Applying Design Research for Cross-Disciplinary Collaboration: Experiences From a Gamification Process

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Abstract: This study explores applying design science research (DSR) frameworks to facilitate cross-disciplinary collaboration towards game development. It uses a DSR framework proposed by Peffers et al (2014) to integrate the knowledge and experiences of a cross-disciplinary research team and develop a game which gamifies the investment decision-making process of energy communities. The framework employed for this paper constituted five phases around problem identification, definition of solution objectives, artefact design and development, demonstration and evaluation. The iterative process of the framework allowed for gradual but incremental improvement in the outcome and the associated artefacts and sustained researcher collaboration. The resultant interactive in-person game required the participants (or their teams) to navigate through the complexities of the decision-making process in a community while considering factors such as information asymmetry, uncertain return on investments, time constraints, etc. The game was instantiated twice and was able to engage players effectively. Moreover, the post-game evaluation indicated that the players acquired learning about energy communities. The participants developed an understanding of the game only gradually and their engagement in the later rounds of the game. Three distinct investment strategies emerged from the two instantiations (diversification, focus on centralised options, or focus on decentralised options). The participants preferred to maintain a strategy rather than reacting situationally. This gamification experience, albeit applicable to this specific research context, shows that DSR frameworks can be successfully applied to facilitate cross-disciplinary collaboration because they allow for more flexible and iterative knowledge exchange. The post-game evaluation helped identify avenues for further improvements, such as focusing on incremental-iterative development of the output, expanding the flexibility and visibility of the game, involving a more balanced research team, etc. The contribution of this study lies in extending the discourse on cross-disciplinary collaboration by incorporating DSR frameworks and demonstrating the application of game-based learning beyond end-user application.

Keywords: Energy transition, Stakeholder engagement, Gamification, Design science research, Energy communities, Cross-disciplinary collaboration

1. Introduction

The grand challenges associated with the ongoing energy transition from fossil fuels to renewable energy sources require cross-disciplinary research and effective stakeholder engagement to develop innovative policies and solutions and facilitate behavioural change. Game-based learning is increasingly used to engage and educate various stakeholders associated with this transition (Wagner & Gałuszka, 2020; Gugerell & Zuidema, 2017).

This paper presents a game that gamifies energy communities' investment decision-making process. Energy communities are community-based organizations that promote local production and consumption of renewable energy by engaging their members. However, they face several challenges, such as eliciting member participation, enabling democratic decision-making and equitable distribution of benefits (Caramizaru and Uihlein, 2020). This game allows its players to understand the inherent complexities associated with the working of energy communities and those related to the uptake of renewable energy solutions. Additionally, stakeholders unfamiliar with the concept can learn about the bottom-up approach for accelerating energy transition and reflect upon their positions about energy communities. Further, energy community members can play this game to enhance their knowledge, system awareness and community decision-making skills. Moreover, researchers can use the game to observe interactions within and across a group of stakeholders and gain insights into their behaviour.

Although there are ample benefits for both researchers and the stakeholders involved in game-based engagement, there is a need to learn more about effective strategies to develop such games, particularly in cross-disciplinary research contexts. The complexity is often amplified due to limited resources (e.g., time and relevant expert availability) and diverse requirements (such as researchers' heterogeneous modes of observing and understanding human behaviour) needed for gamification.

This paper attempts to understand the complex process of game development in a cross-disciplinary setting. It reflects on the experiences and outcomes of a collaborative game development activity involving four researchers from a cross-disciplinary research team who develop a game around the investment decision-making process of energy communities. The activity was conducted in a self-organized way using a framework from Design Science Research (DSR) to iteratively and collectively integrate and assimilate the knowledge and experiences of the researchers into a game. The study shows how design processes can be harnessed to facilitate better outcomes by examining effective approaches, communication methods and collaboration techniques.

The rest of the paper is structured as follows: Section 2 presents the relevant theoretical background, Section 3 discusses the DSR framework applied in this work, Section 4 presents the outcome of the process (the game), and Section 5 reflects on the experiences of the researchers.

2. Theoretical Background

Game-based learning (GBL), gamification and serious games are often used interchangeably in the scientific literature, so distinguishing between the terms is often challenging. While scientists such as Keogh et al (2023) and de Almeida Souza et al (2017) have provided definitions and typologies for these terms, this paper follows the definitions supplied by van Gaalen et al (2021). They define "game-based learning" as an umbrella concept which includes both gamification and serious games. Gamification involves using game elements in non-gaming contexts, while serious games focus on using games to educate stakeholders or the game players. Thus, the final output of this paper can be characterised as a game which gamifies the investment decision-making process of energy communities.

Section 2.1 presents some examples of gamification in the context of energy transition, and Section 2.2 discusses the importance of design science research in collaborative game development.

2.1 Gamification in the Context of Energy Transition

Gamification has emerged as a promising approach to engage various stakeholders and enhance their understanding of the salient features of the ongoing energy transition to address climate change. One such application has been to nudge the energy consumption behaviour in the building and industrial sectors towards sustainable practices through real-time feedback and rewards (Ciabattoni et al, 2022), by employing principles of psychology (Koroleva et al, 2019), or through simulation games of city-wide energy systems (Bauer et al, 2022). Gamification has also been used to educate stakeholders about the operational aspects of solar energy (Hettinga et al, 2021), conflicting perspectives and interests in techno-economic and political decision-making (Schuldt et al, 2018), occupational health and safety issues of photovoltaic systems (Erten, Oral and Yakut, 2022), energy trading (Veeningen and Szirbik, 2018), and collaborative decision-making (Ștefan et al, 2019). Further, it has also been applied in non-educational contexts to facilitate communication across a heterogenous mix of stakeholders to encourage more streamlined policymaking and planning activities (Gissi and Garramone, 2018; Ouariachi and Elving, 2020). Moreover, gamification has also been used to elicit the public perception of issues around digital platforms for electricity trading (Smale and Kloppenburg, 2020), geospatial position of power systems (Steinberger, Minder and Trutnevyte, 2020) and policies like carbon tax (Suzuki and Ishiwata, 2022).

2.2 The Application of Design Science Research in Collaborative Game Development

This paper brings together four researchers from different backgrounds who collaborated to gamify the investment decision-making process of energy communities. Such collaborative research is challenging primarily due to the intricate process of integrating knowledge from a heterogeneous group of researchers (Lang et al, 2012; Gaziulusoy et al, 2016). Recognising the ensuing complexity is essential to enhance collaboration and knowledge exchange amongst the group members and with the stakeholders and ultimately produce a high-quality output.

The tenets of Design Science Research (DSR) can be especially pertinent in such co-development activities as they provide a systematic and iterative approach to designing and refining gamification activities tailored to the unique needs of collaborative research. DSR is rooted in the thought that knowledge can be gained by creating innovative artefacts (such as design frameworks, models or systems) which try to address a specific problem or challenge and focuses on developing and evaluating such artefacts (de Sordi, 2021). DSR has primarily been applied in information system design and innovation to bridge the gap between theory and practice by creating practical solutions and advancing knowledge in various domains (Wieringa, 2014). Integrating knowledge from multiple disciplines with DSR can help develop gamified systems that can effectively support cross-disciplinary research outcomes, foster innovation, and help address complex societal challenges. Figure 1 shows the concept of DSR as applied to this paper. By embracing the complexity and integrating knowledge from multiple disciplines within the framework of DSR, gamified systems that effectively support cross-disciplinary research outcomes can be developed, thereby fostering innovation and addressing complex societal challenges. The following section explains the DSR framework implemented in this paper.

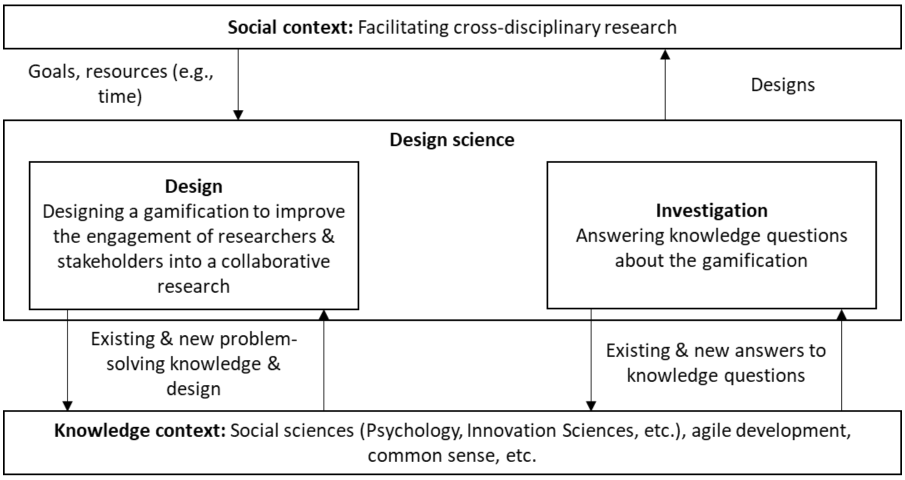

Figure 1: Schematic representation of the utilisation of DSR for this paper to facilitate collaborative development, adapted from Wieringa (2014)

3. Design Process

The game developers (the authors of this paper) applied a DSR process adapted from Peffers et al (2014) as a guiding framework (figure 2). This process consists of five phases, namely, (1) problem identification and motivation, (2) definition of solution objectives, (3) artefact design and development, (4) demonstration and (5) evaluation.

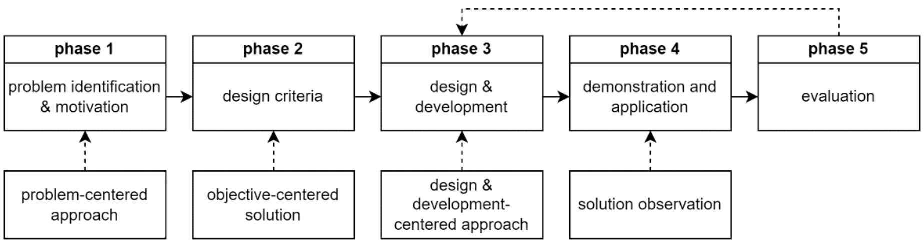

Figure 2: Outline of the study's design procedure, adapted from Peffers et al (2014)

The first phase aimed to identify the problems the design process should address, primarily through brainstorming sessions to leverage researchers' prior experiences. This phase dealt with two issues typical of cross-disciplinary research: (a) engaging diverse stakeholders for knowledge dissemination and (b) integrating knowledge from multiple disciplines to create a somewhat realistic environment wherein the researchers can observe the players' behaviour in a group setting. Since the authors shared a common pool of stakeholders, engaging each separately for each researcher's purposes would be inefficient. Hence, a design that allowed combined data extraction, useful for at least two researchers, was deemed necessary for stakeholder engagement. Moreover, the idea of knowledge integration necessitated that the design enables the stakeholders to actively take on a different perspective and share their views with other stakeholders.

Table 1: Objectives and corresponding design requirements for stakeholders

Objective	Requirement
Motivation	Stakeholder participation is voluntary; hence the session should appear interesting, relevant, and engaging enough to provoke participation.
Engagement	The session should involve elements that make the participants cognitively, behaviourally, and affectively commit to the session. The session should compel stakeholders to take on an unfamiliar perspective.

Objective	Requirement
	Stakeholders should have the opportunity to share their outlooks and thought processes.
Learning	The session should teach participants something about energy community and renewable energy diffusion by forcing them to adopt a system's perspective, future-based thinking through scenarios, design thinking (role-playing), proactivity (lock-in), and awareness (problem, system, and self).

Table 2: Objectives and corresponding design requirements for the game development team

Objective	Requirement
Motivation Engagement	Given the process's voluntary basis, the design process should be engaging enough and of limited intensity (not to interfere with other research activities) to sustain collaboration.
Learning	Research topics (content): observations related to the energy transition (perception, ways to deal with their problems, the crucial problems from stakeholder versus researcher perspectives and assumptions) Social learning (behaviour): observations about the stakeholders' behavioural processes and their approach to solving transition-related problems. There should be enough behavioural freedom to observe (unexpected) behaviour.

The second phase focused on deducing the design requirements based on the output of the first phase. These requirements for the stakeholders and the development team are listed in Tables 1 and 2. Other design criteria based on practical needs necessitated that the game should be developed within four weeks and should be playable within one hour.

The third phase involved operationalising the design requirements determined in Phase 2 into game elements (figure 3). This process generated the artefacts associated with the game, such as game set-up, equipment (game board, coins, etc.), and instantiation. The game thus developed is explained in section 4.1.

The fourth phase focused on demonstrating the game developed through the first three phases by inviting players to participate. The objective of the game developers in this phase was to conduct the game seamlessly while simultaneously observing and recording the interactions between the participants. Section 4.2 elaborates on the instantiation of this game.

The final phase focused on evaluating the experience of the participants and the game developers. The former was done through surveys and informal discussions with the players, while the latter involved reflections by the game developers. These outputs were also compared to the requirements listed in Tables 1 and 2 above to check the extent to which they were realised.

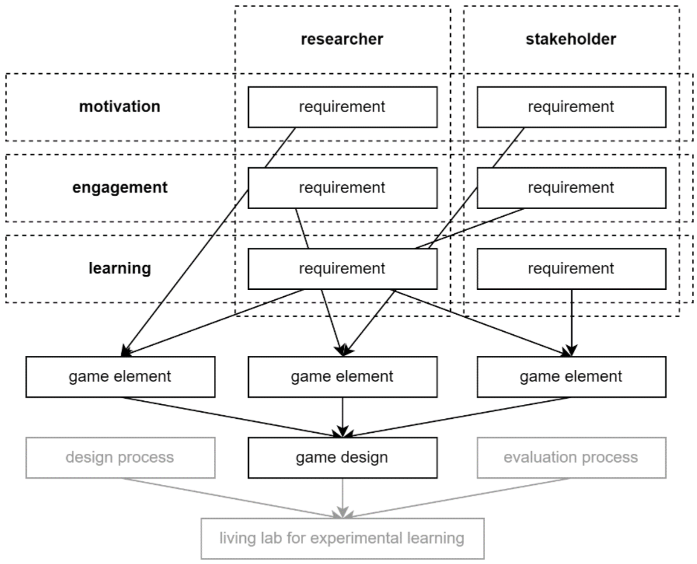

Figure 3: Diagram reflecting the evolution from game requirements to design

4. Gamified Investment Decisions in an Energy Community

This section presents the game that resulted from implementing the abovementioned DSR approach. Section 4.1 describes the game, section 4.2 elaborates on the testing environment, and section 4.3 reflects on the feedback received from the participants.

4.1 Description of the Game

The game required the participants to adopt the perspective of an energy community and provide the observant (the game developers) with insights into their investment behaviour. The participants were divided into groups and challenged to develop the largest energy community by making investment decisions across three rounds. They had three investment options to choose from- (a) increase the number of participants in their community, (b) invest in biomass-based energy projects, and (c) invest in installing roof-top solar with battery storage. Additionally, the teams also had the option to save their capital in a given round and use it in a later round. Each group received an initial endowment at the beginning of the game, which it could invest in one or more options. Each investment option was associated with a return on investment which determined the amount of capital they would have at their disposal in the next round. All the participants had access to the expected return on investment (ROI) associated with each option as well as potentially relevant new information in the form of news headlines, which may (or may not) affect the *actual* ROI. The teams had to process this information and make their investment within a time limit of two minutes per round. At the end of the three rounds, the team with the highest installed capacity won the game (figure 4).

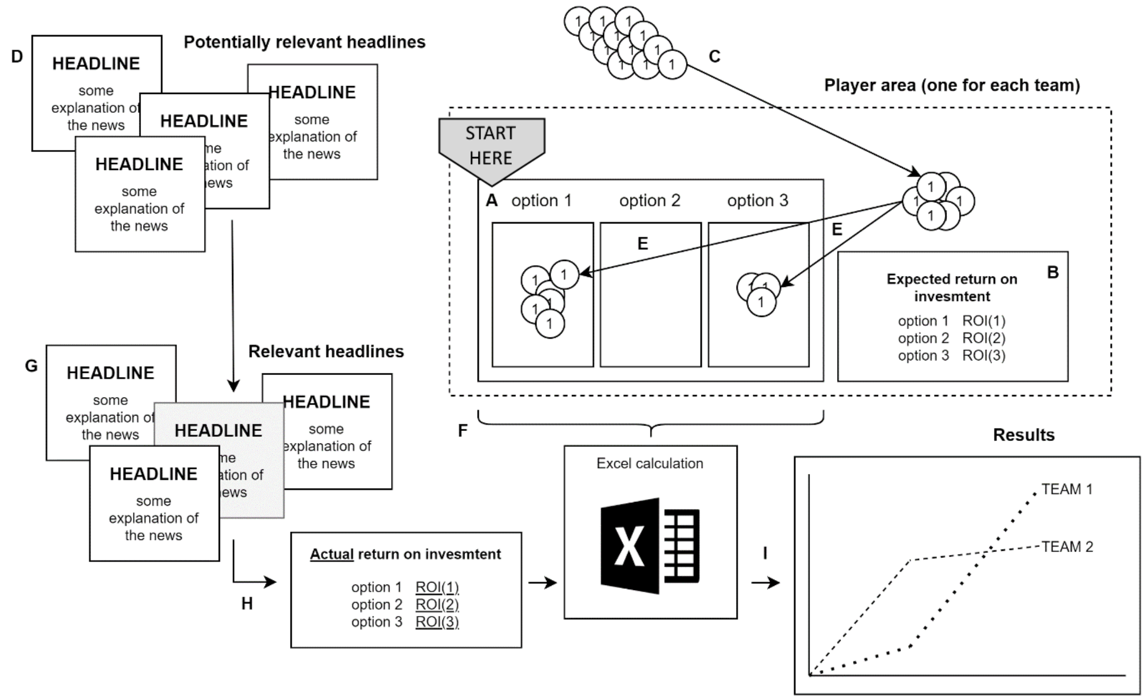

Figure 4: Schematic representation of the DSR instantiation. At the beginning of the game, each team was provided with an investment playboard with three investment decisions (A) and the expected ROI of these decisions (B). The first round commenced with distributing an equal number of coins to the teams (C). Next, the teams received a set of news headlines that could affect the actual ROI (D). The teams discussed the available information internally and made their investment decision by placing the coins on the playboard (E). After the decision window of two minutes was closed, the observers collected the results in the Excel worksheet (F) and the analyst performed the relevant calculations while the narrator explained the relevant news items (G) and how they affected the ROI (H). Each round concluded by displaying the outcome of the decisions made by the teams considering the actual or realised ROI (I).

This game design simulated several features associated with a typical decision-making process around energy investments. These features include information asymmetry (the players did not know which news items could affect ROI), uncertainty about ROI (to what extent the relevant news item affects the expected ROI), time constraints (the players had limited time to process all the information and arrive at their investment decisions), and technological lock-in (it was attractive to keep investing in the same option across the three rounds). Such a design allowed the players to experience the complex and dilemmatic decision-making process as part of a group and evaluate trade-offs often inherent to energy investment decisions (such as risk versus safety, sustainability versus stability, staying with one investment option or altering across rounds). Moreover, this design allowed the game organisers to translate the investment behaviour of the players into measurable indicators and analyse it.

4.2 Instantiation and Testing

The game was first tested in an hour-long workshop with eight voluntary participants (i.e., four teams of 2), all closely associated with the field of energy transition (figure 5). The workshop occurred in October 2022 as part of an energy and mobility conference in the Netherlands. This session was supported by two observers (who collected information from the teams after each round), a narrator (who explained the features of the game) and an analyst (who performed the calculations). During this session, observations from the game development team only were recorded. However, a second instantiation of the game with players of similar characteristics was complemented with a post-game survey. Learning from both these sessions is included in the next section.

Figure 5: The DSR instantiation

4.3 Evaluation

The first instantiation of the game was evaluated through an informal discussion about the general experience of the participants. The second instantiation, however, was complemented with a survey consisting of sixteen questions. This survey was based on earlier works evaluating similar games, such as Ibanez, Di-Serio and Delgado-Kloos (2014) and Alfaqiri, Noor and Ashaari (2020). The survey results showed that the participants acknowledged learning about energy communities, thereby confirming the realisation of stakeholder learning objectives (table 2). In addition, the participants provided several other feedbacks which could be integrated into the subsequent iterations of the game, such as the inclusion of a socio-technical perspective instead of only a technocratic perspective as apparent in the current set-up, increasing uncertainty in the game to allow the emergence of newer behaviour patterns, and allowing more time per round to improve participant engagements and stimulate creative thinking.

The outcome of the evaluation conforms with the observations of the game developers. The participants were observed to develop an understanding of the situation gradually- while they were uncertain about their roles in the initial round, they enthusiastically developed their investment strategies in the subsequent rounds, mainly due to the rivalry between the teams. Three distinct investment strategies emerged from the two instantiations viz diversified investment (spreading investment across all three options), focus on decentralised option (investing in increasing the size and the generative capacity of the community), and focus on centralised options (biomass). Further, the participants maintained the same strategy across the three rounds of the game, confirming the game's technological lock-in character.

5. Reflection

This paper presents an application of a DSR framework in a cross-disciplinary research setting towards the co-development of a game which focuses on educating the stakeholders about a complex societal challenge associated with the ongoing energy transition. The game development process brought together four researchers from different scientific and cultural backgrounds who integrated their knowledge and experiences to develop a game that gamifies the investment decision-making process of energy communities. The game was instantiated twice with similar groups of players and complemented with formal (through a post-game survey) and informal (through a general discussion) discussions to capture the players' experience.

The DSR framework used in the game design process was adopted from the work of Peffers et al (2014) and was implemented in a self-organised way. This framework proved valuable for game developers who came from different backgrounds and had limited exposure to gamification and games. It helped overcome the challenges arising from the group's heterogeneity, making the collaboration feasible and viable. The iterative process of the framework incorporated in the design sessions, complemented with collaborative inputs and reflection points, ensured a gradual improvement of the outcome and the associated artefacts and sustained researcher engagement. Additionally, this approach allowed for flexibility and integration of new requirements as they emerged. It shall prove valuable in future game iterations to incorporate participant suggestions, such as including socio-technical perspectives, nudging group behaviour in a specific direction, etc. However, given the time constraint during the game's development process, the authors implemented the framework intrinsically to create a tangible outcome which prevented them from capitalising on the full potential of the framework. Further research is needed to understand the applicability of this DSR framework by applying it more systematically and rigorously in other collaborative research groups.

A retrospective analysis by the authors followed the game instantiation and testing to reflect on the decisions made throughout the collaborative design process and develop insights for the next iteration of the game. The retrospective was conducted using an agile approach, which is generally efficient for a small development team (Lindvall et al, 2004). This agile approach followed the typical phases of a retrospective, as indicated by Mas et al (2018). The retrospective, which included a review of the game, the game development process and the results, started with a brainstorming session to collect the topics for discussion and reflection. This discussion continued using a sailboat metaphor to identify the enablers, anchors and risks associated with the design journey (Table 3). The next step of the retrospective was to generate insights from the information collected so far. This involved categorisation of the enables, anchors and risks into high, medium and low priority with the idea that high-priority items would need to be addressed immediately and perhaps using a new approach, medium-priority items can be addressed during the subsequent iteration and possibly without necessitating a new approach. In contrast, the low-priority items need not be addressed. This retrospective process resulted in four key outcomes that should be included in the next iteration of the game: (a) improving the agility of the design process and focusing on iterative-incremental development by increasing the number of design iterations, (b) focusing on ideas to expand the flexibility and visibility of the game instead of adding more details, (c) forming a (more) balanced team with members from other (social science) disciplines, and (d) retaining the form of design research while ensuring that the process is more "fun" and less mechanical.

The game development process was primarily governed by selecting specific game characteristics based on the requirements envisaged during the first two phases of the design process. These requirements were based on the objectives associated with motivation, learning and engagement for both the stakeholders and the game developers. This offered a structured approach to effectively and strategically engage stakeholders and the researchers. In addition, the case demonstrates that game elements such as information asymmetry, time constraint, uncertainty, competition and team-based engagement fulfilled the objectives of the game developers to provide an enriching experience to the participants. However, as stated above, this was done somewhat intrinsically. Establishing guidelines linking specific game characteristics to observe, quantify and analyse typical participant behaviour shall significantly enhance the process. Accordingly, further research may be needed to verify if establishing such guidelines enhance the process's efficiency and improve the outcome's accuracy.

Table 3: Lessons learned from the gamification process

Enablers	Anchors	Risks
Openness to change – trust, tolerance, and mutual respect within the research team	Unknown aspects of the demonstration, such as the number of participants	Lack of diversity in stakeholder participation
Developing game prototypes early on in the design process	Conflicting schedules of the research team	Sustaining the collaboration
An attitude of converting threats to opportunities: Using time constraint as a gamification element	Time constraints in the design process and demonstration	Different design objectives of the game developers: game as a collaboration medium vs game as a laboratory

Finally, it is essential to note that the observations and conclusions drawn from this study are specific to its research context, wherein all the game players catered to a single demographic. Moreover, narrow stakeholder participation simplified the process but limited the artefact to meeting research criteria and perceived stakeholder demands. Further research is needed to assess if involving a more diverse selection of stakeholders would impact the effectiveness of the process and yield different results.

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