obtained via desk research, surveys, in-depth interviews, workshops, and more formal meetings. For instance, growers visited crop experiments implemented at the research centres and were asked about their needs, desires, and opinions. Market explorations were carried out to select companies and business partners to produce parts of the equipment needed. In the context of the greenhouse horticultural industry, this required, amongst others, testing samples of products in lab settings. In this stage, one trajectory was put on hold (Plasma Technology). The reason for this decision was that there were different expectations concerning the technological readiness of the aimed device. ("Especially the expectation when the device would be ready. I think that was mainly the decisive factor. If the technique you are dependent on cannot be delivered, it stops.")

One of the management challenges in this stage was to establish openness and trust amongst the team members. The more technologically oriented team members distrusted team members or third parties that were supporting the data gathering. ("If you do not have any experience with the greenhouse horticultural industry, you do not have the expertise to moderate or facilitate discussions about this matter if you do not have a single idea of how the industry works. Without this expertise, you cannot facilitate or have a conversation about this matter.")

Due to the high-tech context of the innovations that requires specific knowledge on the one hand and due to the co-creative perspective of the innovative development that requires specific interview skills and communication skills on the other, it was decided to coach technical people to do part of the research and to conduct qualitative interviews with both technical and human-oriented interviewers and to design questionnaires in close collaboration.

Besides trust, communication is a challenge in this stage. Going through this process together increased knowledge sharing by communicating in a clear language and in a structured way. As the more technically oriented team members have more result-related expectations, the results other members are attaining in their domain should be made transparent, and their competencies should be highlighted.

4.3. Define Stage

During the define stage, the co-creation facilitators presented the results of the discovery stage. After this presentation, a workshop with the core co-creation team was held and resulted in decisions regarding the concept(s) and adaptations to initial concepts that were worthy to be further developed. One of the researchers mentioned that it was useful to approach the innovation development from this angle, since he was aware that he and his colleagues usually interpreted results and information from another perspective, with the risk of losing the broader picture. "I think it is never harmful to take time to reflect on a certain topic from a broader scope."

Based on insights from other stakeholders, a decision on how to approach the innovation is needed. Team diversity posed a management challenge to get technical and plant experts aligned. ("The most difficult part was that there was not always a match between the technology experts and our expertise (plant physiology) and the goals we wanted to achieve. This created some tension. So on the one hand you have the technology expert who looks at it from his viewpoint: "I want to save as much energy as possible." Whereas for me it was very difficult to make it clear to the technology expert: "If you will do it like that, based on my practical experience and knowledge, you will diminish crop quality and production." ... That is still the most difficult challenge in this story and the collaboration.")

To overcome these challenges, facilitating tools were used as a co-creation intervention, to get a grip on decisions concerning sustainable innovation development. A SWOT-analysis (what are the strengths, weaknesses, opportunities, threats for every innovation concept) and a COCD-matrix (which idea(s) are new and original/what is feasible now and in the future are examples of the tools used. COCD is the Dutch acronym of the company name: Center for Development of Creative Thinking [67]). Given the specific greenhouse horticultural context of the innovation trajectories, the stages concerning the definition of the innovative solutions are mainly result-driven. More specifically, the results of the tests in the greenhouse centres that focussed on crop quality and the reactions of the growers influenced the concept definition further. For instance, the innovation trajectory on LED-lighting adapted the lighting spectrum for the different crop types to obtain the best results concerning product quality and labour conditions to prevent difficulties when assessing the crops. The feasibility of the initial concepts of another trajectory (energy balancing screens) was evaluated in view of the production possibilities of potential partners. From a managerial point of view, co-creation tools are especially useful to create a common goal, language, and scope within the team and to safeguard team cohesion.

4.4. Initial Concept(s) Development Stage

The information that emerged from the previous stage redefined the team's common innovation goal and made this goal more tangible. This resulted in better team alignment. Combining all this information resulted in improved concept development in the innovation trajectories. The innovation concepts developed led to new crop experiments and lab experiments.

During this stage, a new management challenge appeared as an expertise gap emerged between the technical partners who were responsible for the innovation development from a content perspective and the communication partners whose task was to capture the value created from the network. (" ... I noticed a gap between the content-driven people within the project, those who are developing the technological innovation and those like us who are focusing on the communication part. How important the content-driven people perceive this communication and how much priority they give to it.")

Team members expressed a need to meet more frequently. This need stems from an interest to learn from other partners. Therefore, in the last nine months of the project, some of the innovation teams organized monthly meetings, resulting in more in-depth interaction. (" ... the second time you notice that there already exists more interaction. And I do think that the more often you organize these meetings, the more other partners will ask a question like: "Why did you do something that way?". This is the only way one can learn. You need those contacts ... ")

The challenge that appeared in this stage was related to communication and to the creation of a 'common language' to overcome knowledge and information gaps. We introduced the idea that the communication about the innovative concepts has to be 'grandma proof' or should at least be understandable by growers. Visualization of the concept (drawings, graphics, posters) and narratives and storytelling were used to gather reactions from the end-users on the improved concepts. Specific for the horticultural context is that new experiments were set up as much as possible so that in the next stage, real demonstrations of the improved concepts could be showed to growers and experts.

4.5. Rediscovery Stage

The communication concept that was developed in stage four is tested in stage five. Here again, external partners were involved in co-creating the best possible innovation. Information is obtained from meetings with crop consultants, growers, and experts, by interviews and surveys based on concept-testing scenarios. As such, the original innovation concept is redefined. In this stage, according to the interviewees, the coordination of the project became smoother, because of the experience and knowledge sharing that took place within the core team. The communication concept also helped the less technical team members to get a better understanding of the goals and achievements. A crop-related challenge that appeared at this stage was that it is important in the context of innovation development in the greenhouse horticultural industry to align the timing of the co-creation interventions with the timing of crop experiments. ("Some of the interventions that took place were planned at a timing that was not very useful to us to integrate the output of the co-creation exercises in the crop experiments. ... So ideally, the intervention should take place before June to adapt the experimental set-up for tomato to the results of the co-creation workshops.")

When developing a timeline for the innovation project and reflecting on milestones, in the early stages (stage one), co-creation teams should consider context-specific aspects.

4.6. Concept(s) Improvement Stage

Based on results from the previous stage, during the concept improvement stage, core team members need to make decisions on further concept improvement and on which (external) organizations will develop or deliver the necessary resources, materials, skills, or knowledge to realize the innovative solutions. The focus of this stage is on concept improvement.

Since the team members have collaborated for a while, it becomes easier for them to discuss ideas for improvement. Over time they get to know each other and have an impression of the communication style and collaboration style of the other team members. Given their teamwork experience, they might predict to a certain level how the other team members will react or will reflect on certain ideas. While the team diversity remains, it is not detrimental per se for the innovation development. In mutual agreement, the co-creation teams managed to achieve concept improvement with an agreement about constructive compromises.

The learning from this stage is the importance of communication. A profound understanding and respect for team diversity are beneficial from the beginning onwards, both for team cohesion and for team performance.

4.7. Prototyping

The redefined concepts are developed into prototypes of sustainable, high-tech innovations. The innovation trajectories on the topic of energy-efficient growing techniques resulted in optimal LED-lightning for the cultivation of lettuce, tomato, and cucumber, an optimal multilayer cultivation system to cultivate strawberries, and the development and testing of a low-grade heat system. The energy savings were on average about 32% [68]. The climate-neutral innovation trajectories developed a vapor heat pump. Growers showed a strong adoption intention towards this system as it seems to resolve often-faced problems related to humidity and crop infections (group discussions with a total of 42 growers). The innovations on climate-neutrality were able to achieve energy savings up to 65% in the cultivation of bell pepper with an energy balancing day screen system and a performant balancing night screen. The energy savings reached in the cultivation of tomato were 41%. The products developed are not all ready for wide/full-scale application, but they show the potential of the developed innovations for the industry's future. As such the project outcomes and the developed innovations contribute to sustainable greenhouse horticulture.

In this stage, communication remains crucial, as the prototype should be described in detail. Seminars and webinars were organized, descriptions of the solutions and achieved results were translated into a common language and made available to all possible stakeholders (e.g., project website). The co-creation process does not end at prototype development. Growers pronounced to be willing to collaborate and test early-stage working prototypes in a real live setting (their own company) in collaboration with research centres.

4.8. Project Outcomes

Overall, the partners interviewed were satisfied with the results obtained during the project and the structure of the co-creation process. The project resulted in the development of sustainable, high-technological innovations that can align the greenhouse horticultural industry in the border region Flanders (Belgium)/The Netherlands with sustainability goals set by the European Union [2,3]. The different innovation trajectories resulted in the development of six sustainable, high-tech innovations that significantly reduced energy usage and improved climate-neutrality without jeopardizing yield results, crop quality, working conditions, and economic results. (Results of each trajectory can be consulted at the project website [69]). Even though the journey to the results was sometimes bumpy, achievements were made, and learnings and insights emerged from this process. ("I do think there are positive results, but not everything on the road went smoothly. We learned from it and we will definitely take these learnings into account in future projects to anticipate.")

4.9. Reflection on the Co-Creation Process

Although at the start of the project, some researchers were rather reluctant towards the co-creative methodology, gradually they got convinced of the added value and acknowledged the potential of co-creation for the innovation process. They mentioned that co-creation made it possible to approach a certain topic or issue from a different angle than they were used to and perceived this as an advantage. ("The analysis we made at the beginning with our work package worked well. In the beginning, we struggled a bit with it. But in the end, you realize that it is necessary to go through this process to achieve the result using co-creation. To look at what the strengths and weaknesses are, to reflect on how growers will perceive the system and how they will implement it.")

Most interviewees consider using the co-creative approach again for future innovation development.

5. Discussion

5.1. The Context

This study reports the management of a co-creation processes to bring the greenhouse horticultural industry in the border region Flanders (Belgium)/The Netherlands in line with sustainability goals by implementing sustainable innovative high-tech solutions. Sustainability is seen as the result of the intersection of economic (e.g., profit, ROI), social (e.g., equality, diversity, and wellbeing), and environmental (e.g., renewable resources, low emissions, and waste) value [70]. Throughout co-creative trajectories sustainable high-tech innovations were developed that support the industry in attaining energy-efficient and climate-neutral goals, while at the same time taking optimal greenhouse micro-climate conditions into consideration such as temperature, humidity, light, and CO_2. We observed the complexity of the initial problem and the evolution of problem and solution definition throughout different stages in which a lot of evaluative moments were embedded, and the need of a structured process became obvious. Viewpoints from different research disciplines (design, management, consumer behaviour) were taken into account to get a grip on this process.

These observations are in line with Ferraro et al., who posit that sustainability-related challenges are often defined as difficult problems on three levels: (1) complexity and non-linearity, (2) uncertainty and problem evolution, and (3) evaluative reflections [71].

5.2. The Process

In line with Ferraro et al. [71], to facilitate the management process of the co-creation trajectories, we provided a structure starting from the Double Diamond Model [20], which enables iterations, takes into account the evaluative character of a process, and provides critical reflection moments. Because of the complexity and the specific context, we divided the process into seven stages. Every stage aims at specific progress towards an innovative sustainable solution and is characterized by challenges that have to be managed. The first stages are crucial for teambuilding and goal definition. The subsequent stages are more result-oriented. The results show that partner's expectations, a clear role division that is understood by all involved parties, unambiguous communication, conflict management, and project management are critical factors that should be monitored and controlled thoughtfully. This insight is in line with Roosens, Lievens, and Dens [14] and Edmondson and Nembhard [10]. The more experienced the team members became with the co-creative process, the smoother it went.

As complex sustainability issues require a multi-level ecosystem perspective, involving different stakeholders in a co-creation process is crucial [72]. From the beginning onwards, team management is challenging. Team composition poses the biggest challenge during the introduction stage. Team composition requires different individuals that relate to team-level constructs leading to collective performance [73].

Special attention should be given to the size of the team, team diversity in terms of skills and personalities, as well as the expectations of the team members. In the current project, we decided to divide the initial project team (59 members) into two topics (energy efficiency and climate-neutrality) and created seven small core co-creative teams (maximum size six members). This is in line with Stewart's [74] finding that a project team ideally consists of less than seven members. Previous research shows that small teams are more cohesive [75]. Members of small teams tend to be more motivated towards team activities and decision making [76,77] and experience fewer conflicts [78]. Larger teams result more often in subgroups and cliques [79].

However, the need to exchange ideas with project members assigned to other teams was observed as well. Since mixed findings of team size are reported in the literature, we tried to overcome this issue by organizing biannual meetings with the overall project team (n= 59) to extend the learning process. Moreover, during the discover and rediscover stage, the team was extended with other stakeholders such as end-users, key partners, and experts [39,54]. Larger teams are considered beneficial to obtain resources such as time, money, and expertise [80]. These resources are expected to be particularly beneficial for completing difficult tasks in complex and uncertain environments. In the context of a sustainable greenhouse horticultural industry, a complex and challenging environment, the large total number of project team members was considered beneficial.

Besides team size, team diversity is also often an issue. We strived for team diversity in terms of skills and expertise [81–84]. Due to these complementary skills and capabilities, the teams performed well and achieved impressive results. Moreover, we noticed differences in personality characteristics within the teams [85,86]. These differences are reflected in communication styles and role assignment. A team role is defined as the performance and team contribution of a team member with specific personality traits and abilities [62].

Our research revealed that it was not always easy for the team members to communicate and understand each other. Some team members value interaction, team connection, and negation, whereas others mainly want to proceed or pay attention to details, and still others want to achieve fast results. In line with Belbin's [62,63] team roles theory, team-balancing and complementary roles worked out well to overcome weaknesses and amplify strengths [87,88]. Since we worked with small teams, the co-creation facilitator holds a central position to effectively coordinate the process and to make team members collaborate [89].

Moreover, expectations are a driver to why one engages in co-creation, team collaboration, as well as to make progress. Some team members are primarily goal-oriented and want to achieve results quickly. Others want to profoundly control the progress. Some of the team members are more oriented to team connection and like to meet frequently (preferably physically). Others are more results-oriented and want to make progress.

Therefore, during the first team meetings, we observed how important it is to facilitate this introduction stage by using tools to get insights into each other's communication styles [90].

5.3. Communication Is Essential

Communication is related to team cohesion and team performance and affects coordination and strategy formulation [91,92]. Team communication is an exchange of verbal and non-verbal information.

We observed that communication is adapted throughout a co-creation process. This corresponds with Jarvenpaa et al. [93] who report that communication measured in a later stage in a team's life cycle was more strongly related to performance than communication measured in an earlier stage. This is also related to the increasing familiarity amongst team members, which was also often mentioned in our study. In the earlier stages, communication was needed to build trust and openness between the team members.

The need for frequent communication differed among team members. Some team members explicitly expressed their need for frequent meetings. Team meetings with the core co-creation team were held frequently, depending on the need of the specific team. Every six months of the project a general assembly meeting was organised with all project partners (n = 59).

In the context of high-tech sustainable innovative solutions, language and jargon was often found to be a burden between partners with different backgrounds. Plant physiologists and technological experts do use jargon that is not always comprehensible by facilitators, researchers, and other co-creative team members. Communicational barriers between subgroups may prevent an adequate information flow [94]. Therefore, creating a common language within the team is challenging. During the case study, tools were used to overcome language barriers. Templates with drawings and figures were integrated during workshops at different stages of the co-creation process that enable information exchange between team members. The most crucial stage is the concept definition stage (stage four—develop). The innovation concept must be presented in a way that it can be understood by different stakeholders. Narratives and visualizations are important tools to use in this stage [95,96].

5.4. Co-Creating Value: A Strategic Approach

Value co-creation can be understood as a "joint, collaborative, concurrent, peer-like process of producing new value, both materially and symbolically" [33]. In the current study, we aimed to create materialized innovations (energy and climate-neutral solutions) that represent 'sustainable' symbolic values. The initial stages (stage one and two) of the co-creation process aim to approach sustainable innovation development strategically. Therefore, insights from business modelling [66] are included in the management of the co-creation process. The team members appreciated this approach as it made clear how the team's skills and resources can connect with the needs and wants of growers and how they can strive towards valuable solutions through customer and relations propositions and partnerships [97,98].

Moreover, from a strategic point of view, in the final stage of the co-creation process, three design dimensions should be taken into account: feasibility, desirability, and viability. Feasibility refers to whether the prototype of the innovation takes relevant factors into account, including economic, technical, legal, and scheduling considerations, to ascertain the likelihood of completing the project successfully. Desirability is the assessment of whether the innovation is fully adapted to the needs and wants of the end-users. Viability refers to the question whether the innovations can be implemented in a practical and useful way. According to the observations during the three-year co-creation process, the market research, the tests with the research centres, the in-depth interviews with experts, growers, and partners, these three dimensions seem to be well-covered.

5.5. Co-Creating Sustainable Innovation: Choices to Make

Co-creation is an ongoing iterative process that starts with diverse idea formulations but converts towards better and useful solutions (e.g., Double Diamond) [20]. In the convergent stages (three, four, six, seven) the team has to make choices based on previously acquired information. The information is gathered (stage two and stage four) through research with end-users, stakeholders, and experts by means of various tools (e.g., workshops, interviews, concept tests, surveys). During our study, we did extensive research with various stakeholders, revealing drivers towards adoption intention by end-users, preferences, and rejection of developed product attributes and barriers for production. In the greenhouse horticultural context, the 'concept development' stage (stage four) consists of the crop experiments executed at the research centres in which numerous parameters are measured.

Workshops with the core co-creation teams evaluated the input from the extended co-creation team and led to choices that improve the innovative solutions in line with the value (sustainability) aimed for and with the strategic choices (grower markets, available resources and skills, increased knowledge) that were set out in the early stages of the process. Idea evaluation happens after ideas to improve the innovation are generated and before the selection of ideas for further implementation [99,100]. During idea evaluation, available options are assessed against certain standards [101] for implementation, rejection, or revision [102]. Creative ideas are generally characterized to be both original and useful [103,104]. During our study, we provided tools for idea evaluation (e.g., SWOT) and idea selection (e.g., COCD-box). In the current study, the effectiveness of the innovation is rated based on energy consumption saving, the sustainable goals reached and the production quality and crop conditions. In the subsequent stages belonging to the innovation solution phase, these tests and experiments are further adapted to reach the most ideal solution that provides the best results.

6. Managerial Implications

The study reveals a lot of managerial challenges to co-create sustainable high-tech innovations. It reports on insights on how to cope with these challenges. Various tools were used in the different stages of seven co-creation trajectories to facilitate innovation development and stakeholder relationship management. Based on this research, a web tool was created by the facilitators of the co-creation process that functions as a navigator for all kind of parties that want to collaborate on sustainable and climate-neutral (high-tech) innovations within the greenhouse horticultural industry [105]. The web tool gives an overview of the seven different stages in a co-creation process based on the Double Diamond Model [20] and the tools that can be used in each stage. Every tool has its own purpose, and the web tool guides the co-creation process to overcome difficulties and misalignment along the co-creation and innovation path. The tools' application gives the co-creation team insight into the different design drivers that shape the progress of innovation development.

7. Limitations and Suggestions for Future Research

The interviews with the project partners took place during the last eight months of the project. This means that the project partners were only asked at one specific moment to reflect on their experience in the project, which may bias the reflections on interventions that took place earlier on in the project. Therefore, future research is advised to conduct interviews more frequently during the process. The current results are based on an extensive case study in a specific niche context, the high-technological greenhouse horticultural context in the border region of Flanders (Belgium) and The Netherlands. As a consequence, the results cannot as such be generalised to other industries or contexts. The focus of this study was on the structure of the co-creation process and how the project partners who were interviewed perceived the co-creation process. There were no interviews conducted with external partner organisations that collaborated on the innovations. We suggest future research to investigate how external innovation partners perceive their collaboration in innovation development.

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