

Article

Engaging Citizens in the Bioeconomy: Insights from the Co-Creation and Co-Design in the Development of the Serious Bioeconomy Game “Mission BioHero”

Merit Tatar ^{*} , Mariia Khrapunenko, Richard Karl Henahan and Andra Asser

Institute of Baltic Studies, Research Think-Tank, Lai 30, 51005 Tartu, Estonia; maria@ibs.ee (M.K.); richard@ibs.ee (R.K.H.); andra@ibs.ee (A.A.)

^{*} Correspondence: merit@ibs.ee; Tel.: +372-6999480

Abstract: In serious game design, there is a growing trend towards involving players more substantially in the development process. However, several scholars and practitioners agree that still more research and empirical data are needed to guide such participatory prototyping processes. So far, less focus has been put on the influence of co-creation and co-design on participants in the process. This article explores the co-creation and co-design process in creating a serious game called “Mission BioHero”, with a focus on sustainability and the bioeconomy. The game aims to engage citizens in the bioeconomy, help them learn in a fun and interactive way, and aggregate their ideas to shape bioeconomy policies. This serious game was fully co-created and co-designed with citizens and stakeholders from eight regions in five European countries. This research investigates the nature and impact of co-creation and co-design on game development and its driving success factors, explores educational capacities of this participatory process on participants, and evaluates its impact on the co-designed serious game. The findings draw upon empirical data gathered from the co-creation and co-design phases, participants’ feedback, and external game players’ input. The study confirms the value of the participatory design process in serious games design and offers methodologies, tools and lessons learned for similar future processes.



Citation: Tatar, M.; Khrapunenko, M.; Henahan, R.K.; Asser, A. Engaging Citizens in the Bioeconomy: Insights from the Co-Creation and Co-Design in the Development of the Serious Bioeconomy Game “Mission BioHero”. *Sustainability* **2023**, *15*, 13364. <https://doi.org/10.3390/su151813364>

Academic Editor: Luigi Aldieri

Received: 14 July 2023

Revised: 24 August 2023

Accepted: 4 September 2023

Published: 6 September 2023



Copyright: © 2023 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

Keywords: co-creation; co-design; design thinking; serious games; serious game design; participatory game prototyping; bioeconomy

1. Introduction

The concept of collective creativity in design, commonly known as participatory design, until the recent emphasis on terms like co-creation or co-design, has been in existence for almost four decades. For instance, in the realm of urban planning [1], product and service design [2,3], and also in game design [4–7] the participation of end users has surged, marking a significant shift in design processes.

Similarly, in the gaming industry, serious games as a tool to share educational content and provide learning experiences have gained popularity in recent years [8] by leveraging the power of games for purposes beyond pure entertainment. Unlike other services, products, or solutions that usually serve a single purpose, a serious game is tasked with not only being fun and engaging but also raising awareness and educating the player [9]. Serious gaming is proven to be effective in presenting complex topics, experimenting, and engaging a wide circle of participants [10–13]. Such games leverage game mechanics, interactivity, and narrative elements to engage players in meaningful experiences, fostering learning, skill development, or addressing real-world challenges. As one of their main purposes, serious games are thus believed to enhance opportunities for learning, practice and behaviour change [14], aiming for so-called social learning [15]. Reviews about serious games addressing the sustainability problems have shown that such social learning is frequently assessed through concepts of cognitive, normative, and relational learning [15,16],

where “cognitive” refers to the acquisition of new or restructuring of existing knowledge; “normative” to a shift in viewpoints, paradigms or values; and “relational” to the ability to cooperate between stakeholders, enhancing trust and improving understanding of others’ mind-sets [15].

Designing effective serious games requires careful consideration of various elements. Game mechanics should be aligned with the intended learning outcomes, providing players with engaging challenges, feedback loops, and rewards [17,18]. A carefully constructed storyline can deepen player immersion and foster an emotional bond with the game’s objectives and overall user experience. Simultaneously, intuitive interfaces play a crucial role in facilitating effortless adoption and encouraging sustained engagement [19]. Moreover, involving target users in the design process through co-creation, co-design, and playtesting allows for iterative improvements and maximizes the game’s effectiveness [20], as serious games often aim for social learning that is transferable to the world outside the game and can fit well with the learning-by-doing approach [8,15,21,22]. By employing collaborative and participatory design approaches, serious games can effectively integrate themselves into real-world situations. Such approaches facilitate the expression and translation of existing narratives, social conflicts, and institutional responses into a game context. As a result, serious games can become powerful tools for representing and addressing complex real-world issues [12].

However, in the game development processes, the user-centric design approach is not common [7]. Stakeholders can be involved in the game design process as users, testers, informants, and design partners fully incorporated in a co-design process, as is argued by scholars [23,24]. Still, game design approaches mostly engage potential players only for game-testing. The target groups and other stakeholders rarely participate in the early phases of the design process [7,20,25–27] and user input and feedback are often gathered too far in the development process, limiting, for instance, the potential to optimise the balance between an engaging, entertaining game and its educational dimension [9,25]. On the contrary, in the participatory design framework, the target audience is already included in the earliest phases of the design process [20].

Even though not yet widespread, the participatory design or co-design has already been recognised as one of the methods to integrate views, ideas, and needs of the target audience into the serious games by involving them in different stages of the game design process [28]. The nexus between co-creation, co-design and serious game development has been increasingly researched, i.e., in [12,23,25]. Serious games are designed to deliver specific learning outcomes or behavioural changes and this has led developers to explore more collaborative approaches that prioritise engagement and effectiveness to develop more relevant games. In the literature, the common notion regarding co-creation and co-design as a method to develop serious games is centred on its capability to embed real-world components in the game environment, while allowing participants of the co-design process to experiment and learn [12,28]. The co-design process helps to express societal issues in an understandable context by involving different stakeholders and combining their perspectives and views on the topic that the game brings to the player [12,29]. Even though no specific protocols exist for developing serious games [30], co-creation and co-design have emerged as a way to incorporate diverse perspectives, ideas and expertise into the game design process, aiming to offer more engaging and impactful experiences, and several case studies have already shown that the co-design approach can be used to create serious games [7,12,20,27]. Furthermore, some argumentation exists that for understanding complex societal issues, not just serious games themselves but also the co-design process to create a serious game is an added value [7,23,31]. Gugerell and Zuidema [12] emphasise that this method facilitates learning throughout its use, meaning that the participants of the serious game co-design acquire knowledge about the topic while being engaged in the development process.

However, while the importance of co-creation and co-design in serious game development is recognised, there has been a relative lack of focus on their potential to initiate such

learning events. It is more known that, for example, co-design has been used to develop game concepts and the initial idea, but less so for the mechanics of the game, gameplay, and other aspects [15,32–35]. The emphasis has primarily been on addressing usability and playability concerns rather than exploring the learning and experimentation opportunities that arise from participatory game design processes [7,24]. Additionally, little attention has been given to the co-creation and co-design process itself in facilitating learning about the serious game topic among the participants, i.e., to the learning that happens during the participatory co-design activities [12,13,24].

Even less research has been done on the co-design of serious games that deal with sustainable development, for example, few of them have been created in the fields of climate change, energy, or the environment, and what directly relates to the topic of this article, in the bioeconomy field [13]. In addition, when it comes to the assessment of the effectiveness of the games that relate to sustainable development, then research has been scarce here as well [11,13,15,32,33].

Developing a serious game is not an easy task and is complicated by the lack of knowledge about concepts, methods, and tools used to create them and lack of studies articulating the game design process [6,13,28,36–38]. Thus, there is the need for proven frameworks and tools to develop more effective serious games [19] as well as evaluation approaches of participatory design processes [23].

The current article contributes to the research on serious games that educate about sustainability and bioeconomy as well as about the use and benefits of co-creation and co-design approach in the game development process. At the centre of this study is the serious bioeconomy game “Mission BioHero” [39] that was created within the Horizon 2020 AllThingsbio.PRO project [40], the goal of which is to involve citizens in the bioeconomy and use their opinions on the topic to further develop the bioeconomy policies in the European Union (EU). This project focuses on four key themes in relation to bioeconomy that are part of daily lives: food packaging, fashion and textiles, kids and schools, and jobs and careers, all of which were incorporated into the developed serious game. The “Mission BioHero” game explains the bioeconomy and its connection to these four topics to citizens in a playful and engaging way. It consists of eight campaigns, each focusing on a specific theme that the player must achieve to save planet Earth. Co-creation and co-design were one of the guiding principles to develop the “Mission BioHero” game. This experiment is a valuable empirical case study to highlight the value of co-creation, co-design with end users and its potential impact on the design of a serious game in the bioeconomy field. The case study also highlights key lessons learned, since during the project implementation, the transformative power of co-creation and co-design in serious game development was explored, its benefits in terms of user engagement examined and learning outcomes and innovation analysed.

This article does not evaluate the effectiveness or impact of the serious game developed, since the needed amount of data for such analysis was not available after the immediate end of the project. The main aim is to understand the nature and influence of co-creation and co-design in developing a serious game for the participants, as well as the end result, i.e., the relevance and potential uptake of the developed game. The co-creation and co-design method was believed to be beneficial here, and the observations and empirical data gathered from co-creation and co-design phases, participants’, project partners’ (called mission partners), and external game players’ feedback have been assessed to find answers to the following specific research questions:

1. How successful were co-creation and co-design in developing the “Mission BioHero” game in terms of process and satisfaction of the stakeholders and what was driving this?
2. What was the (learning) value of co-creation and co-design to the participants?
3. What was the value of the co-creation and co-design to the outcome, i.e., is the co-designed serious game a useful tool as perceived by the target groups to learn about the bioeconomy?

The paper is structured in six main sections. First, theoretical concepts of serious games and notions of co-creation and co-design, including their expected benefits in the serious game design process, are explained. Further, a “Mission BioHero” case study is introduced and the methodology of the study is presented, followed by the analysis of the “Mission BioHero” development process and results. The last sections discuss the results, map the possibilities for further research, and provide conclusions.

2. Background

2.1. Serious Games

Even though there is already much literature available that discusses serious games [13,14,36], their definition remains broad and is mainly interpreted in relation to their aim and purpose. Since the time serious games came to prominence in the 1970s, their main characteristic has been the educational component, which was combined with entertaining aspects to train and/or develop the skills of the players [17]. Tuli and Mantri [28] concisely define serious games as ones that are developed and designed for aims other than entertainment, possessing immersive and interactive features with problem-solving approaches to improve teaching and learning.

Serious games can be effective tools for promoting behavioural change and raising awareness about several topics like social, health, and environmental issues [13,41] and often focus on challenging players with complex problems and decision-making scenarios. The common notion about serious games is that they facilitate an environment that allows the player to experiment and learn through engagement in hypothetical real-world situations [12,42]. Serious games act as a good basis for decision-making and communication, and many of them allow the players to act as a particular character and interact with each other within a regulated setting to achieve the set goals and objectives [13,25,43]. Lanezki et al. [23] add that serious games motivate players to reach goals and learn cooperatively, while at the same time implementing complex issues into the easy-to-understand game environment and raising awareness about them. Thus, they engage players in meaningful experiences, encouraging them to adopt new behaviours, understand complex problems, and make informed decisions (in [13]).

Moreover, serious games, especially digital ones, can serve as effective platforms for research and data collection [14,32]. By designing games that simulate real-world scenarios, researchers can gather data on performance, user behaviour and preferences. This information aids in understanding human interactions and refining further strategies in diverse domains.

The main difference between serious games and regular digital games lies in their end goals. Whereas regular digital games aim to keep the player engaged in the game as long as possible through fun and enjoyable gameplay, the serious game design is more aimed at the learning outcomes and experience with the knowledge that the player will get. The gameplay in serious games is also important, but plays a secondary role compared with educational aspects [11,38,44]. Nevertheless, for serious game design, it is usually a challenge to integrate learning principles in the gameplay without losing its entertainment factor and motivation to play the game further [11]. Thus, it can be argued that the more developers can incorporate the expectations of the potential users on all aspects into such game design, the more relevant is the result and that is where participatory design process potentially adds value.

With technological advancement, particularly digitalisation, the potential role serious games can play is becoming increasingly relevant [45]. The integration of digital tools in education has become even more relevant due to the COVID-19 pandemic, forcing teachers and students to adopt to digital and remote learning [46]. Paired with the fact that schoolchildren spend more time on game-related activities due to the massive increase in mobile devices and game consoles, increases the relevance of serious games concept even more [47]. Serious games can also be applied to science and research, which is well illustrated in the Dekker and Williams literature review on the use of serious games being

co-designed with their target group to address depression and anxiety disorders [48]. Taken together, the use of serious games is highly relevant and topical considering the advancement of digital tools—particularly as educational tools—over the past few years, which underscores its significance in a digital society.

2.2. Evaluating Serious Games

Serious games have proven to be effective when used in various contexts because of their ability to teach, persuade, and entertain [33]. Their effectiveness has been measured through the experience of the players: their increase in literacy; raised awareness about the issue in focus; acquired skills and knowledge, etc. [12] According to Wainess and Oneil [49], the effectiveness of a serious game can be defined in terms of (1) the intensity and longevity of engagement with a game, (2) the commercial success of a game, and (3) the acquisition of knowledge and skills as a result of the implementation of a game as an instructional medium.

There has been research carried out to evaluate the effectiveness of serious games in particular fields to see what further improvements could be made in developing such games. For instance, Wu et al. [50] studied twenty-one serious games related to the area of energy consumption. The results of their study show that a serious game can be a valuable tool in altering energy consumption behaviour for consumers. Additionally, by incorporating a well-designed gameplay concept, a serious game environment can introduce ground-breaking ways of interaction and relationships among consumers. Hammady and Arnab's [13] review of over 200 articles about serious games in different fields aimed to identify game design mechanics and features that are reported to commonly influence behaviour change during and/or after the interventions through these games, and Tan and Nurul-Ansa [8] reviewed the reasons for the increasing popularity of serious games, the features of successful serious games, and current trends in serious game application in environmental education, stressing their potential to “facilitate interaction between learners and the natural environment, and in turn strengthen environmental awareness and appreciation” (p. 19). Indeed, several research findings consistently highlight the effectiveness of serious gaming as a powerful tool for enhancing learning outcomes, and when compared to traditional methods (see also [13]). That is why serious games are a popular method to bring about knowledge on the themes that are important for society and its sustainable development, for example, natural resources management, energy efficiency, urban planning, or climate change, among others [7,10,12,15,23].

Den Haan and Van der Voort [15] examined the current state of the art of different evaluation methods and procedures used to assess social learning outcomes of collaborative serious games by investigating 42 relevant publications and found that most evaluations focused on cognitive learning, few on normative and about half of the reviewed evaluations also on relational learning. In terms of tools, pre–post measures and qualitative interviews have been most widely used, mostly through self-reflective questions. Gameplay participant feedback is also widely used, as it is a relatively inexpensive and quick method for rapid assessment of the immediate impact of the game, and, indeed, is suitably robust when collated over a large number of game workshops (see in [14]). A multi-method evaluation approach is also recognised to fit well with serious gaming in general [15,51].

Some drawbacks related to the attempts to assess the effectiveness of serious games, especially in terms of behaviour change and social learning, are covered by several scholars [11,49,52], for example, the doubt of some researchers in the validity of the use of self-reflective questionnaires to assess the motivational aspects or that often no pretest of knowledge is implemented, which may unintentionally ignore the fact that differences in ultimate learning outcomes could actually be due to knowledge differences between individuals or groups at the start of the intervention [52]. Additionally, they discovered that players' motivation as an important aspect in cases where the effectiveness of digital game-based learning is not always assessed or the type of motivation measured [11]. For assessing motivation, it is advised to assess the motivation to play the game, especially

enjoyment, fun, and immersion; the motivation to continue using the game; and motivation towards learning the educational content of the game [53].

Researchers also discuss a variety of solutions for choosing more accurate evaluation approaches. In-game assessment becomes important to give information about the players' or learners' progress to the researcher and analyses the players' competences at various levels during the play [54]. Indeed, the game itself can generate valuable assessment data by documenting how the player acts and chooses strategies inside the game [55,56]. Thus, serious games open up rich possibilities for data collection with the aim of understanding a wide range of human actions and behaviours [14,57]. Moreover, the need to augment survey-based evaluation scales with qualitative insights gained through observation and interaction with end users is highly recommended [17], thus emphasising the need for mixed-method approaches while evaluating the game design development and final outcomes.

Inevitably, using serious games can be beneficial in educating and raising awareness about bioeconomy topics, which is directly related to the focus of this research. Over the last couple of years, there have been several EU projects developed to raise people's awareness about the bioeconomy and policies related to the topic. The EU-funded project BIOWAYS [58] has released two games—"Bio...What?" and "BIOChallenge"—where the players can discover how different raw materials can be used to produce everyday things and test their bioeconomy knowledge. The AllThings.bioPRO project, based on the outcomes of which this article is developed, has also created a bioeconomy game aiming to involve society in the transition to a more circular economy by introducing the key bioeconomy concepts and knowledge to the citizens and/or consumers. By following the overview of the widely applied evaluation methods and involving a mix of comprehensive evaluation tools, the case study provides learning opportunities in the discussions of serious game designs and potential added value by undertaking this in a fully participative way.

2.3. Co-Creation and Co-Design

The importance of user participation in designing innovative products and services has received growing recognition [29]. The concept of such open innovation promotes the idea that innovation can be enhanced by involving external stakeholders beyond the traditional boundaries of an organisation. "Co-creation", "co-design" and "design thinking" are keywords that are often applied in open innovation approaches [4,29,59]. These concepts originally emerge from transformative processes in the entrepreneurial world by bringing together users and producers for a collaborative creation of new products and services. Fields like research and education have increasingly taken up this approach [60]. This shift from the traditional expert-driven approach emphasises the need to involve end users, such as learners, educators, domain experts, and even the general public in the ideation and design processes. One notion of co-creation is that if a user is involved in the production of a good or service, the end value will be enhanced because the user/customer can tailor the product as he or she would prefer [7,27,59,61].

Co-creation itself is a broad term used to denote stakeholder involvement in creating something, whether it be a specific object, outcome, product, or service [59,62,63]. There is no single universally accepted 'official' definition of co-creation, as the term is used in various disciplines and contexts [64]. However, several definitions offered, for example, by Sanders and Stappers [4], Unalab [65], and the SISCODE project [66], provide a comprehensive understanding. Morello et al. [63] define co-creation as a "collaborative approach to engagement which allows stakeholders to collectively design and build more inclusive and sustainable mechanisms for change" (p. 93), which has become a popular method of engagement in different areas of policy and decision-making.

Co-design (also known as participatory design) can be a part of co-creation and refers to involving stakeholders in designing something and combining collective creativity throughout the entire design procedure [4,20]. Usually, involved stakeholders are the potential users of the designed result (product, service, or otherwise) or other relevant and/or

interested parties. Co-design recognises the expertise and perspectives of all participants, empowering them to contribute their knowledge and insights to create solutions that better meet their needs. The method's flexibility to "accept multiple perspectives and work with a wide range of stakeholders" makes it suitable for application in various contexts [67] (p. 4). If used properly, it is a powerful tool that not only helps to ensure that the final result meets its users' needs but also that there is a relationship between the designer and the users/stakeholders. Similar to co-creation, there is no single universally accepted 'official' definition of co-design, as the term is used in various disciplines and fields. However, there are a few recognised definitions that provide a comprehensive understanding of the concept, for example, those provided by Sanders and Stappers [4], Kleinsmann and Valkenburg [68], Steen [69], and the Design Council [70].

Concepts of co-creation and co-design intertwine closely with another popular strand: the design thinking approach. Design thinking is closely connected with interdisciplinarity. Its tools are helpful to visualise content, knowledge, relations, and mechanics and develop them further in iterative workshops with various stakeholders [23,71,72]. Design thinking offers a range of methods and tools that support collaboration and co-design, such as ideation techniques, empathy mapping, prototyping, and user testing [72,73]. Together, design thinking and co-creation, as well as co-design, foster an environment that encourages collective creativity, user participation, and the development of solutions that address real-world challenges.

Co-creation and co-design in any domain or innovation process should be viewed as a continuous process: neither can be a one-time event but should be thought of as a process in which stakeholders are engaged and followed up on. As such, long-term engagement requires what is commonly known as 'community building', i.e., recruiting participants to not only offer up their ideas but also to learn and collaborate with others (often cross-sectoral actors) while working towards a mutual goal. Some key steps to foster long-term stakeholder engagement and its orchestration are packaged by Unalab and other toolboxes [73,74]. They focus on community building, setting up processes and platforms for collaborative learning, guaranteeing transparency for all participants in the process, planning for options to integrate newcomers to the process at any stage and orchestrating and managing the system so that all components are integrated into their specific needs.

2.4. Benefits of Co-Creation and Co-Design

Since the notions of co-creation and co-design have become more widely accepted in different sectors and domains and methods of design thinking increasingly applied in innovation processes, the value and benefits of these new approaches have been under focus. Co-design brings about two overarching advantages, demonstrating its ability to generate original and valuable design concepts for users [75], while also enhancing overall product quality [76]. Researchers have found that a co-design approach facilitates a greater number of design ideas compared to non-co-design methods [77]. Moreover, innovations proposed by users during co-design activities exhibit a higher level of originality when compared to those generated solely by professional developers [78,79]. In service design contexts, co-design offers a range of benefits, including a deeper understanding of end user's needs, the generation of more original and valuable ideas from users' perspectives, and the creation of a better alignment between services and customer/user requirements [79]. Ultimately, co-creation and co-design enable enhanced service experiences and higher service quality [29].

Regarding the benefits of co-creation and codesign in developing serious games, some case study examples are promising [9–12,23,28,48]. For example, Lanezky et al. [23] analysed the development process of the serious board game "Changing the Game—Neighbourhood" and found that the influence of all participants of the co-design phases was crucial for the development process of the serious game, especially for the expansion of the learning content, the improvement in the gameplay, and the balancing of the difficulty level. All and Nunez Castellar's study of the educational game for road safety [80] indicates that co-design can be a source of additional ideas on top of other research methods such as state-

of-the-art analysis and expert consultation and thus can lead to more effective interactive content creation. In several other cases, including the target groups in the co-design process of a serious game helped create an understanding of current behaviour, preferences, and needs of the user, thereby enhancing the uptake and adherence of the intervention (serious game) [48,81,82].

However, co-creation and co-design do not usually deliver ready-to-use ideas or complete insight into the themes or game mechanics that would attract the whole target group. Rather, one should regard such a participatory design process as a useful source of inspiration for concept development and a method to broaden the perspective of game developers and researchers [32]. Therefore, it is useful to understand the qualitative value of the co-creation and co-design and find the best model, tools, and methods to foster the process to gain maximum benefits for all stakeholders—developers and participants. Kristensson et al. [59] focused on the conditions that lead to the benefits of co-creation in new technology-based services. Their empirical data suggest that user involvement during new product development should consider the following key strategies: (1) users identifying needs in their own setting of use; (2) users identifying needs in their various roles; (3) providing users with analytical tools; (4) motivating users via the apparent benefit to be gained from their involvement; (5) non-reliance on brainstorming when generating ideas; (6) involving users not having too much knowledge of technology; and (7) the involvement of a heterogeneous group of users to ensure that a diversity of ideas is provided for future services. Similar and connected principles that characterise a co-creative process and make it inviting for participants were phrased in 2017 by Jansen and Pieters [83]: (1) togetherness: there is an equal collaboration between all internal and/or external parties; (2) end users: they must play a central role in the overall process; (3) ongoing: the process is ongoing and participative in every phase; (4) productive: it leads to the implementation of the co-created solution; (5) transparent: relevant information is accessible to all; (6) supported: supported by all stakeholders; and (7) value-driven: results in value creation for end users and involved parties.

2.5. Evaluating Co-Creation and Co-Design

While there is widespread agreement on the value of involving end users in the design process of products or services they may eventually use, there is a need for concrete evidence regarding the impact of such involvement [29]. Thus, an important part of any participatory approach is its evaluation to understand the quality and impact of the process. This entails monitoring the process from inception to conclusion and gathering various types of data on the users engaged, activities conducted, and results achieved. Nevertheless, few studies have thoroughly examined the precise and multifaceted effects of end user involvement on the actual design outcomes being developed, especially in the game design field [84].

Evaluating co-creation and co-design is mainly accomplished through a mix of quantitative and qualitative research methods such as counting facts and figures, conducting interviews, and questionnaires [9] that provide data on users/participants, e.g., age, gender; how participants are engaging, how often, how long, and which activities; and feedback about participants' experiences [85]. The user experience and satisfaction with the process is an important criterion for successful co-creation and co-design [64,66]. However, the non-linear nature of these processes can pose a challenge for evaluation, especially because co-design can include a wide range of activities that can make it difficult to directly link and attribute the co-creation and co-design with the outcomes; co-design may not even have predefined outcomes and different participants in co-design may engage in different ways or have different experiences. As such, monitoring the co-creation process and co-design throughout its various stages and constantly recording users' behaviour, engagement patterns, and opinions can provide the main insights into assessing the impact of the co-creation and co-design approach. If available, quantitative data such as participant numbers is helpful as well in supporting evaluation, providing both additional information

and a means of validating the qualitative input, but it alone provides an insufficient basis for evaluating the involvement of stakeholders [86,87]. It is therefore important to combine several methods and tools to gather input for evaluation, especially highlighting collective discussions between participants, using interviews and direct contact with evaluation target groups, combined with more quantifiable and standard surveys helping to keep track of progress over time, and collecting standardised information from the evaluation target groups.

By fostering effective co-creation and co-design in serious game development, the AllThings.bioPRO project aimed to ensure that the game meets the needs of the target audience, addresses complex issues and provides an engaging and impactful experience. In the following sections, the process is described in detail and lessons learned are discussed.

3. “Mission BioHero” Case Study

Bioeconomy as a Background Theme

The concept of the bioeconomy has emerged as a response to addressing challenges related to climate change, food security, health, industrial restructuring, and energy security. These worldwide challenges are persistent, highly complex, open-ended, and characterised by uncertainty in terms of how they should be addressed [88–90]. However, there is little consensus on what the bioeconomy implies [91]. For example, the conceptualisations of the bioeconomy range from closely connected to the increasing use of biotechnology across sectors [92] to one where the focus is on the use of biological materials [93].

The European Commission describes the bioeconomy as “using renewable biological resources from land and sea, like crops, forests, fish, animals and micro-organisms to produce food, materials and energy” [94]. Further, the EU Strategy for the Bioeconomy states the bioeconomy covers all sectors and systems that rely on biological resources, their functions, and principles [95]. The AllThings.bioPRO project subscribes to a simplified version of this, which is that the bioeconomy is everything that is produced with renewable biomass [96].

The EU identifies the bioeconomy as a major contributor to the overall sustainability goals, most notably the European Green Deal, with aims to transform the EU into a modern, resource-efficient, and competitive economy. According to the European Commission, the bioeconomy can contribute significantly to sustainability goals across all sectors in the economy, including carbon sequestration, replacing fossil-based products with biomass, promote clean energy through the use of biofuels, and improve the energy efficiency of buildings by using bio-based materials [96].

Despite these potential benefits, the bioeconomy still faces several challenges to scale. Among those challenges is the need for a skilled workforce to develop the bioeconomy and the integration of bio-based materials in sectors such as construction and textiles and packaging. Furthermore, the scaling of the bioeconomy also requires consumer literacy on the topic to support changes in consumer behaviour, i.e., shopping for bio-based clothes, bio-based food packaging, etc. [97]. Indeed, fostering ecological knowledge and education in society can influence consumption patterns, government policy-making, and contributes to a more sustainable economy [98].

The AllThings.bioPRO project recognises that to address the challenges above, citizen engagement and involvement is necessary. The chosen methodology in AllThings.bioPRO facilitates this engagement through the development of a serious game that educates the user about the bioeconomy and enables them to make sustainable shopping choices. The serious game concept was chosen as the ideal tool for citizen engagement because serious games have been shown to be effective in encouraging behavioural change and can be useful for collecting data for academic or market research (see Sections 2.1 and 2.4). In this context, the serious game developed in AllThings.bioPRO serves the dual purpose of educating citizens about the bioeconomy, while also collecting useful data that could help inform policy-makers, research institutions, and bio-economy industries, thus creating a symbiotic relationship that helps scale the bioeconomy.

Since the project focuses on citizen engagement, the project partners wanted to focus on topics within the bioeconomy they were likely to interact with daily. Therefore, the project focused on four main mission themes, those being: jobs and careers (J&C), fashion and textiles (F&T), food packaging (FP), and kids and schools (K&S). These themes are described in Table 1 below.

Table 1. Missions of the serious bioeconomy game “Mission BioHero”.

Mission Name	Description and Aim	Expected Benefits for the Bio-Based Industry
Jobs and Careers (J&C)	Users match their skills and interests with existing job profiles and related skills and competencies needed in bioeconomy and bio-based industry in a playful environment.	The awareness about the career opportunities in the bio-based industry will be raised and promoted, which will result in the further popularisation of this field and innovative development of it.
Fashion and Textiles (F&T)	Users, together with other players, design bio-based fashion items and explore the production process (and working conditions) of bio-based textiles and fashion.	By actively engaging in the exploration of the production process, citizens can provide valuable feedback, insights, and ideas for improving the quality, affordability and accessibility of bio-based textiles and fashion.
Food Packaging (FP)	The users develop the perfect packaging for different kinds of food.	The development of the sustainable food packaging aligns bio-based industry with the growing demand for environmentally friendly solutions contributes to waste reduction and reduces reliance on non-renewable resources.
Kids & Schools (K&S)	Users explore the fundamentals of bioeconomy and capture how bioeconomy can be implemented in their everyday school life.	By educating students about the principles and practices of the bioeconomy, they gain a comprehensive understanding of the sustainable and renewable resources available for creating bio-based products.

Source: AllThingsbio.PRO website [40].

4. Materials and Methods

The aim of the serious game designed in the AllThings.bioPRO project is to raise awareness of the bioeconomy and to educate the player on different bioeconomy-related issues in four mission areas (Table 1). As a unique element, users were involved in developing this serious game from the very start through a range of focus groups, co-creation meetings and co-design workshops, which is, according to research, the main way of implementing co-creation and co-design with stakeholder groups. Evaluating the whole process was integrated into the overall work plan from the start of activities of the project to observe the process and reveal answers to the main research questions of current article. Evaluation was seen as a process of collecting evidence and reflection that helps to understand the dynamics, progress and effect of the work carried out, to learn from the experiences and to inform future initiatives and approaches. The methodology to assess the whole process and outcome of developing the bioeconomy serious game was along the principles of formative and summative evaluations. Formative evaluation aims at detecting areas for improvement, thus evaluating the process, whereas summative evaluation aims at determining to what extent an intervention was successful, thus judging its effectiveness [32,99,100]. While choosing the evaluation tools, the research team took into consideration that especially in

interventions aiming to reveal behavioural or attitude changes, two steps are important: a baseline assessment and a post-intervention assessment [14,49]. Central focus was also on assessing the effectiveness of co-creation and co-design via the participants', developers' and facilitators' satisfaction with the process (see also [64]).

As discussed above in relation to approaches to evaluate serious games as well as co-creation and co-design approaches to develop such games, the AllThings.bioPRO project opting for a mixed-method approach formed the foundation of the whole evaluation. Pre- and post-measurements were already included in the co-creation phases when the game did not yet exist and additional post-measurement done after the game had been designed and introduced to the participants and other external game testers in dedicated sessions. Further assessment of different aspects the game ultimately wants to achieve, like providing aggregated information about players' demographics, bioeconomy knowledge, bioeconomy interests, etc., is done via in-game assessment mechanisms.

According to the posed research questions, selected evaluation tools were based on the need to concentrate on the satisfaction and effectiveness of the co-creation and co-design process, capturing the drivers of success or drawbacks, assess the perceptions of the participants about the value of such participatory design process as well as get first indications about the potential value of user-centred design to the final result, i.e., the game and its potential uptake. The overview of used evaluation tools is shown in Table 2 and full details of these tools presented in Supplementary S1.

Table 2. The AllThings.bioPRO project evaluation tools.

Qualitative Methods	Quantitative
Document analysis	
Facilitators' self-reflection surveys	
Project partners bi-annual surveys	Statistical generalised data on game users.
Feedback from uptake experts ¹	Game-testing workshops and survey. ²
Interviews and focus groups	
Evaluation journal/log book for the research team	

¹: Uptake experts were contacted and interviewed by Prospex Institute and not by the authors of this article. The results of these interviews and workshops are gathered in [101,102]. ²: This report draws data from the moderated game-testing sessions hosted by the authors of the article. In addition, Bonn Science Shop (Wissenschaftsladen Bonn e.V.) (BSS) presented the Allthings.bioPRO project with their other sustainability projects during the "Bonn Science Night" 2022 and visitors had the chance to test the game on two smartphones and give feedback via printed feedback sheets. Their team received 47 filled sheets and a substantial ratio of persons who filled in the sheets were pupils (approx. more than one third, aged 11–15). The reflections from this feedback round are presented by Waltenberg and Steinhaus [103] as well as similarity to other feedback received through game-testing sessions was considered, as much as possible in the final modifications to the game. Source: Authors' own. Tools are described in detail in AllThings.bioPRO project deliverables [87,104] and Supplementary S1.

Such variation in methodological tools allowed a complex assessment of the co-creation and co-design process, observing its benefit, drivers and downsides, as well as assessing the value to the end result, i.e., the "Mission BioHero" game. Qualitative methods, such as interviews, focus groups, and participant-expressed open thoughts in the surveys and observations, allow us to gain in-depth insights into participants' experiences with bioeconomy, perceptions, and emotions about it as well as learning progress during the participative game development process. These methods provide rich and nuanced data, enabling a comprehensive understanding of the co-creation and co-design activities' effectiveness. On the other hand, quantitative methods via surveys help gather numerical data, such as satisfaction ratings, level of engagement, and performance metrics. These data provide a broader perspective on the game development and allow for some statistical analysis, enabling us to identify trends and patterns. By combining both approaches, a holistic view of the co-creation and co-design process is gained, validating and triangulating findings, and obtaining a more comprehensive and robust evaluation of the participative processes and serious game development. This mixed-method approach ensures the assessment is well-rounded and credible and can offer actionable insights for future improvements and iterations of the final product or for other similar processes.

5. Results

5.1. “Mission BioHero” Game Development Process

The “Mission BioHero” serious game was developed through the process of co-design, which is a part of a broader co-creation process. Co-creation and hence co-design follow an approach involving different perspectives and collaborative design tools, materials, processes, activities, or strategies, as discussed above.

The overall aim was to design the game in such a way that it would appeal to a wide range of target groups. The intended audience for the game encompassed civil society organisations, regional stakeholders, bio-based industry experts, game developers, and environmentally conscious individuals interested in sustainable solutions—thus, an enormously large and heterogeneous group. The co-creation process started in four bioeconomy-related missions (see Table 1 above) in five different countries, where two regional project partners (assigned the role of facilitators) together with their recruited local citizen groups and regional economic, research, policy and civil society experts already active in the specific area of the mission co-developed the concept and design of the serious game. One can imagine the difficulty in narrowing down specific requirements and preferences in the game, as each of these eight subgroups (two per mission topic) had unique needs and expectations. The challenge was in finding a common ground that would effectively address the educational, informational, and entertainment aspects desired by the wide array of potential players (see also [13,28]).

The process implemented within the AllThings.bioPRO project included several steps where the concept of the game and its purpose, logic, and visuals were developed together with the quadruple helix stakeholders. The co-creation and co-design process of the game included several phases with specific workshops, presented in more detail in Supplementary S2. They were held by eight project partners in five different countries (Food packaging—Germany and the Netherlands; Fashion and Textiles—the Netherlands and Sweden; Kids and Schools—Germany and Estonia; Jobs and Careers—Germany and Italy) as the logic was that two regional partners work with the same mission topic (see Table 1). The game development process was organised in two rounds of citizen focus groups and co-creation workshops together with citizens and field experts in the regions of the eight regional partners (co-creation phase), followed by two rounds of mission-specific co-design meetings (co-design phase), moderated centrally and held in English (see Supplementary S2). While the co-creation was taking place in the eight regions in five countries of the regional partners in parallel, the two groups dealing with the same mission topic worked together in the co-design phase [103].

In total, the co-creation and co-design process included 42 meetings. Initially, the focus groups and co-creation workshops as well as co-design meetings were planned to be run as in-person events. Due to the COVID-19 pandemic, all focus groups except for the ones in the K&S mission had to be held online. The involvement of the children’s group in the co-creation and co-design activities required extra preparations since the informed consent of their parents was needed as well as tools adjusted to better suit this target group. For example, the meetings with children were held in person and in their national languages (Estonian and German), since they were not fluent in English [103].

The phases were run during March 2021–December 2022. Figure 1 presents the “Mission BioHero” game development process and timeline schematically. A detailed overview of the step-by-step process of the co-creation and co-design activities implementation is described in the reports by Waltenberg and Steinhaus [60,103,105] and in Supplementary S2. A game developer was involved in all phases to answer questions from the groups about the game development technicalities, help to compile and comment on ideas for user requirements and game designs after the sequences of specific workshops, and support regional facilitators in preparing the next steps.

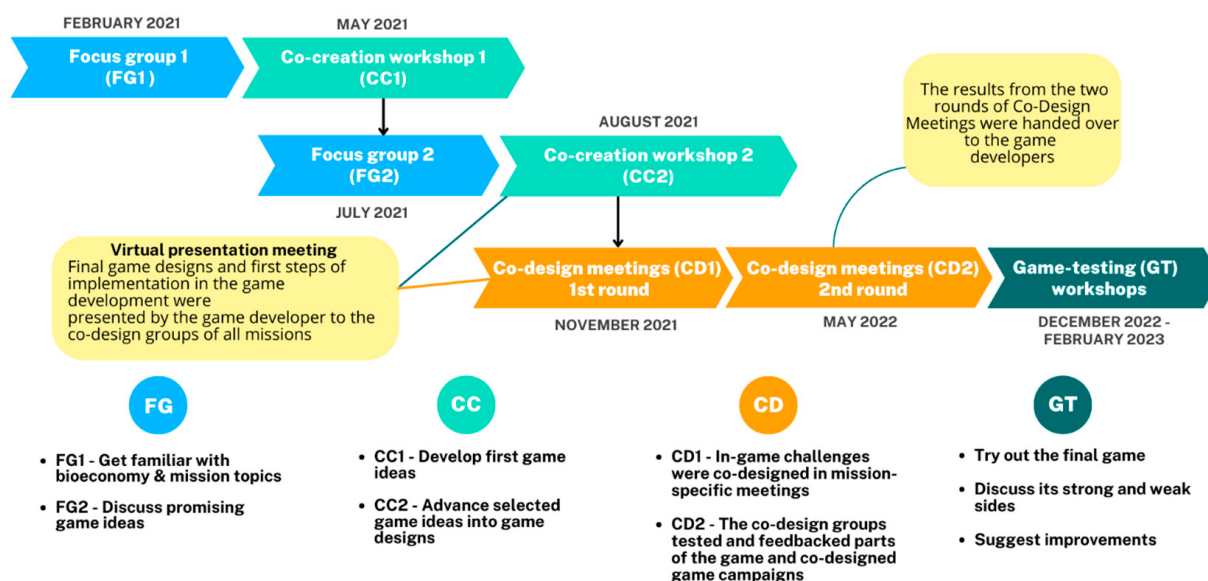


Figure 1. Scheme of the “Mission BioHero” game development process. Source: Authors’ own, based on [60,103,105].

The full engagement phase was occurring hand in hand with the evaluation process that independently assessed the results of the focus group sessions, co-creation workshops, and co-design meetings. The results of this formative evaluation helped to gather information and assess mainly the success of the co-creation and co-design processes and the individual benefits for the partners and all participants in the process. This was followed by the summative evaluation through game-testing workshops and follow-up interviews with partners and participants to explore how relevant, acceptable, and sustainable the co-designed game was. The main findings gathered through evaluation activities are presented in the subsections below.

5.2. Preparations for the Co-Creation and Co-Design

The methodology for implementing co-creation and co-design in developing the serious game contained the following required elements: (1) a fixed sequence of focus groups, co-creation workshops, and co-design meetings; (2) clear aims that need to be achieved for each sequence; (3) in co-creation, a typical structure for each meeting that incorporates design thinking elements (design thinking takes a human-centred approach and consists of five stages: empathise, define, ideate, prototype, test [69,72]); (4) in co-design, a typical structure for each meeting ((1) welcoming the participants and introducing the objectives, (2) getting to know each other, (3) presenting the status of the game and app development, (4) questions, answers, and discussions, (5) co-designing mission-specific in-game challenges, (6) presenting the results, (7) summary and next steps [103])) that focused on the later stages of game design, which builds on the conceptual game designs co-created in the previous phase; (5) recruiting a diverse participant group, which includes a mix of citizens and experts. The design thinking model was applied, which considers users’ needs and problems, challenges, and assumptions to create ideas and try out solutions. There is no singular concept of a co-creation workshop, but typically such workshops follow phases such as: (1) opening and familiarising; (2) diving into the topic; (3) ideating; (4) designing solutions; (5) closing; and (6) evaluating and reflecting [71,73]. These processes are typically not linear but iterative, and for each of these phases a variety of different methodologies can be applied [106].

Most of the partners who had to facilitate the sessions in the co-creation phase had used the co-creation and co-design methodologies before, with some partners being relatively experienced with them and others having only limited experience. What was rapidly found as crucial to deal with parallel processes carried out by different facilitators and

even in different countries was the setup of a central support structure by the overall process coordinator. Thus, the so-called co-creation working group was formed to meet virtually monthly, which dealt with the coordination of the engagement process, ensured proper implementation of the co-creation and co-design methodology, and organised the work of the HelpDesk. Next to the monthly working group meetings, the HelpDesk met every three months and consisted of the project's experts who provided one-stop-shop support to regional facilitators and allowed for deeper reflections and alignments between development processes moderated by different regional partners.

In addition, before the start of the co-creation and co-design activities, an internal training was organised that reintroduced the project goals, game mission, and the tasks to be performed to the regional mission partners who were to organise the co-creation activities. At the beginning of the stakeholder engagement process, the central coordinator developed "Stakeholder Consultation Guidelines" [106] to guide the stakeholder selection process as well as give an overview and guidance about the possible methodologies and tools that could be used within the focus groups and co-creation sessions. However, the focus group and co-creation workshop designs were tailored to the partners' context, if needed.

Therefore, the partners were provided with instructional materials about the focus groups, co-creation and co-design meetings, and discussed their concerns during the preparatory and working group meetings. These components contributed to the thorough implementation of the planned activities and the engagement of the participants in this process. To engage the participants, the partners ultimately used creative approaches, a lot of brainstorming and ideation, like the creation of personas, game pitch documents, work in breakout rooms, etc. These activities also added learning value for the partners, and a richer list of them can be found in [60,105,106].

Interviews with regional facilitators at later stages confirmed that the co-creation and co-design activity facilitators were mostly equipped to carry out the activities after the preparation phase. Regional moderators indicated that they highly valued the debriefing process after each round of activities, where the two partners sharing a mission topic could meet online and exchange their results and experiences. Similarities, differences, and individual focus areas were discussed. Further, all national partners came together across missions to discuss their results and experiences and reflect on them in their monthly working group meetings. This additional support from central coordinators and regular HelpDesk meetings to address overlapping challenges in different missions and regional groups also helped strengthen cooperation within the whole group and between mission partners.

5.3. Assessment of the Co-Creation and Co-Design Activities by the Participants

In the current study, the co-creation and co-design process participants are the people who were invited to take part in the process by the project members and regional facilitators. The participants were the local and international stakeholder(s) (groups)—actors from (civil) society, policy, research, and industry—actively and equitably involved throughout the whole process.

From the data of the follow-up surveys that were provided to the participants of the co-creation and co-design activities, most respondents felt that their ideas and thoughts were considered well when developing the "Mission BioHero" game (Figure 2). In both the co-creation and co-design phases, the respondents also had positive comments and ratings about the workshop materials and content, and they indicated a high level of trust in the organisers by rating highly their personal data use and securing inclusivity.

Co-creation and co-design participants who were interviewed after the "Mission BioHero" game was launched in April 2023 also had the same impression (Supplementary S9). The interviews were carried out to collect their assessment of the co-creation and co-design processes after seeing the final product (the game). The interviewees confirmed that their discussions during the activities had been fully considered. As stated by some participants:

“Most components that we have discussed (during the sessions), are there. We stuck to the collective decisions, so I saw the ideas we discussed put together.” (Interviewee 8)

“We brainstormed and exchanged our ideas. This is how we inspired each other.” (Interviewee 9)

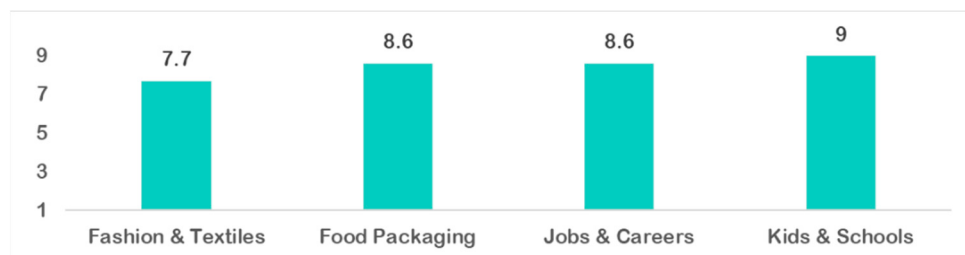


Figure 2. Co-creation participant follow-up survey answers to the question: Do you feel like your opinion and ideas were valued by the mission moderator(s) (on a scale from 1–10, where 1 is “not valued at all” and 10—“very valued”)? The numbers in the figure refer to the average rate on a scale from 1–10 given by the respondents in each mission. Total number of responses: 41. Responses per mission: See Supplementary S6. Source: Authors’ own.

Most co-creation and co-design activity participants found the activities to be enjoyable or very enjoyable (Figure 3), which indicates that they were satisfied with the process and that it met their expectations.

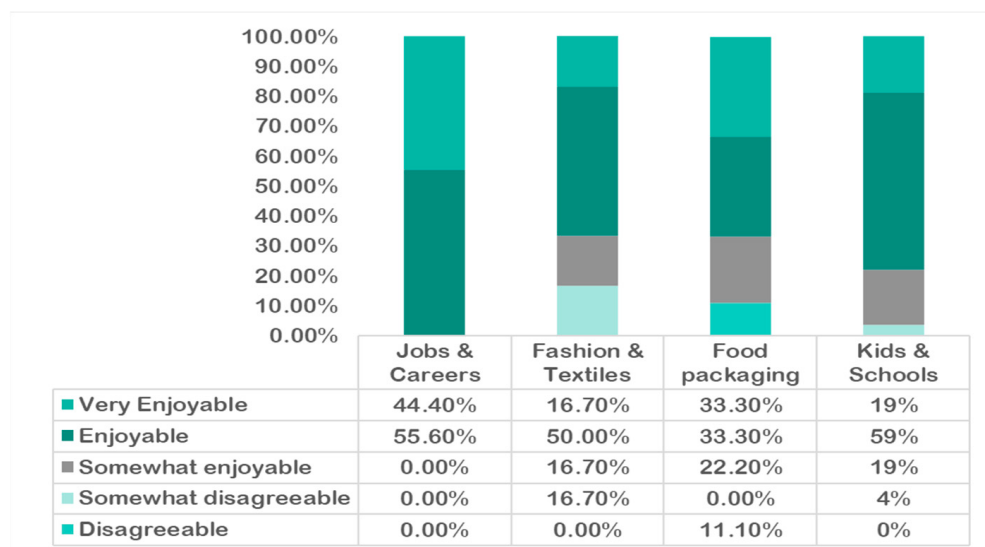


Figure 3. Co-creation and co-design participant follow-up survey answers to the question: Did you enjoy participating in the co-creation and co-design meetings? Responses are presented as a share of 100% per mission. Total number of responses: 92, where 41 are responses from co-creation follow-up survey and 51 are from co-design follow-up survey. Responses per mission: See Supplementary S6 and S7. Source: Authors’ own.

The outcomes of the interviews with co-creation and co-design participants show that overall, the co-creation and co-design process was fun and interesting to attend. As stated by one interviewed participant:

“We started with a few meetings, brainstorming meetings with very different people. It was nice and challenging in a way. We came up with a few ideas, I was always participating because I was curious about participating. Additionally, it was environmentally oriented, so it was cool.” (Interviewee 8)

However, some participants felt there could have been some improvements made in the process. For example, in their open-answer responses of the co-creation and co-design participants' follow-up survey, they noted that the concept of the bioeconomy was not clear and the timing of the workshops that were mostly held in the evening was difficult for some participants because they were tired, and it was hard to focus. Indeed, as reflected by the workshop facilitators, levels of understanding and attitudes differed across and within the focus groups that started the co-creative phase [60,105]. As discussed above, knowledge differences and players' motivation towards the topic and idea in the serious game are important to take into consideration [11,52,53]. If this topic is not interesting or important to the target group, then they are unlikely to use the developed game. At the same time, one should not limit themselves to recruiting only knowledgeable or highly motivated participants for the co-creation and co-design processes, as also highlighted by Kristensson et al. [59]. Having a rather heterogeneous group as co-designers is considered to be more valuable [59]. Further, despite some participants who felt more "lost" in the underlying theme of bioeconomy, the overall knowledge about bioeconomy among "Mission BioHero" co-creators and designers was above average (see also Section 5.4).

When it comes to the differences between the missions (food packaging, fashion and textiles, etc.), there were no significant discrepancies in the co-creation and co-design experience seen by the participants, except for the gender balance aspect. While the average assessment for decent gender balance was generally high, a few participants felt that there were too few men participating. This was particularly evident for the fashion and textiles mission. While a careful strategy to invite an equal number of men and women was implemented, in the co-creation phase, there were altogether still more women participating, but differences occurred within regional groups [60,105]. Diversity was much higher in the co-design phase, where over 100 participants were engaged in total [103].

Rating whether the game concept considers the views of different cultures was most difficult for the participants, who either commented that they do not know enough about other cultures to assess this, or that it is difficult to say at this stage:

"I am unsure, as our co-design group was pretty monocultural. It would be good to have the game tested/reviewed by people from other cultures." (Respondent of the co-design follow-up survey)

The independent evaluation of the process by the authors of this article convinced us that the project actually kept its focus on cultural and overall diversity during the co-creation and co-design processes by setting a strategy of keeping a 50/50% balance between experts and citizens in co-creation and co-design workshops, recruiting a decent proportion of different age groups and having an extra focus on children's participation through one mission topic. This was largely met with only a slight surplus of experts among all participants. Criteria like engaging a variety of stakeholder groups, engagement of public, institutional diversity, flexible attitudes to revise views and actions, changing responsibilities, and application of results and their specifications as stressed in Responsible Research and Innovation [106] were considered to use in the stakeholder selection to be wide-ranging, diverse, include influential stakeholders as well as minoritised groups, and represent sufficiently many perspectives and groups to foster robust outcomes and to serve as an orientation for regional partners to select their stakeholders. The overall strategy to hold co-creation and co-design activities in different countries, developing game translations and promotion materials in several languages (besides English, also German and Italian), as well as testing the game with different target groups and nationalities, as also suggested by the interviewee above, all speak for the appropriate inclusion of various cultural circumstances, not to mention the careful observation to take cultural elements into consideration in the final game design. For example, based on the suggestions of the co-creation and co-design groups, the game developers endeavoured to create a gender-neutral non-human avatar in the game. Additionally, in the introductory video part, the narration is in English, but subtitles in all target languages are available.

Overall, around half of the respondents (there were 92 respondents of the co-creation and co-design follow-up surveys in total) evaluated the co-creation and co-design activities to be effective and dependent on the mission, 11–26% even very effective, children being most positive in their assessment (Figure 4). The effectiveness was perceived as a multidimensional and referred to reaching certain decisions within the co-creation and co-design activities, implementation of the discussed ideas in the serious game or the learning experience that the participants had during the activities.

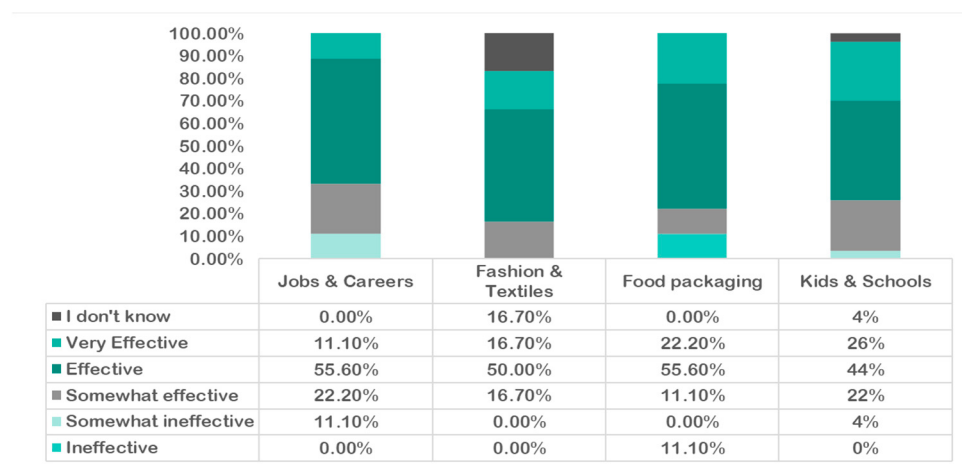


Figure 4. Co-creation and co-design participants' follow-up survey answers to the question: How effective do you think the co-creation activities were for developing a mobile game? Responses are presented as a share of 100% per mission. Total number of responses: 92, where 41 are answers from co-creation follow-up survey and 51 are from co-design follow-up survey. Responses per mission: See Supplementary S6 and S7. Source: Authors' own, 2023.

Feedback from the follow-up surveys provided some critical assessments as well. The critical feedback was mainly concerned with the efficiency of the co-creation and co-design meetings and the clarity of the result that was aimed to be achieved. As stated by one respondent:

"It was sometimes hard to know what we were supposed to achieve when it came to in-game challenges, topics, issues etc." (Respondent of the co-creation follow-up survey)

One mission facilitator reflected on this same observation in [107]:

"We learned that it is crucial to communicate from the start what the timeline of the project is, what expectations or engagements there will be along the line, what participants will be contributing to, how their contributions will be used, and what they can get out of the experience themselves. This also needs to be reiterated and followed up on at different stages of the project." (Project partner and regional facilitator)

The lack of sufficient explanation about the bioeconomy concept and the inability to integrate the ideas that were created throughout the discussion were also mentioned by some participants. On the contrary, one interviewee highlighted that he would like to have seen more critical consideration to incorporate the ideas that were generated during the discussions as the wish to apply maximum of them can make the end result confusing:

"I develop the game myself and the co-design process was very fun to attend. [...] Everyone's idea was implemented, and I am not sure if it is a way to make the game. They were too inclusive of everyone's ideas, and it was too much." (Interviewee 7)

Indeed, the professional game developer noted that they were not in a perfect position to fulfil the requirements of all sides and that one of the hardest was to effectively include feedback from all stakeholders. Thus, there is a need to find the right balance to mediate

between the originality of ideas and making all participants feel that they have contributed and choosing between the ideas in order to design the final product.

This was ultimately rather successfully met in case of “Mission BioHero” [10,23], as all in all, participants were satisfied with the game they helped develop (Supplementary S19), enjoyed the co-creation and co-design experience (Supplementary S18) and perceived the effectiveness of the co-creation and co-design experience was high (Figure 4). However, the comments overall also indicate that the participants value good and effective moderation and need to be aware of the purpose of their participation [20,79].

5.4. Co-Creation and Co-Design Participants Learning Outcomes

While the participants largely enjoyed the engagement process, assessing their personal learning was a more difficult task because of the limitations of the methodology used. To assess the bioeconomy learning experience among the participants, see [14,15,51]. However, the response rate to the follow-up surveys was significantly lower (10%) than the baseline surveys and varied among missions (121 answers to the baseline survey and 41 to the follow-up ones were received in the co-creation phase, for example, the J&C group had the best balance (39/21) and the F&T group had the most baseline surveys (48) but the fewest follow-up surveys filled in (9)). It is not clear why the response rates were so low; however, as regional facilitators discussed, participants may have felt ‘participation fatigue’ given the number of events attended, too much time had elapsed between activities for some participants, or the follow-up surveys being administered via email may have led to a decrease in responses (i.e., easily ignored). Based on this feedback, the authors of this article had co-design participants take a follow-up survey during the workshop at the end of the last activity, where a much-improved response rate was achieved (see also Supplementary S6 and S7). Moreover, there were some changing participants throughout the process who missed either the baseline or follow-up survey. Considering all this, qualitative feedback received from participants in formative evaluation served as the main input for drawing conclusions, being aware of the limitation that the method was relying on self-reflection of the participants’ knowledge, which can give only their own perceived assessment of their learning [14,15,51].

According to the baseline survey (Figure 5), most respondents felt that they had a medium to low-range understanding of the bioeconomy at the start of the process. Baseline respondents from the F&P mission indicated that they had the highest average level of understanding (5.7/10). Figure 5 indicates that, as a general trend, there was a slight increase in knowledge of the bioeconomy across all missions.

While the small sample of the follow-up survey and above average knowledge and motivation toward bio-based options of the participants already in the baseline phase may account for such results about the bioeconomy knowledge, according to mission partners’ observations, their participants learned about bioeconomy, as these concepts were introduced and thoroughly discussed in every mission area. Such results were also reflected in the open-answer section of the co-creation phase follow-up survey and the follow-up interviews with co-creation and co-design participants. Some participants stated that they had diversified and deepened their already existing knowledge about bioeconomy through interaction with other participants throughout the engagement process:

“I have already paid a lot of attention to the bioeconomy topics, but I did pick up the knowledge from the people, who have been in the discussion group with me.” (Interviewee 9)

“The activities allowed us to explore the subject further and share our findings.” (Interviewee 8)

Additionally, when it came to the impact that the co-creation and co-design activities had on the participants’ attitude and behaviour toward the bioeconomy, then some clearly stated that they started paying more attention to the bioeconomy in their everyday life:

“I have been paying more attention when I go grocery shopping, for instance. Some of the elements have transferred to my shopping habits.” (Interviewee 8)

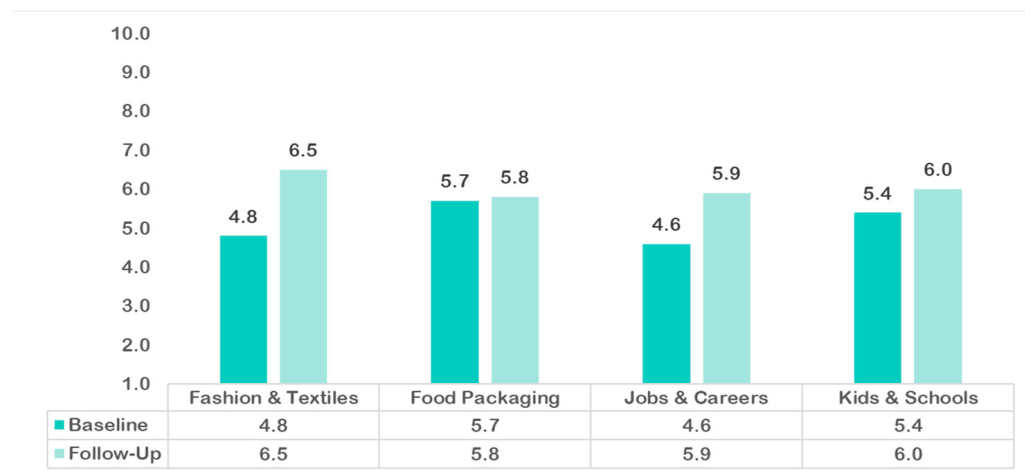


Figure 5. Co-creation participants’ baseline and follow-up survey answers to the question: How knowledgeable are you about bioeconomy? Responses are presented as an average on a scale of 1–10. Total number of responses: 121 baseline and 41 follow-up respondents. Responses per mission: See Supplementary S6. Source: Authors’ own

Another important learning for the participants, according to mission partners, was learning about the mechanics and steps of serious game development. Participants familiar with gaming were especially interested in this, as they would not normally have a chance to contribute to such a field.

There were also single cases where the participants felt that their own bioeconomy knowledge was not sufficient to understand the topics of the co-creation workshops, emphasising that a thorough explanation of the topic was missing:

“There were a lot of discussions about the pros and cons of “bio-something”, a concept that was unknown to me, and that was never explained during the workshop.” (Interviewee 7)

This shows that the activities should be planned in a detailed way, considering the baseline knowledge of every participant and providing explanations for every concept discussed during such activities. As reflected by the facilitators themselves, it was sometimes challenging that many co-creation participants did not join again in the co-design phase, and thus newcomers had to be informed about the state of the art, as sessions also included referrals to previous sessions. Thus, the collective learning was to keep this in mind and, as also asked by several participants, to send out questions/tasks in advance, for example, before the second round of meetings, to boost creativity and give participants the chance to prepare the sessions.

The gathered data mostly indicate that the co-creation and co-design process affected the participants so that they learned about bioeconomy and its related concepts, and serious game design.

5.5. Assessment of the Co-Creation and Co-Design Activities by the Project Partners and Regional Facilitators

5.5.1. Success Factors

The success of the co-creation and co-design activities from the perspective of the project partners relates to whether the results produced from these activities yielded helpful feedback and if the game was enhanced as a result of those processes. AllThings.bioPRO project partners and mission facilitators reflected their views about the participatory design process via moderator self-reflection surveys, bi-annual partner surveys, central co-creation working groups and HelpDesk meetings, and through interviews with the authors of this article (see also Table 2 and Supplementary S1). Their experiences in specific local

missions were different in many cases [60,103,105]; however, from their reflections, it can be concluded that the co-creation and co-design process was valued by all. Partners concluded that the co-creation events were enjoyable for the participants, the ones who participated were motivated and collaborated well, the results of the meetings were both creative and informative [60], and the co-design phase was fruitful.

Partners carried out the activities with local stakeholder groups, and the results of these parallel participatory events (focus groups and co-creation workshops) differed from one mission partner to another due to differences in facilitators, participants, the partner's expertise and local contexts [105]. As reflected by the facilitators themselves, the differences in opinions and feedback from participants enriched the game results, for example, facilitated by discussions that were shaped by regional bioeconomy structures, personas shaped by regional cultural differences, game ideas inspired by national popular games etc. Thus, these differences were considered valuable, as this way, more perspectives and local differences could be taken into account in the handling of one mission topic [64].

Regarding the co-creation phase, regional facilitators felt that in general, the focus groups and co-creation workshops were carried out effectively and were pleased with the level of participation from the participants (Figure 6).

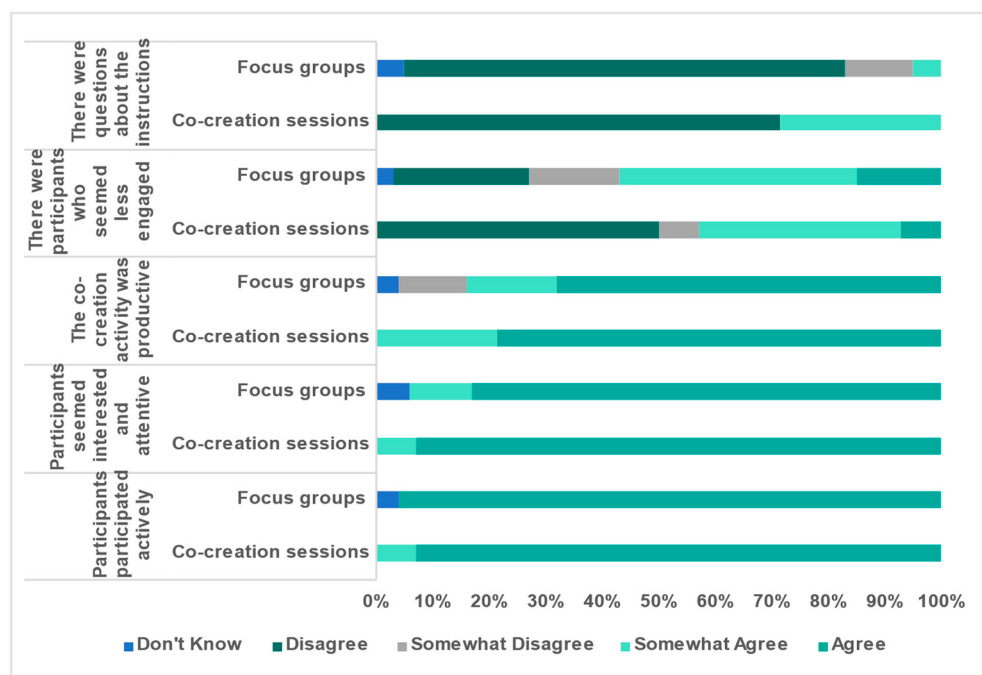


Figure 6. Facilitators' self-reflection on the participants' engagement in the focus groups and co-creation sessions (% of responses). Total number of responses: 28. Responses per mission: See Supplementary S4. Source: Authors' own.

Some takeaways from the co-creation phase for the facilitators were that there was high enthusiasm and motivation to contribute and create among the groups; participants enjoyed the playfulness of the events; all workshop groups came up with highly creative and unique game design ideas; and working in small groups (also in breakout rooms) gave more space for individual input and interaction. Virtually all moderators of the co-creation activities agreed or somewhat agreed with the statements that the "participants seemed interested and active" and "the participants participated actively" (Figure 6). Most felt that the activity was productive, even if there were a few participants in some meetings who were less engaged.

In their self-reflection surveys (this self-reflection survey was not done in the co-design phase, since the co-design activities were coordinated centrally and responses gathered in bi-annual surveys and interviews reflect the experiences during the co-design activities.),

facilitators noted that the range of ideas and creativity exhibited by the participants exceeded their expectations and helped them to understand the needs and expectations of the “Mission BioHero” game target groups better. As illustrated by one facilitator:

“The event exceeded all our expectations and hopes. The group unleashed great creativity and energy and developed team spirit. The team developed an enormous number of creative and unique game ideas. The event lasted for 4 h with only 5 min (!) break. Still, people were excited to continue working on the ideas and said time flew by and it was a great pleasure to participate.” (Facilitators’ self-reflection survey respondent)

Regional facilitators recorded that the key success factors of a co-creative process were equal collaboration between stakeholders and relevant and continuous information sharing. In practice, this means ensuring everybody’s voices are heard and opinions valued and that everybody is constantly in the know of what is and will happen. The participants need to feel like they contributed something valuable and that the co-creation is not only a one-time thing: they need to be kept informed of progress even after the participatory phase ends. As stated by one partner in the survey about lessons learned [107]:

“It takes time to engage and build trust but processes should not be too long. Participants need to have regular feedback and incentives to engage.” (Project partner and regional facilitator)

Attempts to ensure openness and transparency were incorporated into the design process of “Mission BioHero” serious game. For example, “between the first and the second round of co-design meetings the regional partners stayed connected with the co-design groups and sent regular updates on the game and app development. At Christmas 2021 the AllThings.bioPRO stakeholders received a Christmas card and a two-pager with a summary of results from the first round of co-design meetings and an outlook into the activities in 2022. In March 2022 the stakeholders received a comprehensive report on the status of the game and app development including the uptake of their ideas. Although, this overview and report were not a part of the initial plan, the consortium deemed it highly important to stay in touch with the co-design group.” [103], p. 25. These practical steps were important. Indeed, surveys and interviews with the participants also showed that they felt included, well informed, and considered their opinions to be valued by the organisers and the whole group (see also Figure 2).

Designing the “Mission BioHero” serious game is an interesting case because it included children as one target group to design the game (co-creation and co-design events were held with children aged 10–14; altogether, 8 children participated in the co-creation phase, 27 in the co-design phase and 5 in the game-testing phase (see also Supplementary S5, S7 and S8)). Some other scholars have highlighted that efforts to engage children as co-designers have presented challenges that necessitate sustained involvement using appropriate tools and techniques tailored to their developmental stage and the specific study context. Previous research has highlighted recurring issues such as limited creativity, unfocused or irrelevant ideas, and the inclusion of violent content, which directly contradict the educational objectives of the game. These challenges have been attributed to children’s insufficient domain knowledge and their limited literacy in game design principles. Therefore, there have been claims that children should be constrained to the role of informants [71,108] and not true co-designers [33]. However, these observations for child participants were not observed in the current study. Even though engaging children from two different countries, Germany and Estonia, was challenging, as engagement and evaluation had to be adjusted to them and also totally separate co-design meetings in their own language were held compared to others that were centrally coordinated and held on-line in English, these meetings were valuable. Children generated great ideas, learned from the sessions (see also Figure 5 and Supplementary S15) and provided valuable constructive critiques to modify the game when it was adjusted for educational purposes [60,103,105]. Moreover, some of their ideas were integrated into the game. For example, they designed polluted and healthy versions of the Earth, different suggestions for the avatar and other

in-game creatures, equipment and accessories were included, and the main theme in city builder, where the player wanders around a game map and can zoom into different worlds to learn about different environmentally friendly solutions and products by solving different tasks or day quests, came directly from the co-design sessions with children. A statement from the game developer is more than illustrative here:

*“Their (*children) feedback is very open, direct...even more valuable experience for us.../Even if you design something for children then it’s usually for leisure or entertainment purposes. But for here, it’s a new perspective/.../”* (Interviewee 2)

Further, for the game developers, being engaged in the co-creation and co-design process was a new experience, and some scepticism was noted in the first interview with the developers (similar to what is described in [25]). As stated above by some research, interviews revealed that the game design process normally takes a top-down approach, where internal brainstorming and ideation processes are undertaken by a core team, then the game is launched. This participative process implemented in the case of “Mission BioHero” allowed the developer to connect with their potential users, learn about the topics being discussed, and identify creative ways to include their feedback in the game. This was also reflected in one of the interviews with the game developer:

“We do not have access to the target group. That is why research projects are interesting for us because we can test with the target group. New perspectives, experiences, game development, process etc. For us, it was a benefit to be able to test with the target group.” (Interviewee 2)

It was mentioned that without this process, the game designer would likely have omitted many of the mission topics because it would have been too difficult to include everything in one game. However, with the assistance of participants in the co-creation and co-design process, they were able to co-create solutions and include all four mission topics in the game. Moreover, the interviewee mentioned that co-creation and co-design were helpful for understanding the “general feeling” and “which direction” the participants would like to take the game. The participants’ feedback was also enlightening for the game design team in that it allowed them to better understand the types of games that are popular for their potential user base. This is because the participants, some of whom are active gamers themselves, have a pulse on what types of games are popular, and this feedback can then be used to help the design team create a game that better matches the current gaming trends. The value of co-creation and co-design is seen to be especially important in serious game development, which has to balance between leisure and education. For developing content and securing the educational component of the game, the inclusion of thematic experts is as important as inclusion of representatives of broader target groups.

Usually, game developers will not be able to measure the success of a game until they hit a critical mass of responses from the game users, measured in downloads, playtime, drop-off rate, etc., which is generally in the thousands. The co-creation and co-design process engaged a smaller pool of participants, which usually means that the opinions of these participants should be taken with “a grain of salt” until sufficient quantitative data can be collected. However, despite contradicting such industry norms, the game designer clearly found value in using a participatory approach for developing a serious game.

5.5.2. Challenges

The co-creation and co-design process has also shown several challenges. One of the biggest challenges in many participatory design processes is recruiting and keeping the participants [37]. Self-reflection surveys as well as survey about lessons learned [107] among the project partners show that during the co-creation workshops and co-design meetings, some participants dropped out of the process. It was discussed in project meetings that this could be due to tight timing, little compensation, and a lack of clear benefits for the participants, although the strategy was to keep the same participants over the course of the entire engagement process. Only one mission was able to keep most participants

throughout the whole sequence of the co-creation and co-design phase. It was especially difficult to engage the same participants from the co-creation phase. Supplementary S17 illustrates the retention rate throughout the co-creation and co-design process of “Mission BioHero”. The main reason considered here was the long time between the events. Each participant had the opportunity to attend six total events: four co-creation activities and two co-design workshops. It was originally planned to have the same participants attending every event; however, most participants attended only one event.

In the co-design phase, the number of returning partners from co-design round 1 to co-design round 2 was quite satisfactory and almost all co-design participants attended both events (Supplementary S7). This can be explained by the early recruitment of the participants, good information flows as well as gained experience of the activity organisers and mutual constant reflections. The actual retention overall influenced the size of the target audience that was initially planned, but according to partners’ reflections did not have a crucial impact on the final product, and all in all the missions were completed still with a satisfactory participant group.

The regional facilitators used their own networks to recruit participants and were instructed to include both citizens and experts. As assessed by the workshop facilitators themselves [105], among the experts, it was much easier to mobilise representatives from science and academia or civil society than from business, industry, and policy. For example, one partner stated:

“It was much more difficult than expected to keep citizens and experts onboard. The time between events and the fact that experts found it difficult to see the added value for their business, meant that the number of participants decreased.” (Facilitators’ self-reflection survey respondent)

It has been found that effective co-creation and co-design processes would need to engage heterogeneous groups as diversity of thoughts at the beginning of a product or service development project often leads to innovations [59,68]. This was one of the baseline ideas also in the “Mission BioHero” development process. However, and as already discussed above, some concerns over sufficient diversity in the participant groups were raised, especially in the co-creation phase. Even though a lot of attention was put on guiding the partners in stakeholder recruitment by providing guidelines [106] and HelpDesk support, it remained challenging to reach and keep a decent balance of stakeholders in the process. For example, it was collectively assessed in [103] that it was difficult to reach representatives from minoritised groups with “silent voices”. “If we were to repeat the stakeholder selection, we would increase attention to specialised mobilisation and communication strategies (formats, language, channels, locations) to reach minorities. Additionally, we would decrease the time between the meetings to increase the rate of repeat participants. If this is not possible, the planning of other activities to keep participants interested and involved during the engagement events could be helpful. Further, more concrete incentives and personal benefits from participation could have improved the stakeholder selection.” [103], p. 37.

Another challenge from the moderation side of the co-creation and co-design meetings includes difficulties with setting up an online meeting and engaging participants in an online format as well as that too many activities were on the agenda. Events were moved online, but participants usually are not willing to spend as many hours in an online meeting as they would in a physical one, which meant still trying to address everything on the agenda, but having to do it in a shorter amount of time. Further, most facilitators said that they would allow more time in future meetings and try to overcome any difficulties they had from re-occurring. Further drawbacks to online participation include not being able to get to know each other, difficulties with keeping participants engaged, different group dynamics as opposed to face-to-face meetings, and technical challenges in terms of using online tools and meeting platforms. Some partners mentioned that taking a “hybrid approach” and having some online meetings and some in-person meetings would be a nice option. This way, the participants could get the benefits of both styles of meetings, and

they can optimize the time that is spent together, build trust, and foster communication and connections between engaged participants.

While some partners felt that in-person meetings would have worked better in terms of being able to build better relationships with participants and have larger turnouts, there were benefits to having to adapt the process to this sudden change and the feasibility to co-create online by regional partners was reported. The shift to online activities resulted in the partners learning new (online) methods and tools and widening their contact networks due to online events not being restricted by having to be physically present. The online format also enabled mission partners to observe each other's events whenever the language barrier was not an issue, which was an important means of experience exchange and mutual learning. Additionally, missions were able to engage people from other regions and countries and were not limited because of travel constraints (especially important in the co-design phase). Sometimes, online meetings were more convenient for the participants as they could attend them from the comfort of their homes and could easily fit their schedules.

5.6. Co-Creation and Co-Design Facilitators' Learning Outcomes

As stated above, in the research still little attention has been given to exploring how co-creation and co-design processes themselves facilitate learning that happens during the participatory co-design activities [12,13,24]. With regard to learnings for the mission partners/workshop facilitators, these were recorded via the biannual surveys, partner interviews, and joint discussions during project meetings. Many partners mentioned gaining new personal skills while using co-creation and co-design. Most often mentioned learnings were new engagement and participation methods and methodologies (including online methods and tools); new knowledge of project management and communication; knowledge about (serious) game development and gamification; new skills regarding creativity and creative thinking; and new knowledge about bioeconomy and its relationship with other topics. As another positive aspect, a few respondents mentioned sharing their new skills within their teams as well:

"I have learned about engagement and creativity methods, which will be of use for my team as well." (Project partner, bi-annual survey 1)

Several partners mentioned a notable increase in the capacity of their organisation or other positive effects on their organisation while using co-creation and co-design. These include opportunity to reach their target groups in a new way or to reach a broader target group than previously; more in-depth knowledge of bioeconomy topics; a new and/or improved image of the organisation as one that works with the topic of bioeconomy; increased visibility and publicity; knowledge of EU projects and capability to implement them, e.g., regarding project management and workflows; new skills regarding online participation methods and online communication in general; knowledge of new methods and tools, e.g., regarding (online) co-creation and co-design tools; learning to use new formats to target new audiences.

Several respondents also mentioned new cooperation opportunities because of the co-creation and co-design experience. These have come both in the form of new contacts with new stakeholders, but also as opportunities for greater visibility, for example, invitations to new collaboration projects, or to conferences and meetings. Several partners mention improved networking:

"We were brought in contact with citizens and groups we did not have much relationships with before the project." (Project partner, bi-annual survey 4)

Indeed, in one of the latest surveys among the partners about the lessons learned from the co-creation and co-design process, knowledge transfer and reaching out [107] almost all indicate notable positive impact mentioning increased connection and interest from other projects and networks; several mention increased contacts to school networks, big brands and governmental organisations as well as the Bio-Based Industries Consortium (BIC).

Another interesting aspect of the feedback received through the biannual surveys (the description of this methodology part can be found in Supplementary S1) was being able to identify how learning new skills increased from the first survey and throughout the project (Figure 7). Naturally, at the start of the project, one would not have many experiences to cite specific knowledge or growth; however, as the project progressed, so did the learning outcomes. Shown in Figure 7 below, the number of learning experiences (indicated by a partner responding that their organisation or themselves personally had learned something new) increased from the first two biannual surveys to the later biannual surveys (BA), indicating that over the course of the project, learning outcomes at an organisation and individual level increased.

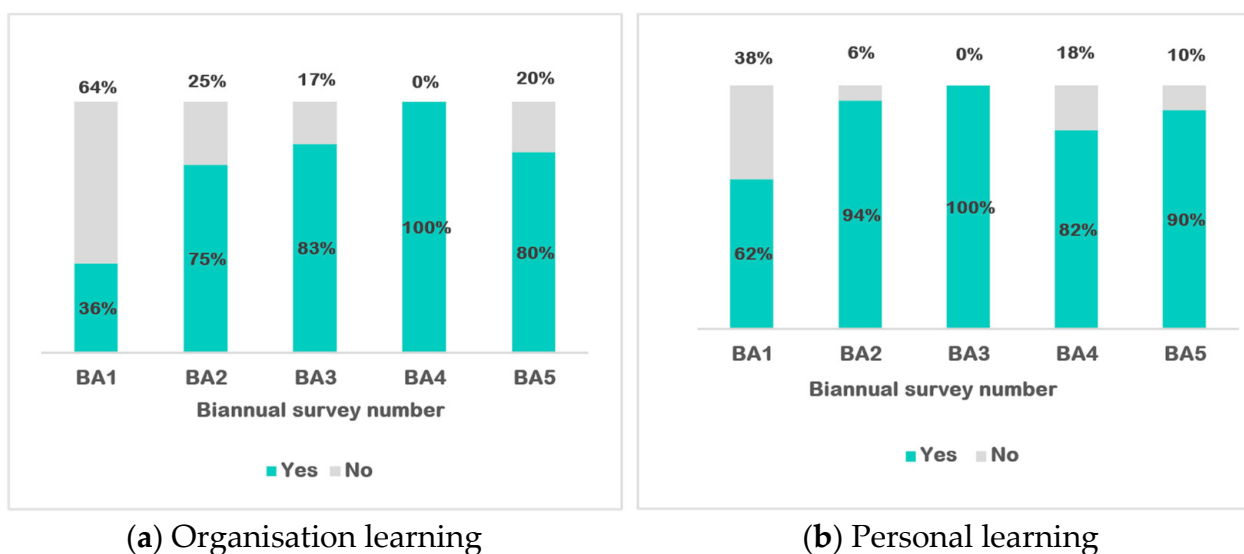


Figure 7. Organisational and personal learning outcomes of workshop facilitators (% of responses). Total number of responses: 63. Responses per BA survey: See Supplementary S3. Source: Authors' own.

On average, an increasing number of partners indicated that they had learned something by participating in project activities. In general, affirmative learning experiences were consistent from BA3–BA5 in both scenarios (Figure 7). A reason for a possible decrease for BA5 in both cases was that for some partners, their primary facilitation activities had ended, so they were not as actively in contact with the co-design participants anymore. However, when the project was most active (co-creation phase and BA3–BA4), most or all partners indicated that they had learned something new to the benefit of their organisation or themselves.

Thus, mission partners noted considerable growth and learnings in various areas both professionally and personally. As such, the engagement process provided many opportunities to learn, adapt, and gain new skills for the regional facilitators and coordinating partners in the process.

Taken from the discussion above (Sections 5.3–5.6), the main value of co-creation and co-design process of “Mission BioHero” to different stakeholder groups has been summarised in Table 3.

Table 3. Summary of the main value of co-creation and co-design processes.

Benefits of Co-Creation and Co-Design	
Game design	Meeting the needs of potential end users better as co-creation and co-design help to:
	- gather different points of view and opinions; - engage people of different ages and backgrounds, countries and cultures—the diversity of input was interesting and helpful, helping the game design process; - participant feedback helped the game designers to neatly combine the different mission topics into one game. Without that creative process, it would have been difficult for the game developer, as non-bioeconomy experts, to create a game that incorporates the needs of the target groups. - the iterative co-creation and co-design process allowed the game designers to connect and learn from the users who could potentially use the game.
Participants	- Learning about bioeconomy. - Empowerment through being able to design their own “product”. - Learning about the mechanics and steps of serious game design. For participants familiar with gaming, being involved with a game design process was especially interesting for them. - Also, for bioeconomy experts, applying their knowledge and expertise to a unique objective (i.e., designing an educational game) was also interesting for them.
Organisers/facilitators	- Understanding the needs and expectations of the users better. - Using participation to its maximum effect, i.e., not only consulting with end users but engaging them in a long-term process of ideation and design. - Reaching a wider range of people, oftentimes beyond the usual target groups. - Several benefits for personal or organisational learning and growth like learning new methodologies and tools, widening cooperation networks, increasing visibility etc.

Source: Authors’ own, based on surveys and interviews.

5.7. Result of the Co-Creation and Co-Design Process: The “Mission BioHero” Game

The goal of the thorough application of co-creation and co-design in AllThingsbio.PRO has been to develop a serious game, that has the potential to be utilised to foster citizens’ awareness, participation and co-creation of the future of bioeconomy. Thus, the reflections about moving towards this goal were evaluated throughout the process (formative evaluation). Even though at the end of the co-creation phase the game design shown to participants was not yet complete, the enthusiasm of the participants was high. The co-creation groups came up with eight game designs, which they handed over to the professional game development team. After careful analysis, the team decided that instead of deliberately splitting the four missions (see Table 1) within the game world, they should be more interconnected. This means that players would have the chance to play content from different missions simultaneously. This decision was influenced by recurring elements found in the game designs from the co-creation phase [103]. In the end, elements from all four missions were included in the overall game design. The J&C group developed the game’s narrative, the K&S group designed the in-game world and the avatar, the FP group contributed to the city builder mini game, and the F&T group contributed to the real-life and in-game tasks. Additionally, ideas such as multiplayer options, educational aspects, quizzes, happiness points, and the ability to train and unlock skills were integrated into the game based on suggestions from multiple groups [103]. As a result, the mission topics

are not represented separately in the game, for example, through four distinct mini games. Instead, they are interconnected through the campaigns (Figure 8).

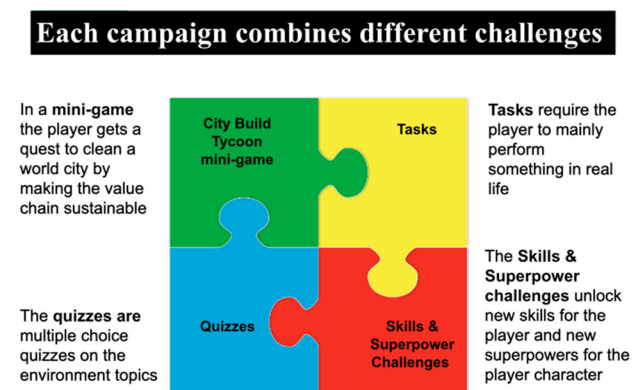


Figure 8. Outlook and structure of the “Mission BioHero” game. Source: [109].

The reflections of co-creation and co-design participants were captured after the co-design meetings, as there, the participants had a chance, first, to work on with the game designs handed over from the co-creation phase and, second, to see and try out the first game designs after the adjustments during the co-design phase.

Their first impressions were mostly positive, and most respondents felt the game they helped design was visually appealing; most respondents gave above-average rankings for the intuitiveness and ease of use for the game; indicated they would play the game on a weekly or monthly basis and most respondents indicated they would recommend the game to others (Supplementary S10–S13). Moreover, respondents for the J&C, F&T, and FP missions mostly felt that the game would help the players learn about their specific mission topic (scores in range of 7.2–8.4 from 10), but at this stage had mixed opinions about whether the game would be effective in encouraging users to search for a career in the bioeconomy; wear and/or shop for bio-based clothes; or encourage people to purchase bio-based products and bio-based packaging (scores in range of 6.2–7.4 out of 10). This was an important indicator because one of the goals of the game is to induce a behavioural change with regard to environmentally harmful practices and towards more circular/bio-friendly habits and practices.

At this stage, there were also more critical statements and doubts, especially from the K&S mission. As referenced in Section 5.5, feedback from children was generally more blunt, honest, and provided a new perspective for the game designer, participants stating that they would either never or only yearly play the game. While children are normally avid gamers, this outcome may also be somewhat expected, as most children do play games regularly and as a result, are likely to have specific preferences or expectations in place when it comes to games. Some children even noted that it was not the “type” of game that they enjoyed. Several respondents among children felt the game was difficult and confusing to use and more guidance would be needed to progress in the game.

As indicated, the game design at the end of co-design phase was still in the status of very first prototype, all feedback was valuable for the professional development team and was taken into account when adding improvements to the game. The co-design feedback sessions showed that the objectives and reasons to play must be made clearer (in-game and transfer to real life). Further, the game needed a proper introduction (intro and outro video were added based on feedback), step-by-step instructions and tutorials, especially in the city builder mini game, because the target groups are not experienced gamers, but citizens interested in sustainable lifestyles. The game developer also had to make efforts to make the game more fun and less informative. Learning processes were suggested to be improved, e.g., by optimising the explanations for right and wrong answers [103]. An option of introducing a “kids’ mode” was also brought up for evaluation

and potential future integration in the game, after the initial data of interactions with the game is evaluated.

5.8. External Game-Testing Results

5.8.1. General Feedback about “Mission BioHero” User Experience

The developed “Mission BioHero” game was tested with external stakeholders by the authors of this article during a series of game-testing workshops held in December 2022–February 2023 (see Figure 1). The workshops gathered children, university students and adult participants who have some interest in bioeconomy (see Supplementary S8 for more details).

When it comes to the evaluation of the co-designed “Mission BioHero” game among the general audience, who did not take part in the co-creation and co-design activities, then the overall impression of the respondents about the game was either positive or neutral. During the game-testing workshop discussions, the results of which were gathered also on Padlet boards and in their feedback the participants mentioned that they liked the overall idea of the “Mission BioHero” game, i.e., saving the Earth (see Figure 9), and the diversity of different tasks that it offers, the information presented in the game was noted to be relevant; and the look of the game was described as nice, but needing improvements regarding the quality and style of the graphics.

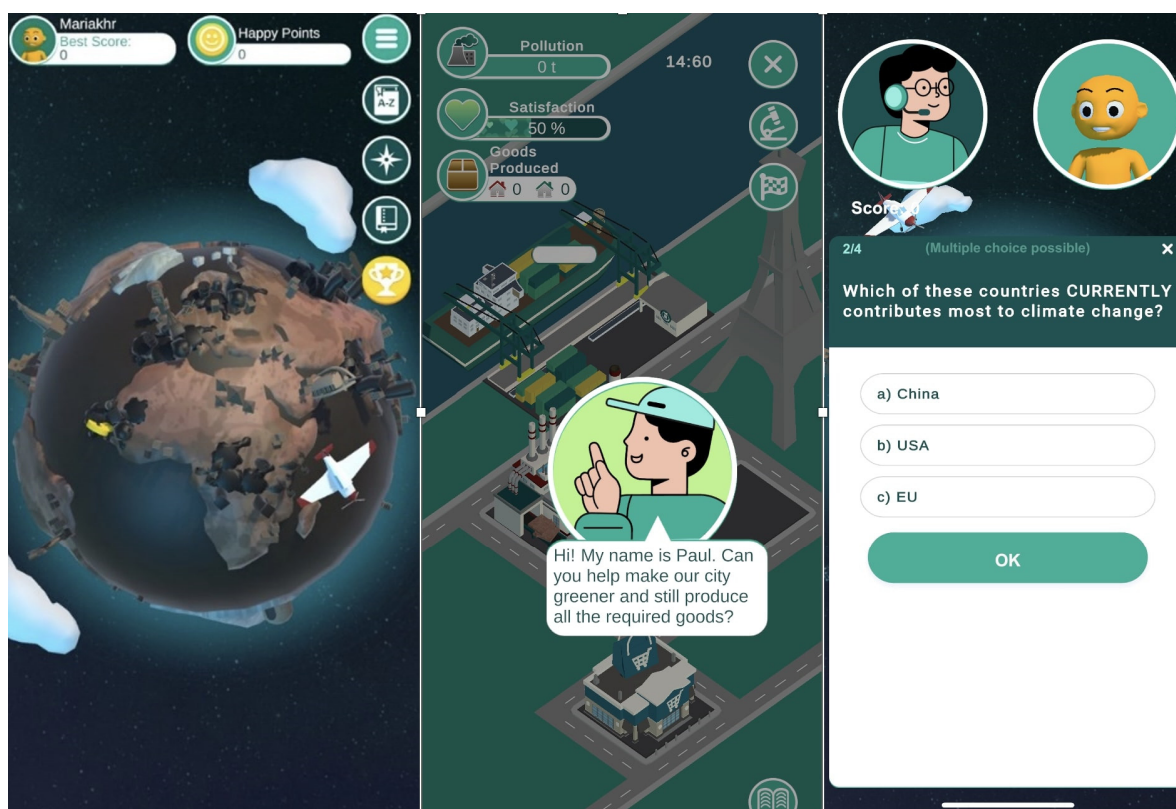


Figure 9. Mission BioHero game interface. Source: [109].

A serious game should be adaptable and respond to the users’ needs within the game, i.e., level of difficulty, and provide a positive user experience [110]. To this end, several questions were asked to game-testing participants (62 participants in total) to understand the user experience, where the participants were asked to evaluate their experience on a scale between poor, average, good, and not sure (Figure 10). The “not sure” option was hardly chosen by the game-testing workshop participants and was estimated to be less than 1% of the responses.

Graphics and visuals, installation, and setup were highly rated, which indicates that these elements of the game were positive. The same applied largely to the story/narrative of the game. Controls and navigation, tutorials and instruction, and the gameplay are the aspects that the workshop participants were less satisfied with, and which indicated for the professional game developers that more attention has to be put there.

Some of the main issues with the game aspects were related to the difficulty of the game, especially the quizzes. 40% of the respondents agreed or rather agreed that the content of the game and its questions were difficult, and 49% found them somewhat challenging (see Supplementary S14 for more information). Especially difficult was this task for children, who did not understand the bioeconomy definitions well (four out of five children participants found the game difficult, more info in Supplementary S15). Additionally, the complications were caused by the fact that it was not possible to see all answers that were wrong and explanations to why they were wrong. Some difficulties were seen with the user interface faced with dragging and clicking on the icons, which are quite small and require preciseness, overall glitches, and occasional unresponsiveness of the touch screen. This was important feedback. At the same time, it is also important to point out that one does not need to be an expert to play the game. Rather, the purpose of the game is to educate players about the bioeconomy. As such, while the feedback might have been negative about users' understanding of the game, a longer-term study of the educational impact may have shown an increase in their knowledge about the bioeconomy. In fact, most respondents felt they had learned something about the bioeconomy after playing the game (Supplementary S14).

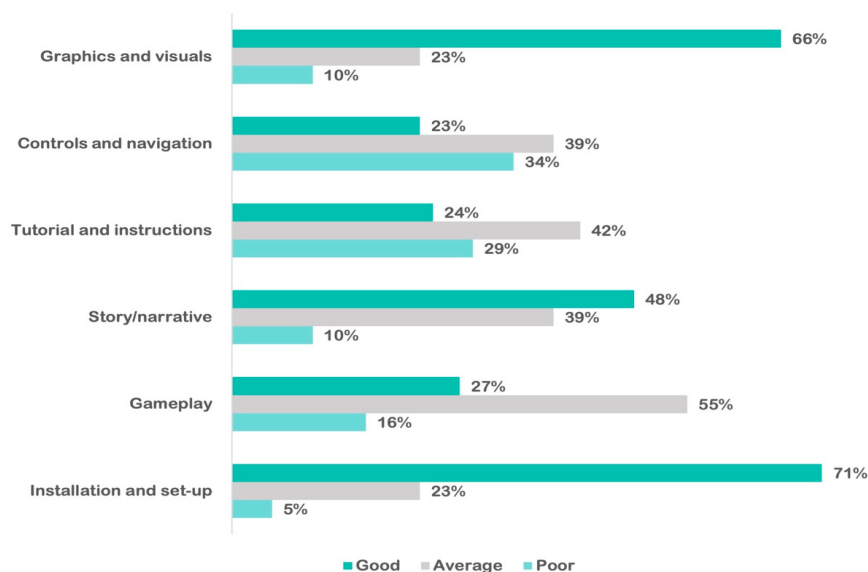


Figure 10. Assessment of the different aspects of the game by the game-testing workshop participants (% of responses). Total number of responses: 62. Responses per workshop: see Supplementary S8. Source: Authors' own.

The design of the game received the most positive assessment; however, there still were several remarks about it, like the unreadability of some fonts and the clumsiness of some graphics. Another problem that the participants faced and stated in their feedback was that it was difficult to understand and make progress in the game because many actions that the game missions require needed prior explanation.

Based on the game-testing participants' feedback, the game developers already have applied further changes in the game, for example, the most difficult questions were removed and/or fewer answer choices were given in the quiz. The simple "Not all answers were correct" screen has been changed so that it is now clear which answer was selected and whether it was correct or incorrect (Figure 11). Some questions or answer choices have been changed or removed because they were incorrect or ambiguous or that some user

interface elements have been adjusted and the bugs fixed. Within the scope of the project, project partners who have more knowledge in the bioeconomy have been able to provide updated content and text for the game developer to make the instructions clearer. Further, an instructional handbook for educators [111] was developed that would explain how to use the game in an academic setting, i.e., teaching students about the bioeconomy using the game.

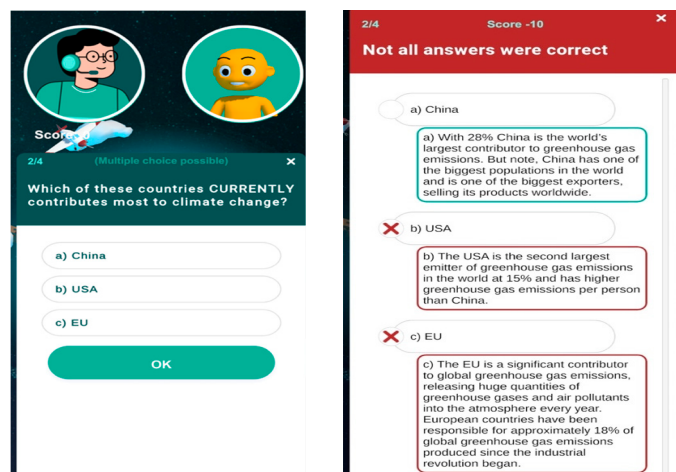


Figure 11. The outlook of the Mission BioHero quizzes. Source: [109].

5.8.2. “Mission BioHero” Educational Potential

The educational aspect of the game, which was evaluated during the game-testing workshops through the discussion of the participants’ learning experience and their view of the applicability of the game in the educational framework, showed its potential effectiveness to teach bioeconomy topics. To see how the game was experienced by the game players, the difference between the players with high and low levels of knowledge about bioeconomy was looked at, which brought the following findings (see also Supplementary S16 for more details):

- 44% of the participants with a self-assessed low–medium bioeconomy knowledge level feel that they have learned more about bioeconomy while playing the game, while among the participants with a high bioeconomy knowledge level, this indicator is only 17%.
- 60% of the participants with self-assessed high bioeconomy knowledge levels think that the game will have a considerable impact on the players’ knowledge about bioeconomy.

Moreover, to assess the learning potential of the game, game-testing participants were asked to rate their learning experience with the “Mission BioHero” game. As seen in Figure 12, game testers’ perceived learning outcomes were viewed as mostly positive, with most of the respondents selecting “Somewhat” followed by “Rather yes” or “Yes”. The exception to this trend is indicated in the second statement, where more respondents indicated that “Yes” they feel like they know more about the bioeconomy after playing the game.

While further studies would need to be conducted to understand the full learning impact from the game—including knowledge retention—the responses provided by game testers as well as interviewees are mainly positive (see Table 4). The feedback received underscores that the information about the bioeconomy was communicated in such a way that the users were able to learn about the sustainability and bioeconomy topics, which further supports the effective integration of these concepts and the potential of the game as a learning tool.

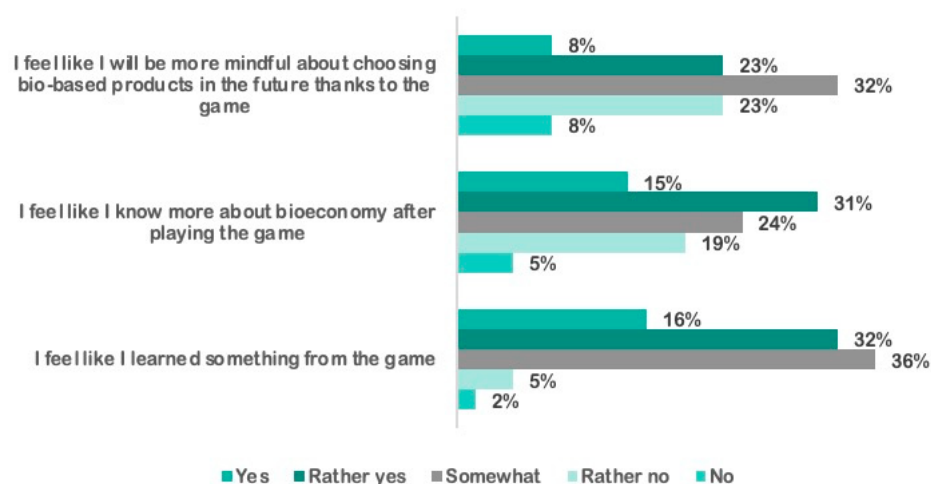


Figure 12. Game-tester responses to the potential learning value from the game. Total number of responses: 62. Responses per workshop: see Supplementary S8. Source: Authors' own.

Table 4. Assessment of the educational potential of “Mission BioHero” from game-testing feedback survey and by interviewed co-creation and co-design participants.

Game Testers via Game-Testing Feedback Survey (Open Answers Given in the Survey, All from Different Respondents)	Interviewed Co-Creation and Co-Design Participants
<i>“I like that in addition to it being educational it’s also fun and interesting”</i>	<i>“...it has very relevant information concerning the bioeconomy and its different aspects.” (Interviewee 7)</i>
<i>“I like the educational play of the game. A great concept that will be beneficial for educators and students.”</i>	<i>“It is clear that people will learn something out of the game—it is a proper serious game.” (Interviewee 8)</i>
<i>“I like the awareness it could provide younger people.”</i>	<i>“The progression of campaign topics and the fact that the campaigns get increasingly harder are very good in this sense”. (Interviewee 9)</i>
<i>“Got some new knowledge about sustainability in a fun way”</i>	

Source: Authors' own.

5.8.3. Potential Uptake of “Mission BioHero”

During the co-creation and co-design phase and in parallel with the activities with the design partners from the civil society and other field experts, discussions with the bioeconomy uptake community experts were held, since among others one of the ultimate aims of the whole undertaking was to exploit and further develop the AllThings.Bio Platform [40] for bio-based economy communication to the broader public by linking it with the serious game, and a European Bioeconomy Citizen Action Network. The intention was to ensure engagement and uptake of developed results through an early and regular involvement of regional partners and citizens as well as of key bio-based economy stakeholders, policy-makers and the Knowledge Centre for Bioeconomy (KCB) [112]. These stakeholder groups were referred to as the uptake stakeholder community from the fields of industry and consumer protection, civil society and environment, policy and government,

education, research and media and are considered “key potential users” of the data coming from the serious game (detailed overview about the uptake strategy and mapping of key potential users of project insights, their engagement process and results are described in AllThings.bioPRO public project deliverables [101,102,112]). Their inclusion aimed to find out what wishes the uptake experts have about the serious bioeconomy game and what results they expect it to bring. The summary of some main expectations are presented in the table below (Table 5).

Table 5. Uptake experts’ expectations about the “Mission BioHero” game and impressions after testing the first prototype.

Expectations from the Uptake Experts	Initial Results (after the Game Was Tested in Spring 2023) ¹ [101]
Game to educate about bioeconomy, bio-based alternatives, and consumer behaviour	Most experts have noted the educational capacity of the game, saying that the learning objective of it is very clear, and that the game is very good for educational purposes. They mentioned, however, that the bioeconomy terms (lexicon) could be expanded.
Game to raise awareness about sustainability and bioeconomy	It was noted that the game is good for raising awareness; however, changing consumer’s attitudes is more difficult and requires more than just awareness.
Promote information about the bio-economy and motivate players to engage with these topics	The promotion of information about bioeconomy was mentioned together with educational aspects by most of the experts. However, engagement with bioeconomy topics depends on a variety of factors, so the opinions about it were mixed.
Filtering the data according to the country of living/chosen language	The game collects these types of data when the user registers before playing, what could help in putting together educational programmes and inform the initiatives.

Source: Authors’ own, based on [101]. ¹: By the time of writing this article the final results, especially for assessing the data value from the game, from this community were not yet accessible.

From Table 5, it is visible that the expectations of the experts were largely met and reflected in the “Mission BioHero” game, but still, suggestions for improvements for impact increase were noted. For example, in some bilateral interviews with experts (these interviews were conducted by Prospex Institute and anonymous quotes from experts shared with the authors of this article for the purpose of the research, see also [102]), it was recommended by the uptake stakeholders to make sure the serious game is properly maintained and kept current to reflect the latest changes in the Bioeconomy. Additionally, it was recommended to simplify the serious game instructions, tutorials, and quizzes, a few uptake stakeholders felt as if there was too much content which could frustrate and deter users from using the serious game.

Further, potential uptake of the game was also assessed during the game-testing sessions where the participants were asked to rate some statements related to this (see Supplementary S14).

On average, the respondents felt that the game will be most likely played by adults rather than children (45% stated “Yes” or “Rather yes” to this claim), which aligns with the previous feedback of the game being rather difficult for children. Child participants commented in the game-testing sessions that some of the concepts related to the bioeconomy were confusing and that the games and quizzes were too hard for them. Specifically for Estonian children, the game was confusing for them as it was not in their native language and this may have exacerbated their confusion [109]. However, it is important to note that

the purpose of the serious game is to educate the users about the bioeconomy, so confusion and lack of knowledge of the topic when first playing the serious game is expected to an extent, but if the content is confusing to the point where it decreases the motivation of participants to use the serious game, then changes to the content should be made.

Most respondents (40%) indicated that they would rather not look for educational games of this type to play in their free time. This finding for serious games is unsurprising, since one typically does not download and spend time playing serious games for their own enjoyment; rather, there needs to be some type of coercion to play the game, such as in school setting [32]. Thus, the game's uptake strategy should focus on captive users, such as in an educational setting to be used by a teacher.

The statement "I will recommend this game to others" is an indicator of how likely the test group would be to share the game by word of mouth to their friends, family, and peers: 40% of respondents were more likely not to share the results, which shows a general lack of enthusiasm for playing the game. This can be connected with the following statement where participants were asked to rate the statement "I will continue to play the game regularly", which shows an overwhelming number of participants selecting "No" (34%) and "Rather no" (19%), indicating that over 50% of the respondents would not continue playing the game.

Interviews with co-creation and co-design participants offered some insight into the motivation for users to return to play the game. When asked about the sustainability of the game, then the interviewees mentioned that improving the gameplay of the game (i.e., adding arcade elements) and making it "catchier", would improve the uptake of the game among the target audience, which was mainly viewed to be high school students or university students, since the game was believed to be quite technical and topic-heavy for younger children. In the current state of being mostly an educational game, the interviewees do not see the game going viral.

"I think I won't play it consistently, but I will have some sessions to solve nearly all tasks. and I will surely have sessions to renew my knowledge." (Interviewee 8)

"Regular usage is another thing-I played the game for 30–60 min initially but haven't really felt the need to open it again afterwards." (Interviewee 7)

"I do not know enough about gaming, but I feel like the game works well and it might be interesting to spend some time with it. But it does get boring with time" (Interviewee 9)

This feedback as well as the game-testing sessions showed that the developed "Mission BioHero" game is potentially more suitable for teaching than pure entertainment purposes [9,38], where players are engaged in it in a controlled environment. Based on the results of the game-testing workshops especially with younger audiences, it became clear that without proper guidance, children may miss the full potential of the game and understand its concepts. These findings together with discussions and suggestions with the project's advisory board led to the development of the "Teachers Handbook" [111], which was also translated into English, Italian, German, Dutch, and Estonian and that helps to effectively implement the game in the educational environment and help the players to experience the game to its fullest.

Speaking to the educational value, uptake stakeholders positively reviewed some aspects of the serious game, emphasising its educational relevance and how it would be a fun and playful way to teach essential environmental knowledge. For example, uptake stakeholders highlighted the elements of the game content as being particularly attractive and engaging, including the minigames, city builder, and quizzes which were seen to have learning value, which may result in some users changing their behaviours [102]. However, the uptake stakeholders had doubts about the appeal of the serious game to adults without incentives to play the game. Thus, the focus of the serious game in educational settings should be prioritised [102]

Overall, the external game-testing sessions have been additionally valuable for further refinements of the developed game [14] which can increase the impact and uptake of it.

Despite further efforts needed to improve the uptake of the game, the decision to create this game via a challenging and intensive co-creation and co-design approach has been valuable to the result. Game developers emphasised that without co-creation and co-design the serious game would have reflected the points of view of a much narrower target group or would not have been as imaginative. It was emphasised that the co-creation and co-design process 100% increased the current quality of the game, particularly the look, setup, story, and player functionalities. This reflects some of the claimed benefits of the participatory design process demonstrated in previous research [75,79].

6. Discussion

According to research [4,7,29,79], there is great value in co-creation and co-design whether it comes to addressing common problems or developing a new service or product. Keeping several potential values of such participatory design approach in mind, clear structure and framework for co-creation and co-design of the “Mission BioHero” game was set. The “Mission BioHero” empirical example and contribution to the field can be noteworthy as “co-creation as a research area is multifaceted, there is a need to formalise the co-creation process in a greater extent and to assess methodologies that apply techniques for involving customers in co-creation” [113] quoted in [37], pp. 4374. In the following paragraphs, the results of such a participatory game development process are discussed along the posed research questions.

6.1. The Success and Effectiveness of Co-Creation and Co-Design in Developing “Mission BioHero”

The analysis of the “Mission BioHero” participatory process shows that all set requirements (see also [59,79,83]) were ultimately met in co-designing the “Mission BioHero” serious game, namely, the planned sequence of the co-creation and co-design workshops, preparing different mission partners to facilitate the sessions in different countries, putting extra focus on securing the diversity of participants as well as providing them an inclusive and safe place to discuss topics and design the game, or feeding back the results of their participation to them, despite challenges that occurred during the journey.

With reference to the first research question, it can be concluded that engagement and the participatory design process of a new serious game in the bioeconomy has been valuable and gathered creative ideas for the game in the co-creation phase, tested and refined these concepts in the co-design phase, and provided participants with an enjoyable experience. Design thinking elements were present throughout the sequences of events and provided valuable guidelines for session facilitators with different experience levels. According to several recurrent surveys and interviews with session facilitators, the partners felt like they had achieved the goals set out for them. Like several other interesting cases [7,17,20,33], this study demonstrated that stakeholders and targeted users can provide the development team with valuable insights.

As to better capture the variety of “local” insights and to co-develop the game, it was decided at the very beginning that in the first phases of co-creation, citizens as the potential target group and experts in the field in different missions are recruited locally, even though co-creation sessions were organised in parallel in different countries. Thus, horizontal orchestration of the co-creation and co-design to work towards the common goal was extremely important in this setting (see also [114]). HelpDesk function setup for the regional mission facilitators was a necessary driver to keep the enthusiasm to continue with long co-creation and co-design phase. It is evident from this case study that effective coordination, clear instructions, open communication, trainings, etc., and mutual support from project partners as facilitators in different cultural settings, like experience exchange and observing each other’s events is helpful in organising such “intercultural” participatory design processes.

Developing “Mission BioHero” serious game demonstrates some important aspects that have been highlighted by other scholars [29,59,83]. It can be argued that, indeed, concentration on some key principles that the organisers took as a basis, like focus on

end users since the beginning, equal collaboration between participants regardless of their previous experience and knowledge, openness, adaptation, and process orientation as important principles are central to the success of the co-creation and co-design.

Having co-creation workshops together with citizens and experts alike (togetherness); holding regular iterative and ongoing participative process, but also with a possibility to include new participants (transparency); aiming to involve as heterogeneous group as possible in each mission; providing the users some preliminary training into the topic and design thinking tools and enhancing the provision of environment where all stakeholders supported each other [20,59,83] are some of the key things that can be attributed to the success of the whole process.

The case study also demonstrates some common difficulties in such design processes. In spite of the widely acknowledged value of the co-creation process [29,79,115], limited participation and retaining the participants over a long course of time can pose a significant problem [37]. Even though in designing the “Mission BioHero” game, the partners praised the co-creation workshops for being highly creative, productive, and producing many ideas and all were also satisfied with the diversity of participants, still, the retention of participants increasingly became an issue for some regional facilitators. This may be considered a hindering factor in all long-term co-creation and co-design processes that rely on voluntary contribution (see also [116]): without a clear set of benefits (other than being able to participate and contribute) and with a long timeline, it is difficult for the organisers keep participants engaged. Thus, good examples and motivation measures to retain a steady participation rate are still needed in processes of co-designing the serious games [116]. Knowing, what motivates the participants, is essential to tailor the process and strategy towards them. In case of “Mission BioHero” game, some facilitators suggested that even better and more frequent communication with participants could have helped improve the engagement of the participants as it would have kept them “in the loop”.

Even though “Mission BioHero” game development could be assessed as an exemplary case of following a useful co-creation and co-design approach, it was found in final reflection rounds and surveys a clearer “lesson plan” for the co-creation and co-design activities would have been helpful from the beginning. Additionally, for some regional partners, it was not always clear what the main outcome and/or objective(s) were for each co-creation and co-design activity, thus illustrating the challenges highlighted also by Morello et al. report [63] and what Winn describes as “creative but sometimes chaotic” (quoted in [23]). It is difficult to speculate where this confusion came from, since communication between partners was assessed as open and frequent. It still shows that it is worthwhile spending time on creating greater clarity about the objectives and guidelines at the beginning of such processes.

In spite of some confusion at the beginning, mutual communication and coordination were overall highly praised and attributed as a core driver of the success of the co-creation/co-design activities. Additionally, appointing a central coordinator to orchestrate the whole process in different cultural settings; training the regional facilitators before the start of the co-creation process; providing written instructions and guidelines; and HelpDesk function to support the facilitators over the long period of participative activities were some of the main success drivers of “Mission BioHero”.

The lesson from the “Mission BioHero” case study is, from one side, the importance of having a clear strategy and long-term plan for co-creation and co-design process as valued highly by the facilitators and participants, but at the same time being able to adjust and adapt the process, when needed. For example, the K&S mission adapted the formats and, the feedback surveys to the children’s needs to ensure the children are engaged throughout the sessions and that the materials used are age-appropriate as well as had some differences in conducting the workshops compared to other missions. Sessions with children in each phase and game testing generated rich input for the final game and were highly valued by the game developer. Thus, “Mission BioHero” case study shows that children can act as true co-designers (see also [33]).

Most comprehensive adjustment to the plan was made due to the COVID-19 pandemic and because of the need to move all activities online. It posed difficulties for some partners not being used to or aware of moderating online sessions, using digital tools like Padlet, Miro or similar, and required to dedicate resources for sufficient preparation from the HelpDesk. Surprisingly, the unexpected shift to online formats may have had a positive impact on the process as it allowed for more stakeholders from different regions to attend and for project partners to observe each other's events. Being able to adapt to the crisis and still organise successful co-creation and co-design processes is a testament to the methods' flexibility and usability in various contexts. In the post-covid world, digital tools have been integrated into our daily lives. Thus, the use of digital tools in these methodologies should be considered standard practice and integrated into the co-creation and co-design process as a primary tool to host meetings or at the very least a contingency plan in case face to face interactions are not possible. For others wishing to implement co-creation and co-design methodologies, one should also consider different formats for hosting participative sessions, considering the cultural, demographic, etc. characteristics of the participants (and the target group for the serious game) and prepare the facilitators beforehand to cope with most probable situations from the beginning of the project. The "Mission BioHero" case study shows that co-creation and co-design can be effectively conducted also via online setting.

6.2. Learning Value of the Co-Creation and Co-Design

The second research question explored the value of co-creation and co-design to the participants and partners organising the process. This was more difficult to explore due to the limitations of the study in terms of suitable methodologies to explore the increase in benefits and the assessments have remained based on the self-reflective answers of the participants in different surveys and interviews [15,32]. However, the gathered data indicate that the participants learned about bioeconomy and its related concepts, and serious game design and for the project partners, the engagement process provided many opportunities to learn, adapt, and gain new skills, confirming that learning already via the participatory process itself is evident through this empirical example.

In the "Mission BioHero" development process, levels of understanding and attitudes differed across and within the participating groups, especially at the start of the co-creation phase and within citizen focus groups. Nevertheless, and according to the principles of successful co-creation [59,83], involving different levels of experience was important as the game was intended to be designed for the general public to learn about bioeconomy. The varied levels of knowledge about the bioeconomy and game design process may have also contributed to sharing and knowledge exchange about these topics among the groups. Notably, the game designer mentioned that they would not be able to include all the concepts had it not been for the collaboration with co-creation participants which underscores the importance of this process (see also Section 5.5). Moreover, since most participant groups had a mix of citizens and experts, this also contributed to sharing and exchanging knowledge about these topics among the group.

Thus, the case study argues for some evidence on rapid cognitive learning (see also [14–16]), but also value of the process to the participants' normative and relational learning, the latter especially connected to the approach of having the first workshops in their own local settings, building contacts with other participants, being invited to follow the related networks of moderators and facilitators keeping regular contacts with their participants and promoting each following step in the game development process. Even though the actual impact on learning would need deeper investigation, interviews with some of the co-creation and co-design participants revealed how they had taken the experience and especially topic-wise knowledge into their daily habits. As also evident from gathered feedback in this research, almost all mission participants as well as facilitators were largely convinced in the learning value of this process.

For the facilitators of the participative sessions, one value was to understand the needs and expectations of their target groups better, and many admitted that the bioeconomy

focus and the online format helped them to expand their contact networks and work with target groups they had not worked with before. This indicates increased and extended cooperation between all parties and thus a relational learning effect. Regional facilitators noted considerable growth and learnings in various areas both professionally and personally including how to use new engagement methods, practical knowledge about project management, new knowledge about bioeconomy and serious game development, demonstrating larger significant impact on stakeholders' learning that happens during the participatory co-design activities, see also [7,12,13,24].

6.3. End Result: "Mission BioHero"

Finally, the third specific research question explored the value of the co-creation and co-design to the results. Based on the feedback from participants, facilitators and coordinators, many expected benefits from co-creation and co-design were realised. All mission partners felt that the users' contribution in the process was invaluable: the range of ideas and creativity was even surprising for some partners, see also [17,77–79]. Participants, external game testers as well as uptake experts largely agreed that the game has potential to be an effective educational serious game. The complexity of the game was continuously on the table through the design process and even during the testing, but because having the possibility to discuss it regularly after each modification round, several adjustments were made based on that feedback.

Serious game uptake can be indeed difficult as it is challenging to score high on both levels: being fun and educational at the same time [38]. "Mission BioHero" did not succeed in overcoming this. Even though results on the user experience and educational value were well reviewed and the playing experience was generally enjoyable, game-testing results indicated that the users were not interested in continuing to play the serious game on their own. Furthermore, the serious game has a finite ending, meaning that once the game has been beaten, it is unlikely the user will play it again. What is more, the serious game is competing against thousands of games and apps on the market, of which serious games are not ranked in the top categories for mobile game downloads. This is not indicative of the quality or educational value of the serious game, but more so that on its own, serious games are not in a popular category. Indeed, it has been cited in literature that it is difficult to get people to play a serious game without their being an impetus to do so and that some form of coercion is needed to encourage users to play it [32]. This is also supported by the "Mission BioHero" case.

In the light of this, using the serious game in an educational setting could be a solution to encourage its repeated use, which is also supported by feedback from co-creation and game-testing participants, uptake stakeholders (see Section 5.8), and the project partners. Thus, the results of this study enable us to identify potential exploitation and uptake strategies for the game, through tailor made promotion to a carefully defined target group (educational) organisations, networks and by providing supporting guidelines, like the "Teachers' Handbook" [111]. Without the feedback of the target group in the co-design and game-testing process (including uptake stakeholders), having a defined uptake strategy would not have been possible, thus illuminating an additional benefit for this co-creation/co-design process.

6.4. Co-Designed or "Traditional" Development of the Serious Games?

What would interest many developers of (serious) games is the actual value of such process to the professional game developers. Indeed, there is no doubt that developing especially serious games for educational purposes can be very complex, expensive and entail significant challenges [14,36]. For the developers, there are always costs related to choosing between different strategies to develop games and questions arise, whether the benefits of co-creation and co-design, indeed, "pay back"—the additional costs in the long term (see also [37,79]).

From the perspective of professional game developers included in the “Mission BioHero” serious game development, co-creative processes are normally done internally and with professional stakeholders (see also [7,24]), so including participants in the game design process was new. From a business perspective, game design is normally a metric-driven process, where commercial success is essential, so in some cases, it may not make sense to incorporate such specific feedback from a limited target group. However, leaning on research about benefits of co-design [79], in addition to the immediate benefits in one project, reflecting that participatory design offers many opportunities to further promote a focus on customers and users, to foster creativity and cooperation, and to improve organisations’ innovation capabilities and practices, is noteworthy.

The critical focus point is to involve the right people from various stakeholder groups into the process with appropriate roles [79]. Thus, even a small group representing the potential user can open new perspectives for the product or service to be successful en masse. It is inevitable that achieving successful learning outcomes in a game requires significant dedication of time resources but especially in cases where learning is a primary objective the organiser ought to strategise a sequence of engagement opportunities [14]. The fact that this content could be immediately reflected and tested with “ordinary” citizens via the co-creation and co-design added even more value to fine-tune the final outcome.

Ultimately, the concrete cost-related benefits for the professional game development remained unclear in this case, and one could agree with Steen et al. [79] that costs and risks of co-design, especially related to increased complexity of the project to mediate and coordinate between diverse set of stakeholders and interests still need further research (and this case also more time for assessing such impacts once the game has been more widely taken up).

What then can be learned from the “Mission BioHero” case study? Similarly to what was expressed by Eriksen et al. [117], all in all, this case study shows that participatory processes can add coherence and informed content, ties to real experiences and social practices, and instigate a sense of confidence with and ownership of the final game. Indeed, especially the latter was evident from the feedback rounds with the participants. An enthusiasm around the developed game was created, which the participants, including children as co-designers in one specific mission, appreciated. Social learning occurred for both participants invited to the process and for the facilitators. There are positive indications towards at least cognitive and normative learning because of this participation by the stakeholders, but also some relational learning effects as observed by the facilitators. Thus, embracing participatory game prototyping, where future players and stakeholders, including field experts, actively participate as informants and design partners rather than just users and testers, holds great promise for the field of serious game design [24].

Moreover, this case study is another indication that developing a serious game and balancing between the expectations of regular fun gameplay and “viral” games vs. educational content can be extremely challenging [38]. Here, co-creation and co-design processes can still be helpful to direct the developer in the most favourable direction. Some of the key driving factors for success that appeared in this empirical study are similar to what has been stated before [14], namely, building robust levels of trust among researchers, practitioners, and community participants at both inter and intra levels where all stakeholders can collaborate more effectively and openly. This was facilitated via incorporating strong debriefing sessions, feedback loops, and evaluation practices that allow for continuous reflection and refinement throughout the design process to build a shared understanding of the goals, methodologies, and desired outcomes. Understanding the co-creation and co-design process in detail, providing more empirical cases like the current one and lessons learned could be very useful learning for the future similar attempts to design serious games in sustainability and bioeconomy topics (or any topic).

6.5. Limitations of the Study and Further Research

Some of them already mentioned above, there were limitations included in the design of this study, which do not (yet) allow us to make precise conclusions about many other interesting aspects of the co-creation and co-design value in developing serious (digital) games. This study could only to a limited extent touch upon the actual relevance and impact of the serious game in bioeconomy. Thus, the research has limitations in assessing real outcomes in social learning and especially related to normative and relational learning. The applied methodology here could mostly assess participants' perceived cognitive learning effects from participating in the co-creation and co-design phases of the game development [12,23] as well as from playing the game, for example, in the testing sessions [14]. This is because the first in-game data with the help of designed in-game measurements had just begun to appear after the public launch of the "Mission BioHero" game in spring 2023. Although this kind of in-game data was also gathered through testing sessions, it was under continuous development responding to the feedback from the stakeholders from the testing phase as well as being still lacking in data in order to make more robust conclusions.

This case study offers several further angles to investigate, for example, being a perfect research base to assess the nature of the developed game and its effectiveness and impact of being educational serious game. If there is an opportunity to create a follow-up study, the authors would focus on the actual learning impact of the developed serious game to assess whether the users gained new knowledge about the bioeconomy and if it impacted their shopping habits. The research team could test the serious game with different groups, especially students, controlling for them with and without the serious game as a learning tool to understand the effectiveness and impact of field-specific serious games in general. Potential value in society, industry and policies could be also researched. For this, future baseline information can include in-depth feedback sessions with uptake experts and in-game data analytics. This can contribute to the scarce research about the impact of the game to influence policies or other wider actions in the society [14,36,118,119].

In the case of "Mission BioHero", the retention of the same group of stakeholders throughout the co-creation and co-design process was a challenge, leading to lower-than-expected results for the follow-up survey in the co-creation phase. This is seen as a limitation because it does not allow for a full comparison between the baseline survey responses, and concrete conclusions cannot be made for changes in knowledge or perception from the beginning of the process to the end of the co-creation activities. While the authors could not control the participation of stakeholders and engagement with them (this was the responsibility of mission partners), future studies should try to compensate the participants if resources allow or focus on quality over quantity, that is, host fewer workshops and try to achieve more within that time period to optimise the time and effort of the participants.

Further, similar to what Füller et al. [116] looked at, this case study is not yet successful, but could provide a good basis to study more in depth the motivations of participants to be involved in such participatory design processes and so help to design the processes for tomorrow to retain the participants in iterative processes more effectively.

7. Conclusions

Stakeholder engagement for developing the bioeconomy serious game "Mission BioHero" has been a thorough, co-creative, step-by-step process managed by partners from five different countries across four bioeconomy mission areas (food packaging, fashion and textiles, kids and schools, jobs and careers). The engagement process was monitored by the project's research team through various evaluation tools directed to both co-creation and co-design participants and project partners, observation, joint discussions, and follow-up interviews. The main aim has been to understand the nature and influence of co-creation and co-design in developing a serious game on the participants as well as to the result, so that this experience and key takeaways could be taken into consideration in future similar attempts. Three specific research questions were posed to explore the case study:

1. How successful were co-creation and co-design in developing the “Mission BioHero” game in terms of process and satisfaction of the stakeholders and what was driving this?
2. What was the (learning) value of co-creation and co-design to the participants?
3. What was the value of the co-creation and co-design to the final outcome, i.e., the serious game?

What can be concluded from the case study is that the co-creation and co-design activities used in “Mission BioHero” game development have been successful since they have largely matched the expectations of the participants and even exceeded the expectations of facilitators. In spite of some challenges, all partners agreed that using co-creation and co-design in designing the serious game was very valuable. Additionally, as serious games are designed to provide also educational value next to pure entertainment, “Mission BioHero” is believed to influence a user’s consumer behaviours and to be an effective tool to learn more about bioeconomy, relevant to the everyday topics where bioeconomy is present. The case study shows that participatory game prototyping, which involves future players and stakeholders as design partners, offers a promising method for the field of serious game design. This collaborative approach has the potential to revolutionise the way games are created, making them more engaging, effective, and impactful, e.g., by finding through co-creation and design the best directions for their further uptake. By valuing the input of diverse voices and empowering individuals to shape the game’s development, new frontiers in serious game design can be unlocked. Inevitably, stakeholder engagement in the long-term co-creation and co-design process is a challenging and multi-faceted undertaking, but as the “Mission BioHero” case study shows, the potential benefits of participatory game prototyping likely outweigh these hurdles. For the developers wanting to learn from the “Mission BioHero” example, this case study can add some invaluable takeaways for confirming some already known valuable steps and drivers in the co-creative process and serious game designs, and hopefully unleash also some new empirical knowledge for future practical implementation.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/su151813364/s1>, Supplementary S1: The AllThings.bioPRO project evaluation tools. Supplementary S2: Co-creation and co-design phases of the “Mission BioHero” game development process. Supplementary S3: Biannual partner survey overview. Supplementary S4: Moderator/facilitator self-reflection survey overview. Supplementary S5: Number of participants per mission and co-creation sequence. Supplementary S6: Overview of co-creation phase baseline and follow-up survey responses. Supplementary S7: Co-design workshops, participants, and the number of follow-up survey responses. Supplementary S8: “Mission BioHero” game testing workshop dates and stakeholder groups involved. Supplementary S9: Follow-up interviews with partners involved in the co-creation and co-design process. Supplementary S10: Co-design participants’ follow-up survey answers to the question: On a scale of 1–10, do you think the game design you helped develop is visually appealing? Supplementary S11: Co-design participants’ follow-up survey answers to the question: On a scale of 1–10, do you think the game design you helped develop is intuitive, i.e., easy to understand for the player/user? Supplementary S12: Co-design participants’ follow-up survey answers to the question: How regularly do you think you would play the game? Supplementary S13: Co-design participants’ follow-up survey answers to the question: Would you recommend the mobile game to others? Supplementary S14: Assessment of game-playing experience by the game-testing workshop participants (%). Supplementary S15: Assessment of game-playing experience by the children’s (age 12–17) game-testing workshop participants. Supplementary S16: Game experience of the participants with low-medium and high bioeconomy knowledge (% of responses). Supplementary S17: No. of unique participants compared to the total number of events (Focus group, co-creation workshop, or co-design workshop) they attended distributed by mission and country (participants per event). Supplementary S18: Co-design participant responses to “Did you enjoy participating in the co-design meetings” by mission and total (% and number of respondents). Supplementary S19: Level of satisfaction of the co-creation workshops by follow-up respondents (% and number of respondents).

Author Contributions: Conceptualisation, M.T.; data curation, M.T., M.K., A.A. and R.K.H.; formal analysis, M.T., M.K., A.A. and R.K.H.; funding acquisition, M.T.; methodology, M.T. and R.K.H.; project administration, M.T.; resources, M.T.; visualisation, M.T., M.K., A.A. and R.K.H.; writing—original draft, M.T., M.K., A.A. and R.K.H.; writing—review and editing, M.T., R.K.H. and M.K. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by European Commission grant 887070.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Informed consent was obtained from all participants involved in the study.

Data Availability Statement: The authors confirm that the data supporting the findings of this study are available within the article and its supplementaries. Further data are available upon request.

Acknowledgments: Besides the European Commission funding opportunity, we wish to thank all AllThings.bioPRO partners and regional co-creation and co-design process facilitators for their close collaboration in this study, and especially the project coordinator Fachagentur Nachwachsende Rohstoffe e.V. (FNR), participatory process central coordinator Bonn Science Shop (Wissenschaftsladen Bonn e.V.) (BSS), game developer NuroGames, and Prospex Institute (PI), who conducted the inclusion of uptake stakeholders and field experts and provided insights from this process to the current study for their scientific support. We are also grateful to all participants in the co-creation and co-design process who gave us valuable feedback and participated in our surveys and interviews.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

References

1. Maier, K. Citizen Participation in Planning: Climbing a Ladder? *Eur. Plan. Stud.* **2001**, *9*, 707–719. [\[CrossRef\]](#)
2. Björgvinsson, E.B. Open-Ended Participatory Design as Prototypical Practice. *CoDesign* **2008**, *4*, 85–99. [\[CrossRef\]](#)
3. Kankainen, A.; Vaajakallio, K.; Kantola, V.; Mattelmäki, T. Storytelling Group—A Co-Design Method for Service Design. *Behav. Inf. Technol.* **2012**, *31*, 221–230. [\[CrossRef\]](#)
4. Sanders, E.B.-N.; Stappers, P.J. Co-Creation and the New Landscapes of Design. *CoDesign* **2008**, *4*, 5–18. [\[CrossRef\]](#)
5. Khaled, R.; Vasalou, A. Bridging Serious Games and Participatory Design. *Int. J. Child-Comput. Interact.* **2014**, *2*, 93–100. [\[CrossRef\]](#)
6. Lange-Nielsen, F.; Lafont, X.V.; Cassar, B.; Khaled, R. Involving Players Earlier in the Game Design Process Using Cultural Probes. In Proceedings of the 4th International Conference on Fun and Games, New York, NY, USA, 4 September 2012; Association for Computing Machinery: New York, NY, USA, 2012; pp. 45–54.
7. Ampatzidou, C.; Gugerell, K. Participatory Game Prototyping—Balancing Domain Content and Playability in a Serious Game Design for the Energy Transition. *CoDesign* **2019**, *15*, 345–360. [\[CrossRef\]](#)
8. Tan, C.; Nurul-Asna, H. Serious Games for Environmental Education. *Integr. Conserv.* **2023**, *2*, 19–42. [\[CrossRef\]](#)
9. Beg, I.; Looy, J.; All, A. *Evaluation of the Game Development Process of a Location-Based Mobile Game*; Academic Conferences International Limited: Reading, UK, 2014; Volume 1.
10. Billger, M.; Kain, J.-H.; Niwagaba, C.B.; McConville, J.R. Lessons from Co-Designing a Resource-Recovery Game for Collaborative Urban Sanitation Planning. *IOP Conf. Ser. Earth Environ. Sci.* **2020**, *588*, 042041. [\[CrossRef\]](#)
11. All, A.; Nunez Castellar, E.; Castellar, N.; Looy, J. Measuring Effectiveness in Digital Game-Based Learning: A Methodological Review. *Int. J. Serious Games* **2014**, *1*, 2. [\[CrossRef\]](#)
12. Gugerell, K.; Zuidema, C. Gaming for the Energy Transition. Experimenting and Learning in Co-Designing a Serious Game Prototype. *J. Clean. Prod.* **2017**, *169*, 105–116. [\[CrossRef\]](#)
13. Hammady, R.; Arnab, S. Serious Gaming for Behaviour Change: A Systematic Review. *Information* **2022**, *13*, 142. [\[CrossRef\]](#)
14. Flood, S.; Cradock-Henry, N.A.; Blackett, P.; Edwards, P. Adaptive and Interactive Climate Futures: Systematic Review of ‘Serious Games’ for Engagement and Decision-Making. *Environ. Res. Lett.* **2018**, *13*, 063005. [\[CrossRef\]](#)
15. Den Haan, R.-J.; Van der Voort, M.C. On Evaluating Social Learning Outcomes of Serious Games to Collaboratively Address Sustainability Problems: A Literature Review. *Sustainability* **2018**, *10*, 4529. [\[CrossRef\]](#)
16. Baird, J.; Plummer, R.; Haug, C.; Huitema, D. Learning Effects of Interactive Decision-Making Processes for Climate Change Adaptation. *Glob. Environ. Chang.* **2014**, *27*, 51–63. [\[CrossRef\]](#)
17. Moizer, J.; Lean, J.; Dell’Aquila, E.; Walsh, P.; Keary, A.; O’Byrne, D.; Di Ferdinando, A.; Miglino, O.; Friedrich, R.; Asperges, R.; et al. An Approach to Evaluating the User Experience of Serious Games. *Comput. Educ.* **2019**, *136*, 141–151. [\[CrossRef\]](#)
18. Buil, I.; Catalán, S.; Martínez, E. Exploring Students’ Flow Experiences in Business Simulation Games. *J. Comput. Assist. Learn.* **2018**, *34*, 183–192. [\[CrossRef\]](#)

19. Bellotti, F.; Berta, R.; Gloria, A.D. Designing Effective Serious Games: Opportunities and Challenges for Research. *Int. J. Emerg. Technol. Learn. IJET* **2010**, *5*, 22–35. [\[CrossRef\]](#)
20. De Jans, S.; Van Geit, K.; Cauberghe, V.; Hudders, L.; De Veirman, M. Using Games to Raise Awareness: How to Co-Design Serious Mini-Games? *Comput. Educ.* **2017**, *110*, 77–87. [\[CrossRef\]](#)
21. Geurts, J.L.A.; Duke, R.D.; Vermeulen, P.A.M. Policy Gaming for Strategy and Change. *Long Range Plann.* **2007**, *40*, 535–558. [\[CrossRef\]](#)
22. Mayer, I.S. The Gaming of Policy and the Politics of Gaming: A Review. *Simul. Gaming* **2009**, *40*, 825–862. [\[CrossRef\]](#)
23. Lanezki, M.; Siemer, C.; Wehkamp, S. “Changing the Game—Neighbourhood”: An Energy Transition Board Game, Developed in a Co-Design Process: A Case Study. *Sustainability* **2020**, *12*, 10509. [\[CrossRef\]](#)
24. Mildner, P.; Mueller, F. Design of Serious Games. In *Serious Games: Foundations, Concepts and Practice*; Springer: Berlin/Heidelberg, Germany, 2016; pp. 57–82, ISBN 978-3-319-40611-4.
25. All, A.; Looy, J.; Nunez Castellar, E. Co-Designing Interactive Content: Developing a Traffic Safety Game Concept for Adolescents. In Proceedings of the 6th European Conference on Games Based Learning (ECGBL-2012), Cork, Ireland, 4–5 October 2012; p. 20, ISBN 978-1-908272-70-6.
26. Zaman, B.; Poels, Y.; Sulmon, N.; Annema, J.H.; Verstraete, M.; Cornillie, F.; De Grooff, D.; Desmet, P. Concepts and Mechanics for Educational Mini-Games. A Human-Centred Conceptual Design Approach Involving Adolescent Learners and Domain Experts. *Int. J. Adv. Intell. Syst.* **2012**, *5*, 567–576.
27. Ampatzidou, C.; Gugerell, K. Mapping Game Mechanics for Learning in a Serious Game for the Energy Transition. *Int. J. E-Plan. Res.* **2019**, *8*, 1–23. [\[CrossRef\]](#)
28. Tuli, N.; Mantri, A. *A Co-Design Methodology to Design and Develop Serious Educational Games: Integrating the Actors and Challenges in Each Phase*; Springer: Berlin/Heidelberg, Germany, 2018; p. 52, ISBN 9789811307546.
29. Cockbill, S.A.; May, A.; Mitchell, V. The Assessment of Meaningful Outcomes from Co-Design: A Case Study from the Energy Sector. *She Ji J. Des. Econ. Innov.* **2019**, *5*, 188–208. [\[CrossRef\]](#)
30. Slimani, A.; Bakkali Yedri, O.; Fatiha, E.; Bouhorma, M. Towards a Design Approach for Serious Games. *Int. J. Knowl. Learn.* **2016**, *11*, 58–81. [\[CrossRef\]](#)
31. Stappers, P.J. Doing Design as a Part of Doing Research. In *Design Research Now: Essays and Selected Projects*; Michel, R., Ed.; Board of International Research in Design; Birkhäuser: Basel, Switzerland, 2007; pp. 81–91, ISBN 978-3-7643-8472-2.
32. All, A.; Nunez Castellar, E.; Looy, J. A Systematic Literature Review of Methodology Used to Measure Effectiveness in Digital Game-Based Learning. In Proceedings of the 7th European Conference on Game Based Learning, Paisley, UK, 25–26 October 2007; Publishing International Limited: Gloucestershire, UK, 2013; Volume 2, p. 616.
33. Menestrina, Z.; Pasqualotto, A.; Siesser, A.; Venuti, P.; De Angeli, A. Engaging Children in Story Co-Creation for Effective Serious Games. *Sustainability* **2021**, *13*, 10334. [\[CrossRef\]](#)
34. Moser, C.; Fuchsberger, V.; Tscheligi, M. Rapid Assessment of Game Experiences in Public Settings. In Proceedings of the Proceedings of the 4th International Conference on Fun and Games, New York, NY, USA, 4 September 2012; Association for Computing Machinery: New York, NY, USA, 2012; pp. 73–82.
35. Gennari, R.; Melonio, A.; Raccanello, D.; Brondino, M.; Dodero, G.; Pasini, M.; Torello, S. Children’s Emotions and Quality of Products in Participatory Game Design. *Int. J. Hum.-Comput. Stud.* **2017**, *101*, 45–61. [\[CrossRef\]](#)
36. Stanitsas, M.; Kirytopoulos, K.; Vareilles, E. Facilitating Sustainability Transition through Serious Games: A Systematic Literature Review. *J. Clean. Prod.* **2019**, *208*, 924–936. [\[CrossRef\]](#)
37. Durugbo, C.; Pawar, K. A Unified Model of the Co-Creation Process. *Expert Syst. Appl.* **2014**, *41*, 4373–4387. [\[CrossRef\]](#)
38. Moreno Ger, P.; Burgos, D.; Martinez-Ortiz, I.; Sierra, J.; Fernández-Manjón, B. Educational Game Design for Online Education. *Comput. Hum. Behav.* **2008**, *24*, 2530–2540. [\[CrossRef\]](#)
39. AllThings.bioPRO Learning by Playing: AllThings.Bio Turns People into Bio-Heroes. Available online: <https://www.allthings.bio/learning-by-playing-allthings-bio-turns-people-into-bio-heroes/> (accessed on 24 August 2023).
40. AllThings.BioPRO Project Website. Available online: <https://www.allthings.bio/about-allthingsbiopro/> (accessed on 13 July 2023).
41. Susi, T.; Johannesson, M.; Backlund, P. *Serious Games—An Overview*; School of Humanities and Informatics, University of Skövde: Skövde, Sweden, 2007.
42. Raphael, C.; Bachen, C.; Lynn, K.-M.; Baldwin-Philippi, J.; McKee, K.A. Games for Civic Learning: A Conceptual Framework and Agenda for Research and Design. *Games Cult.* **2010**, *5*, 199–235. [\[CrossRef\]](#)
43. Sutcliffe, M. Simulations, Games and Role-Play. In *The Handbook for Economic Lecturers*; The Higher Education Academy Education Network: Bristol, UK; pp. 1–26.
44. Pagulayan, R.; Keeker, K.; Wixon, D.; Romero, R.; Fuller, T. User-Centered Design in Games. *Hum. Comput. Interact. Handb.* **2012**, *2012*, 795–822. [\[CrossRef\]](#)
45. Ávila-Pesántez, D.; Rivera, L.A.; Alban, M.S. Approaches for Serious Game Design: A Systematic Literature Review. *Comput. Educ. J.* **2017**, *8*, 3.
46. Gameil, A.A.; Al-Abdullatif, A.M. Using Digital Learning Platforms to Enhance the Instructional Design Competencies and Learning Engagement of Preservice Teachers. *Educ. Sci.* **2023**, *13*, 334. [\[CrossRef\]](#)

47. Homer, B.D.; Hayward, E.O.; Frye, J.; Plass, J.L. Gender and Player Characteristics in Video Game Play of Preadolescents. *Comput. Hum. Behav.* **2012**, *28*, 1782–1789. [\[CrossRef\]](#)
48. Dekker, M.R.; Williams, A.D. The Use of User-Centered Participatory Design in Serious Games for Anxiety and Depression. *Games Health J.* **2017**, *6*, 327–333. [\[CrossRef\]](#)
49. Wainess, R.; Oneil, H.; Baker, E. Classification of Learning Outcomes: Evidence from the Computer Games Literature. *Curric. J.* **2005**, *16*, 455–474. [\[CrossRef\]](#)
50. Wu, X.; Liu, S.; Shukla, A. Serious Games as an Engaging Medium on Building Energy Consumption: A Review of Trends, Categories and Approaches. *Sustainability* **2020**, *12*, 8508. [\[CrossRef\]](#)
51. Wouters, P.J.M.; Spek, E.; Oostendorp, H. Current Practices in Serious Game Research: A Review from a Learning Outcomes Perspective. *Games-Based Learn. Adv. Multi-Sens. Hum. Comput. Interfaces Tech. Eff. Pract.* **2009**, 232–250. [\[CrossRef\]](#)
52. Clark, R. Learning from Serious Games? Arguments, Evidence, and Research Suggestions. *Educ. Technol.* **2007**, *47*, 56–59.
53. Schonau-Fog, H.; Bjorner, T. “Sure, I Would Like to Continue”: A Method for Mapping the Experience of Engagement in Video Games. *Bull. Sci. Technol. Soc.* **2012**, *32*, 405–412. [\[CrossRef\]](#)
54. Shute, V.; Rieber, L.; Van Eck, R. Games and Learning. *Trends Issues Instr. Des. Technol.* **2011**, 321–332.
55. Vincent, K.; Dougill, A.J.; Dixon, J.L.; Stringer, L.C.; Cull, T. Identifying Climate Services Needs for National Planning: Insights from Malawi. *Clim. Policy* **2017**, *17*, 189–202. [\[CrossRef\]](#)
56. de Suarez, J.; Suarez, P.; Bachofen, C.; Bachofen, C. *Games for a New Climate: Experiencing the Complexity of Future Risks*; Boston University: Boston, MA, USA, 2012.
57. Juhola, S.; Driscoll, P.; Mendler de Suarez, J.; Suarez, P. Social Strategy Games in Communicating Trade-Offs between Mitigation and Adaptation in Cities. *Urban Clim.* **2013**, *4*, 102–116. [\[CrossRef\]](#)
58. EU Horizon 2020 Project BLOWAYS. “Serious Games”. Available online: <https://www.bioways.eu/bio-learn/serious-games> (accessed on 13 July 2023).
59. Kristensson, P.; Matthing, J.; Johansson, N. Key Strategies for the Successful Involvement of Customers in the Co-creation of New Technology-based Services. *Int. J. Serv. Ind. Manag.* **2008**, *19*, 474–491. [\[CrossRef\]](#)
60. Waltenberg, T.; Steinhaus, N. D3.1: Report of the First Sequence of Focus Groups and Co-Creation Workshops. Deliverable 3.1, AllThings.BioPRO, H2020 Grant No. 887070; Wissenschaftsladen Bonn e.V.: Bonn, Germany, 2021.
61. Burby, R.J. Making Plans That Matter: Citizen Involvement and Government Action. *J. Am. Plann. Assoc.* **2003**, *69*, 33–49. [\[CrossRef\]](#)
62. Lusch, R.F.; Vargo, S.L.; O’Brien, M. Competing through Service: Insights from Service-Dominant Logic. *J. Retail.* **2007**, *83*, 5–18. [\[CrossRef\]](#)
63. Morello, E.; Mahmoud, I.; Gulyurtlu, S.; Boelman, S.; Davis, H. CLEVER Cities Guidance on Co-Creating Nature-Based Solutions: PART I—Defining the Co-Creation Framework and Stakeholder Engagement. Deliverable 1.1.5, CLEVER Cities, H2020 Grant No. 776604; Politecnico di Milano: Milan, Italy, 2018.
64. Meister Broekema, P.; Horlings, L.G.; Bulder, E.A.M. Understanding the Value of Co-Creation for Social Innovation Interpretations of Social Innovation and Co-Creation in European Policy-Related Documents between 1995 and 2018. *Innov. Eur. J. Soc. Sci. Res.* **2022**, *35*, 291–308. [\[CrossRef\]](#)
65. Co-Creation in UNALab | UNALab. Available online: <https://unalab.eu/en/co-creation> (accessed on 13 July 2023).
66. A SISCODE Definition of Co-Creation | Ecsite. Available online: <https://www.ecsite.eu/activities-and-services/news-and-publications/siscode-definition-co-creation> (accessed on 13 July 2023).
67. Manohar, A.; Smith, M.; Calvo, M. *Capturing the “How”: Showing the Value of Co-Design through Creative Evaluation*; Brunel University London: London, UK, 2016.
68. Kleinsmann, M.; Valkenburg, R. Barriers and Enablers for Creating Shared Understanding in Co-Design Projects. *Des. Stud.* **2008**, *29*, 369–386. [\[CrossRef\]](#)
69. Steen, M. Co-Design as a Process of Joint Inquiry and Imagination. *Des. Issues* **2013**, *29*, 16–28. [\[CrossRef\]](#)
70. Design Council Design Council Website. Available online: <https://www.designcouncil.org.uk/> (accessed on 13 July 2023).
71. Robertson, T.; Simonsen, J. Challenges and Opportunities in Contemporary Participatory Design. *Des. Issues* **2012**, *28*, 3–9. [\[CrossRef\]](#)
72. Plattner, H.; Meinel, C.; Leifer, L. *Design Thinking Research: Studying Co-Creation in Practice*; Springer: Berlin/Heidelberg, Germany, 2012; p. 277. ISBN 9783642216428.
73. UNALAB Toolkit. Available online: <https://unalab.enoll.org> (accessed on 13 July 2023).
74. Jeffery, N. *Stakeholder Engagement: A Roadmap to Meaningful Engagement*; Doughty Centre, Cranfield School of Management: Wharley End, UK, 2009.
75. Kristensson, P.; Magnusson, P.R. Tuning Users’ Innovativeness During Ideation. *Creat. Innov. Manag.* **2010**, *19*, 147–159. [\[CrossRef\]](#)
76. Roser, T.; Samson, A.; Humphreys, P.; Cruz-Valdivieso, E. Co-Creation: New Pathways to Value: An Overview. *Promise LSE Enterp.* **2009**.
77. Mitchell, V.; Ross, T.; May, A.; Sims, R.; Parker, C. Empirical Investigation of the Impact of Using Co-Design Methods When Generating Proposals for Sustainable Travel Solutions. *CoDesign* **2016**, *12*, 205–220. [\[CrossRef\]](#)
78. Magnusson, P.R. Benefits of Involving Users in Service Innovation. *Eur. J. Innov. Manag.* **2003**, *6*, 228–238. [\[CrossRef\]](#)
79. Steen, M.; Manschot, M.; Koning, N. Benefits of Co-Design in Service Design Projects. *Int. J. Des.* **2011**, *5*, 2.

80. All, A.; Nunez Castellar, E. An Evaluation of the Added Value of Co-Design in the Development of an Educational Game for Road Safety. *Int. J. Game-Based Learn.* **2013**, *3*, 1–17. [\[CrossRef\]](#)
81. Fleming, T.; Dixon, R.; Frampton, C.; Merry, S. A Pragmatic Randomized Controlled Trial of Computerized CBT (SPARX) for Symptoms of Depression among Adolescents Excluded from Mainstream Education. *Behav. Cogn. Psychother.* **2012**, *40*, 529–541. [\[CrossRef\]](#)
82. Roepke, A.M.; Jaffee, S.R.; Riffle, O.M.; McGonigal, J.; Broome, R.; Maxwell, B. Randomized Controlled Trial of SuperBetter, a Smartphone-Based/Internet-Based Self-Help Tool to Reduce Depressive Symptoms. *Games Health J.* **2015**, *4*, 235–246. [\[CrossRef\]](#)
83. Jansen, S.; Pieters, M. *The 7 Principles of Complete Co-Creation*; Laurence King Publishing: London, UK, 2018; ISBN 978-90-6369-473-9.
84. Visser, F.S.; Stappers, P.J.; van der Lugt, R.; Sanders, E.B.-N. Contextmapping: Experiences from Practice. *CoDesign* **2005**, *1*, 119–149. [\[CrossRef\]](#)
85. Abrams, M.M.; McLeod, R. *Implementing and Evaluating Co-Design. A Step-By-Step Toolkit*; New Philanthropy Capital: London, UK, 2019.
86. Riedel, V.; Dziekan, K.; Müller, S.; Abraham, M.; Kettner, S.; Daubitz, S. *Evaluation Matters. A Practitioners' Guide to Sound Evaluation for Urban Mobility Measures*; Waxmann: Münster, Germany, 2013; ISBN 978-3-8309-2881-2.
87. Asser, A.; Tatar, M.; Henahan, R. D7.2: *Evaluation of Stakeholder Involvement Process. Deliverable 7.2, AllThings.BioPRO, H2020 Grant No. 887070*; Institute of Baltic Studies: Tartu, Estonia, 2022.
88. Schuitmaker, T.J. Identifying and Unravelling Persistent Problems. *Technol. Forecast. Soc. Chang.* **2012**, *79*, 1021–1031. [\[CrossRef\]](#)
89. Upham, P.; Klitkou, A.; Olsen, D.S. Using Transition Management Concepts for the Evaluation of Intersecting Policy Domains ('grand Challenges'): The Case of Swedish, Norwegian and UK Biofuel Policy. *Int. J. Foresight Innov. Policy* **2016**, *11*, 73. [\[CrossRef\]](#)
90. Coenen, L.; Hansen, T.; Rekers, J.V. Innovation Policy for Grand Challenges. An Economic Geography Perspective. *Geogr. Compass* **2015**, *9*, 483–496. [\[CrossRef\]](#)
91. Klitkou, M.M.B.; Teis Hansen, A. What Is the Bioeconomy? In *From Waste to Value*; Routledge: Oxfordshire, UK, 2019; ISBN 978-0-429-46028-9.
92. Wield, D. Bioeconomy and the Global Economy: Industrial Policies and Bio-Innovation. *Technol. Anal. Strateg. Manag.* **2013**, *25*, 1209–1221. [\[CrossRef\]](#)
93. McCormick, K.; Kautto, N. The Bioeconomy in Europe: An Overview. *Sustainability* **2013**, *5*, 2589–2608. [\[CrossRef\]](#)
94. European Commission Bioeconomy. Available online: https://research-and-innovation.ec.europa.eu/research-area/environment/bioeconomy_en (accessed on 19 August 2023).
95. European Commission. A Sustainable Bioeconomy for Europe: Strengthening the Connection between Economy, Society and the Environment: Updated Bioeconomy Strategy. Available online: <https://op.europa.eu/en/publication-detail/-/publication/edace3e3-e189-11e8-b690-01aa75ed71a1/language-en> (accessed on 19 August 2023).
96. Bioeconomy & European Green Deal | Knowledge for Policy. Available online: https://knowledge4policy.ec.europa.eu/bioeconomy/bioeconomy-european-green-deal_en (accessed on 19 August 2023).
97. Dinu, M.; Pătrălgăeanu, S.R.; Petrariu, R.; Constantin, M.; Potcovaru, A.-M. Empowering Sustainable Consumer Behavior in the EU by Consolidating the Roles of Waste Recycling and Energy Productivity. *Sustainability* **2020**, *12*, 9794. [\[CrossRef\]](#)
98. Zhang, Y.; Chabay, I. How "Green Knowledge" Influences Sustainability through Behavior Change: Theory and Policy Implications. *Sustainability* **2020**, *12*, 6448. [\[CrossRef\]](#)
99. Taras, M. Assessment: Summative and Formative: Some Theoretical Reflections. *Br. J. Educ. Stud.* **2005**, *53*, 466–478. [\[CrossRef\]](#)
100. Calder, J. *Programme Evaluation and Quality: A Comprehensive Guide to Setting Up an Evaluation System*; Routledge: London, UK, 1994; ISBN 978-0-203-06201-2.
101. Faradsch, K.; Dewagtere, M.; Puerari, A. D6.2: *Report on Policy Labs. Deliverable 6.2, AllThings.BioPRO, H2020 Grant No. 887070*; Prospex Institute: Brussels, Belgium, 2022.
102. Faradsch, K.; Matkovits, D.; Munkler, S.; Puerari, O.A. D6.3 *Report on the AllThings.BioPRO Roadshow. Deliverable 6.3, AllThings.BioPRO, H2020 Grant No. 887070*; Prospex Institute: Brussels, Belgium, 2023.
103. Waltenberg, T.; Steinhaus, N. D3.3. *Report on the Draft Concept for Each Mission: Co-Design Process and Results. Deliverable 3.3, AllThings.BioPRO, H2020 Grant No. 887070*; Wissenschaftsladen Bonn e.V.: Bonn, Germany, 2023.
104. Tatar, M.; Henahan, R.; Asser, A. D7.1: *Evaluation Plan. Deliverable 7.1, AllThings.BioPRO, H2020 Grant No. 887070*; Institute of Baltic Studies: Tartu, Estonia, 2020.
105. Waltenberg, T.; Steinhaus, N. D3.2: *Report of the Second Sequence of Focus Groups and Co-Creation Workshops Including the Final Concepts for the Game Design. Deliverable 3.2, AllThings.BioPRO, H2020 Grant No. 887070*; Wissenschaftsladen Bonn e.V.: Bonn, Germany, 2021.
106. Waltenberg, T.; Steinhaus, N. D3.4: *Stakeholder Consultation Guidelines. Deliverable 3.4, AllThings.BioPRO, H2020 Grant No. 887070*; Wissenschaftsladen Bonn e.V.: Bonn, Germany, 2020.
107. Sartorius, V. D5.5 *Lessons Learned from Knowledge Transfer, Working and Engagement. Deliverable 5.5, AllThings.BioPRO, H2020 Grant No. 887070*; Fachagentur Nachwachsende Rohstoffe e.V.: Gülzow, Germany, 2023.
108. Druin, A. The Role of Children in the Design of New Technology. *Behav. Inf. Technol.* **2001**, *21*, 1–25. [\[CrossRef\]](#)
109. Khrapunenko, M.; Tatar, M.; Henahan, R. D7.3: *Results from the Game Testing Workshops. Deliverable 7.3, AllThings.BioPRO, H2020 Grant No. 887070*; Institute of Baltic Studies: Tartu, Estonia, 2023.

110. Streicher, A.; Smeddinck, J. Personalized and Adaptive Serious Games. In *Entertainment Computing and Serious Games: International GI-Dagstuhl Seminar 15283, Dagstuhl Castle, Germany, July 5-10, 2015, Revised Selected Papers*; Springer: Berlin/Heidelberg, Germany, 2016; Volume 9970, pp. 332–377, ISBN 978-3-319-46151-9.
111. Henriques, M.; Akay Melih, K.; Kahara, T.; Farassopoulos, N. *Teachers Handbook. Mission BioHero*; The Community for Science Education in Europe: Brussels, Belgium, 2023.
112. Faradsch, K.; Dewagtere, M.; Gramberger, M. D6.1: *Uptake Strategy and Mapping of Key Potential Users of Project Insights. Deliverable 6.1, AllThings.BioPRO, H2020 Grant No. 887070*; Prospex Institute: Brussels, Belgium, 2021.
113. Zhang, X.; Chen, R. Examining the Mechanism of the Value Co-Creation with Customers. *Int. J. Prod. Econ.* **2008**, *116*, 242–250. [\[CrossRef\]](#)
114. Délèze, N.; Bürki, F.; Nyffeler, N.; Mastelic, J. Orchestrating Creative Chaos: The Role and Key Competencies of Living Lab Managers and Their Team. In *Proceedings of the Digital Living Lab Days Conference, Barcelona, Spain, 21–23 September 2021*.
115. Zwass, V. Co-Creation: Toward a Taxonomy and an Integrated Research Perspective. *Int. J. Electron. Commer.* **2010**, *15*, 11–48. [\[CrossRef\]](#)
116. Füller, J.; Hutter, K.; Faullant, R. Why Co-Creation Experience Matters? Creative Experience and Its Impact on the Quantity and Quality of Creative Contributions. *RD Manag.* **2011**, *41*, 259–273. [\[CrossRef\]](#)
117. Eriksen, M.A.; Brandt, E.; Mattelmäki, T.; Vaajakallio, K. Taking Design Games Seriously: Re-Connecting Situated Power Relations of People and Materials. In *Proceedings of the Proceedings of the 13th Participatory Design Conference: Research Papers—Volume 1, New York, NY, USA, 6 October 2014*; Association for Computing Machinery: New York, NY, USA, 2014; pp. 101–110.
118. Mayer, I. Towards a Comprehensive Methodology for the Research and Evaluation of Serious Games. *Procedia Comput. Sci.* **2012**, *15*, 233–247. [\[CrossRef\]](#)
119. Wu, J.S.; Lee, J.J. Climate Change Games as Tools for Education and Engagement. *Nat. Clim. Chang.* **2015**, *5*, 413–418. [\[CrossRef\]](#)

Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.