Sustainability in IT education

A game-based approach

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Abstract. Information Technology (IT) has a critical role in supporting sustainable development. However, there are also various ways in which IT contributes negatively to it. Despite the ever-growing need for IT professionals qualified to take on these challenges, education in sustainability and IT has so far been lacking. IT students need an understanding of the far-reaching implications of IT, and to acknowledge their responsibility for the systems they create, to actively contribute to positive change. To address this need, our research explores how collaborative games can be utilized as a tool to develop IT students' knowledge and perception of sustainability and its connection with IT. Previous research has found the use of games to teach sustainability promising, and in this paper, we present SustainIT, a 3D collaborative game for IT students. In SustainIT, the players communicate across the past and future to make more sustainable decisions for an IT company. The learning goals of the game are to promote systems thinking, an understanding of the connection between sustainability and IT, and to challenge existing perceptions. Focus has been put on finding effective game elements to promote learning and engagement to support these learning outcomes. In the paper we present the design and the evaluation of the game. The final prototype was evaluated by an expert in sustainability in IT education, and a group of students within the target group. The overall evaluation was positive, with the game being evaluated as relevant and interesting. However, the evaluation also pointed out some challenges with the integration of background information about sustainability into the game. Our findings can inform the development of games aimed at cultivating the understanding of the impacts of IT on sustainability.

1   Introduction

Information Technology (IT) can support the transition to a more sustainable world with innovative solutions and digitalization [15]. However, IT might also impact negatively on the socio-economic and natural environment due to the influence of software systems on energy usage at the global level [10] and users' behavior and habits [2]. It is therefore critical to teach IT students about sustainability and give them an understanding of how IT systems may have far-reaching consequences outside of the system itself. They also need to reflect on their role as IT practitioners and understand their responsibility for the long-term impacts of the systems they develop [1]. However,

sustainability as a topic is poorly integrated into IT and computing education, with barriers including the scarcity of relevant resources and literature, as well as a lack of awareness [22].

Previous research has found that using games to learn sustainability has a positive effect on both learning outcomes and engagement [5, 24]. Following this line of research, in our work we address the following research question: How can a collaborative game be designed to develop knowledge about IT and sustainability among IT students, and challenge their perception of the topic? The game presented in this paper is an initial exploration of this research question.

The paper is organized as follows. Section 2 elaborates on the problem, positioning it in the current body of knowledge. Section 3 presents SustainIT, while Section 4 summarizes its evaluation. Section 5 discusses the results and the contributions of our work.

2 Related Work

2.1 Sustainability in IT education

Previous research on sustainability and IT has found that IT can contribute both positively and negatively towards sustainable development [2, 15, 21]. According to [2, 21], these effects can be seen in five interrelated dimensions: individual, social, environmental, economic, and technical, and be distinguished into three orders of effects: immediate, enabling and systemic. A collection of principles to guide practitioners within software development and research have been detailed in The Karslkrona Manifesto for sustainability design [1]. Here, they emphasize the importance of system thinking, the five dimensions of sustainability, and the three orders of effects, among other principles to adopt a sustainable practice within software engineering.

System Thinking and Sustainability. Systems thinking is a challenging concept to teach and learn and it is often considered too abstract to be embedded in higher education curricula [8]. Interviews with experts reported in [22] resulted in several recommendations for teaching about sustainability and IT. In particular, students should engage in debates about values, learn to see problems from different perspectives, and learn to analyze the impact of systems in their totality. The experts also pointed out the importance of being open about mistakes [22].

An interesting tool specifically designed to raise students' awareness of how software systems can impact sustainability is the Sustainability Awareness Framework (SusAF) [7]. The framework consists of the Sustainability Awareness Diagram which helps visualize the five dimensions of sustainability and the three orders of effect [2, 21], and five question sets that aid the process of filling out the diagram.

Perceptions of Sustainability and IT. To ensure that students not only learn more but are also motivated to change their practices, it is important to challenge their perception of sustainability and their own profession [19]. In [18], the authors present a framework created to engage and change students' perceptions of sustainability. Two of the dimensions of the framework are particularly relevant for this research: (a) facts and

values, underlying the need to not only conveying facts but also facilitating discussions on values and creating a safe space to open up about uncertainties and fears; and (b) "vanilla sustainability" vs. "doomsday sustainability", relating to the difference between talking about sustainability as something that eventually will be solved through innovations and mitigation strategies, versus sustainability as something that is already unobtainable, and that the way forward is learning how to adapt with the coming changes [18].

2.2 Serious Games on IT and Sustainability

Game-based learning can promote engagement and learning outcomes, and these effects have also been shown in serious games on sustainability. A few studies utilizing educational games to teach sustainability in IT are reported in the literature. For example, in one study a mobile application game was created where sustainable development was combined with computer science knowledge to learn to solve algorithmic problems using JavaScript while learning about environmental issues and increasing the motivation to protect the environment [26]. The study yielded positive results for both objectives and showed that teaching environmental topics and computer science together through game-based learning is achievable. Leifler et al. [14] held seminars where the students played the board games Dilemma and Fish Banks, about the interrelated dimensions of sustainability and the effects of IT. Pargman, Hedin, and Eriksson [20] introduced the board game Gasuco in their course on Sustainability and Media Technology, where two of the objectives were to both make students more interested in sustainability, as well as increasing their knowledge about it. The results for both studies were promising. In another study by E. Eriksson et al. [9], introduced system thinking games in a course on sustainability and media technology. The games were chosen from the ones presented in The Systems Thinking Playbook for Climate Change [25], and the activities were deemed valuable as a teaching tool although there were some issues raised with the implementation. Research has also been done on educational games on sustainability in engineering courses outside of IT, like for example the game described in [23] for raising awareness of sustainability for aerospace engineering students.

However, as discussed in [24], only a small number of serious games on sustainability promote a holistic view, and most tend to focus on only a few educational aspects of the sustainability dimensions. They call for more studies that look for features that can support such learning. They also propose that researchers developing serious games for sustainability in the future, use 3D graphics to make the experience more realistic and to increase the intensity of the social interaction to further support the social dimension of sustainability.

3 The Game Concept: SustainIT

SustainIT is designed for IT students at the university level. It is a digital 3D collaborative adventure game where two players play together, one in the past and one in the future. Players work together to make more sustainable decisions for an IT company based on what they learn from their respective perspective. The game

combines game elements from adventure, mystery, and escape room games. The storyline is created to be engaging for the players and is set in a workplace familiar to IT professionals.

3.1 Learning Goals

Based on the findings of the literature (Section 2), three learning objectives have been identified.

System Thinking. Experts agree that computing students need to learn system thinking to get a better understanding of sustainability [8, 22]. System thinking has been defined in several ways in the literature [4]. In our work we use the definition in [27]: "Systems thinking is about understanding the underlying drivers, interactions, and conditions that influence our decisions, helping us articulate problems in new and different ways and expand our boundaries of time and space to avoid or reduce potential unintended consequences. It is the intentional process of understanding how to alter the components and structures that cause a system to behave in a certain way and identifying places where relatively small actions can lead to potentially transformative systemic changes…" [27, p.5]. A learning goal for the game is, therefore, to give IT students a better understanding of how IT systems are part of a bigger complex context, and that their decisions may have far-reaching unintended consequences outside of the system itself. A part of this learning goal is to move away from thinking about sustainability as a problem to be solved, and toward an understanding of sustainability as a wicked problem; a challenge to be addressed [1].

The Impact of IT on Sustainability. The second learning goal is to learn about the ways IT artifacts can impact sustainability, both positive and negative. The Karlskrona Manifesto [1] underlines that designers of software technology are responsible for the long-term impacts of the technology they are designing and that they need to address the potential harm of these effects. Students should understand the various ways IT can harm sustainability, both immediately and long term. The five dimensions of sustainability and the three orders of effect as described in [2, 21] can be a helpful basis for facilitating an understanding of how IT has impacts across multiple dimensions and timescales.

Perception of sustainability in IT. One barrier to the introduction of sustainability in the IT curriculum is the understanding of sustainability as something that does not concern computing education [27]. Students need to be engaged with a critical mindset that influences their education and professional life [18]. The third goal of the game is therefore to challenge students´ perceptions toward sustainability and their role as IT practitioners. Students should have an understanding that all choices they make within an IT project can have far-reaching consequences for sustainability outside of the IT system itself. Students should also understand the responsibility they have as practitioners to address these issues in their work.

3.2   Game design

SustainIT supports the achievements of the above learning goals by making the players discuss and reflect upon the various ways decisions in an IT project can affect sustainability in different dimensions, both positively and negatively. It also shows that the effects happen both in the short and long term, by letting the player in the past see the immediate effects of their choices, while the player in the future sees the enabling and systemic effects. The game is set in a company developing a short-term rental platform. This is inspired by the use of a well-known platform as an illustrative example in [2] to show how an IT solution can end up with severe unintended effects on sustainability.

The design of the game has been informed by guidelines and recommendations for the design of games for learning, with focus on the game elements that promote learning and engagement [13]. We also adopted guidelines for the design of games that are collaborative [28] and gender-neutral [6].

The literature on teaching sustainability highlights the importance of promoting discussion, reflection, talking about values, and learning about different perspectives when teaching sustainability to IT students [18, 22]. This provides further justification for the use of collaboration as a main component in the game, as this has been shown to encourage social interaction and shared knowledge construction [17].

When it comes to challenging the students' perceptions, a major component is to avoid teaching sustainability as a problem that will eventually be solved in the future, resulting in a "happy ending" to the issues [18]. Instead, it is seen as necessary to dare to change the narrative towards the very real possibility that the world as we know it will change, and that there is no easy solution that can prevent it. Being faced with such bleak out-looks of the future can create a very emotional response within a person and feelings of dread but may also be key to motivating real change in their perception of the problem at hand. This can be achieved by designing a game that includes storytelling and fantasy, which promotes the emotions, immersion, and real-world relatedness motivators. Creating a game experience that triggers emotion can also make the experience more memorable [13].

3.3   Concept Description and gameplay

Storyline. The IT company FuturIT has been very successful for a couple of years and the people working there are happy and enthusiastic about their projects. The company is the number one provider of software and IT solutions in the country. Recently, FuturIT has been taken over by the charismatic CEO Thomas Tech, who wants to increase the profits and productivity of the company even more, through any necessary means. When several years have gone by, the office is now abandoned, and the once vibrant and green city is now in ruin, with thick fog and dust surrounding the run-down buildings. The decisions and actions made by FuturIT over time have resulted in a dystopian future, due to their unsustainable practices and solutions (Figure 1).
This is where the players come in. They have been recruited to influence the company in a more sustainable direction, to hopefully change the future for the better. The players play from different times, where one is situated in the past where FuturIT is thriving, and the other is situated in a dystopian future. Together they can communicate about

what they experience from their perspectives, to investigate and learn about the impacts of each IT project. These findings can then be used to make more sustainable choices for the company.
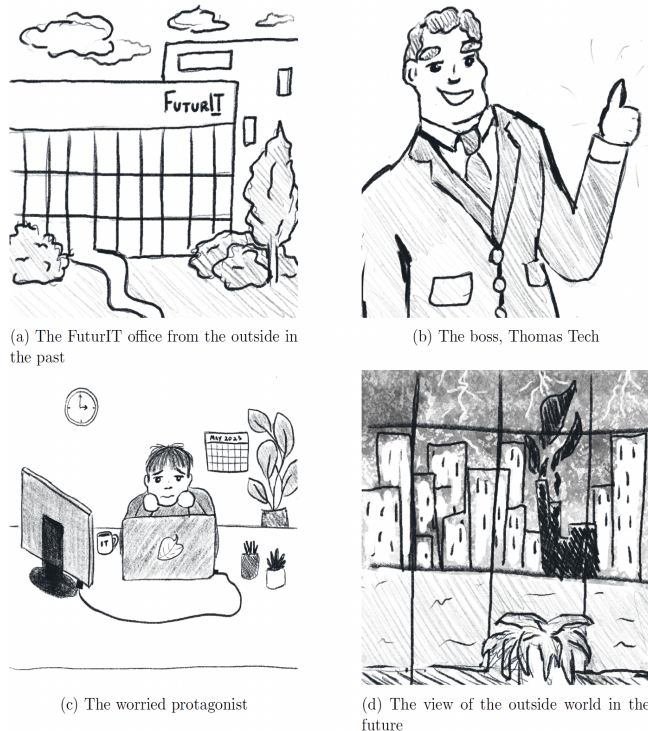

(a) The FuturIT office from the outside in the past

(b) The boss, Thomas Tech

(c) The worried protagonist

(d) The view of the outside world in the future

Fig. 1. The start of the storyboard (sketches)

Gameplay. The game is meant to be played in pairs, where one player is playing in the past while the other is playing in the future. In the game, the players explore different team spaces within the offices of FuturIT, each relating to a different dimension of sustainability. The players will have different perspectives and information available to them and must therefore communicate what they see and experience on each side to piece together what has gone wrong in each team. They can then ensure that the teams make more sustainable choices to alter future outcomes. Some clues can be found in the past, while others lie in the future, and different puzzles must be solved to obtain all the clues. These puzzles require collaboration between the players to decipher them. The players will be able to explore the office and search for clues and information that can inform their choices, by giving them more context and showing the potential consequences of a particular decision. After the decisions have been made, they will see the effects in their respective time.

The prototype starts with a game menu where the players can choose between playing in the past or in the future. Each player is positioned in different versions of the FuturIT office, with different ambiances. Both players begin in the hallway and have a

prompt panel giving them prompts regarding the in-game tutorial. Players are then asked to go to the boss's office. Here, the player in the past receives the quest to improve the work of the company´s teams, while the player in the future is alone. Both players are asked to look for items, which are letters detailing the problem and goals of the game, the tablet that "syncs" the players with each other, and hidden items that provide them with one piece each of an information paper explaining the sustainability dimensions and three orders of effects. When they have these, they proceed to the offices of the short-term rental team.

The short-term rental team office contains more items to be found and inspected in both the future and the past. In the past, the player can speak to the Non-Playing Characters (NPC) around the room and learn more about their thoughts about the project they are working on. The future version of the office is again empty but contains other types of clues as to what went wrong. Finally, when the players have found all the relevant info, they can begin to input their advice sentences for the team, by interacting with a NPC representing the tech leader or using the tablet. The advice panel contains a set of words and a set of sentence connectors that can be combined in multiple ways to form advice sentences for the team (Figure 2). This is intended to scaffold the process of formulating advice.
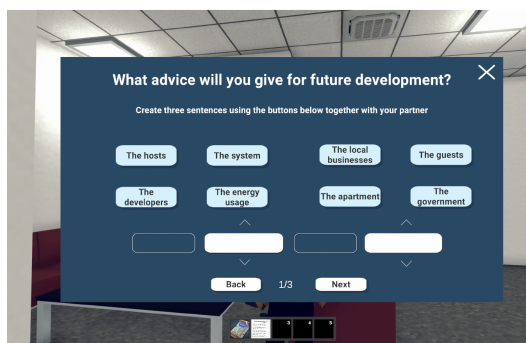

Fig. 2. Structured panel for formulating advice.

3.4 Game Elements: Learning and engagement

SustainIT uses various elements to promote learning and engagement that we briefly summarize in this section.

Decision-making and consequential play. In SustainIT, the players are faced with different cases with a set of choices, where they must analyze and discuss the information available to them to make a decision. These decisions then affect the game world, by implementing the effects induced by the input choices. One of the recommendations in the literature for teaching about sustainability and IT is that students should learn to ask questions about the systems they are making and what problems they will solve, and where this skill can be utilized [22]. By making informed decisions in the game, players can gain understanding of how questioning the design choices in an IT project can be of value and reflect upon the ways these choices impact

sustainability. This learning element also furthers the learning goals detailed in Section 3.1, by making the players think about the complex nature of sustainability, giving insight into the impacts of IT and the different effects, and making them face the consequences of their decisions for an IT system.

Cooperation. The players are separated into two different times and are not able to see the perspective of their partner. This can create an incentive for cooperation and discussion, as [28] notes that spatial isolation can encourage communication. This element also addresses the recommendation of making students engage in debates and seeing problems from different perspectives [22]. Furthermore, a recommendation for sustainability serious games was to strengthen the intensity of social interaction [24]. Creating an environment that pushes the players to collaborate and communicate can enhance their teamwork skills and create a space for mutual sharing of knowledge and experiences, which can further enhance the learning outcomes. In SustainIT, the players must collaborate to proceed in the game and if one player quits the other will not be able to go on in the game. Inter-dependability and taking on different roles have been noted as important in promoting collaboration in games [12, 28]. This can cultivate a socially engaging experience. Cooperation is also found to promote engagement in girls [6].

Real-life context. The game is set in a realistic office space, and the storyline features an IT company with projects rooted in real-life cases. This can help link the game content to the knowledge and experiences of the player, in line with the relevance and relatedness design principles [13].

Storytelling. The game has a storyline that features both a real-world and a dystopic future scenario. The story promotes the common goal of improving the sustainability of the company, to save the world from the dystopic future scenario. Storytelling can promote engagement and motivation through immersion, real-world relations, and emotions [13]. The storyline was created to display how IT impacts sustainability and aims to trigger emotions within the player by not sugar-coating the potential consequences of not addressing sustainability, but instead exaggerating the game environment in the future. In [18], they argue that taking on the perspective of doomsday sustainability instead of vanilla sustainability can inspire more fundamental action. The storyline can therefore also support the achievement of the learning goal to challenge students' perceptions. Graphically, the two worlds are very different to strengthen the storytelling element of the game and emphasizing differences between past and future.

Control. The game will allow the players to make choices that result in different effects in the past and the future. The players will also be able to explore the office space and the teams in any order they please and control the player character's movement. The game therefore promotes the control motivator which relates to the autonomy of the player and their ability to influence the game world and its events [13].

Puzzles and challenge. The game feature escape-room-like puzzles that must be solved to find all relevant information and hints that can help inform the decision-making

process. Challenge can be a powerful motivator provided the player perceives it as fair, and cognitive challenges can also support the learning process [13]. The puzzles require the players to collaborate to solve them, as the hints and solutions to each puzzle will be spread across the past and the future. Including puzzles in the game can also promote exploration and curiosity in the players, and further push collaboration between the players.

Feedback. Feedback is realized by providing instructions and/or a tutorial in the game. This can provide players with a more equal ground at the beginning of the game, and help the players learn the mechanics of the game.

Game resources. To let the players have the items they find available at all times, an inventory is available. Hidden items that could be found by inspecting objects in the game are also added, to expand the controls available to the players. This can promote the challenge, curiosity, and exploration motivators found in [13].

3.5   Game Implementation

The prototype of SustainIT is a 3D game application developed in the game engine Unity, using C#. It is important to emphasize that the goal of this research has not been to implement a fully functional game, but instead to evaluate and test the game concept and its game elements, to see how these are perceived and understood by the target group. Focus has been on including features of the concept that were both feasible and important to test. The prototype therefore only provides a minimal viable product of the game concept. The most important feature that is omitted relates to changing the game environments based on the advice sentences the players create, to visualize the different impacts of their decisions.

4   Evaluation

4.1   Method Description

The research is positioned within Design Science Research [11]. The game prototype has gone through two main iterations, from a simple concept to a working prototype. Initially, some game concepts were generated, based on the current state of the art and the identified learning objectives. One of the concepts was then elaborated further and evaluated with one IT student as member of the target group and two experts, one with expertise in game design and one in sustainability. The final prototype was then evaluated with an interview with an expert of sustainability and IT education and with a game session with six IT students. Before the final evaluation, a pilot evaluation was held with two volunteers outside of the target group to identify and correct major usability issues. Due to space constraints, we focus here on the final evaluation, but we will also report some feedback from the first evaluation in the discussion as relevant. Qualitative data was collected through interviews, a questionnaire, and observation. Written consent was signed by all participants. Data was collected, processed, and managed following a process approved by the national agency for research data.

4.2 Final expert evaluation

The purpose of the evaluation with the expert in sustainability and IT was to assess the potential of the game as a learning tool. The recruited participant for this evaluation is an expert in sustainability and IT who has experience with teaching these topics to IT students. The evaluation with the expert was held digitally via Microsoft Teams and started with an introduction and a short demonstration of the game using a recorded video. The demo was followed by an interview organized in two parts: (a) general feedback on the game concept and (2) learning objectives and suitability of the game for facilitating teaching and learning.

The general feedback from the expert was that the prototype was thought-provoking and fun, and she was positive toward the idea of using it as a learning tool for teaching sustainability and IT. However, she underlined that she was not sure to what extent the students would learn by the game alone, and overall commented throughout that it would be important to put the game in a bigger learning context, where more information about the content of the game could be given, and discussion and reflection around the game experience could be facilitated.

One of the game elements that were viewed as engaging was the storyline. The expert liked how the contrast between the past and the future was implemented in the aesthetics and thought that playing with the concept of time could be intriguing to the players. She also thought that it was a good way to let the players see reality in the eye, by facing them with the not-so-nice aspects of future scenarios. She also pointed out that the escape-room-like puzzles and the collaborative aspects were engaging, and that collaboration could support the problem-solving element of the game.

The expert found the use of the SusAF framework very interesting. As a result of the insights provided by the sustainability expert, items describing the sustainability dimensions and the order of effects were added to the game for the final evaluation with students. Due to time constraints, this addition was implemented in the simple form of bonus material and an extra hint, which could support the players in piecing together the different impacts they learn about in the game. It could also help them create advice sentences based on how they thought these changes to the project would play out.

4.3 Final Group Evaluation with IT Students

The final evaluation aims to investigate how the game is received by the target group and gather insights into which elements support engagement and learning.

Process. After the recruitment, participants were asked to fill in a short questionnaire to collect some information about the participants' prior experience with sustainability in their studies, their experience with games, and their perceptions of sustainability and IT, and provide some context for understanding better their experience with the game. The evaluation of the prototype was performed in person in a classroom with the author acting as facilitator. All the participants were co-located and played in pairs based on their study-year. The students were asked to bring their own computers, and the game was thus tested on three different platforms (namely Windows, Apple Silicone Mac, and Intel-based Mac). Students were first introduced to the game and then they could play it. The game session was followed by a group interview consisting of two parts,

one focusing on the general impression of the game and the second on its use as an education tool.

Participants. A group of six IT students were recruited through the author's network, including three male and three female participants in their 3rd, 4th, and 5th-year, two in each year. All students had experience with games, also in the context of university courses. Only three of them have been exposed to the topic of sustainability in relation to IT through their university studies, though without playing a core role. All the students also had experience with playing games, although the frequency of playing differed, and most of the students had played games in courses at the university. They also reported that sustainability has been an important factor in their prior IT projects.

We here acknowledge the limitations in the recruitment process. Knowing one of the authors, participants might have been influenced. Given the exploratory nature of the study, this is not considered having a major impact on the feedback that have been received. It should also be considered that they volunteered to participate. This might be related to a specific interest in the topic of sustainability, that might not be generalized to the overall target group.

Results. The participants liked the overall narrative, the escape room feeling, and puzzles. As expressed by one of the participants: *"Opening locks and codes and understanding the world around you, the environment, and how the past influences the future... I think that is the engaging game elements that help".* Even though the students found some of the elements of the game unclear and the puzzle difficult to solve, they all reported enjoying the game experience. This was in part due to being two together, which pushed them to continue despite feeling frustrated at times, *"I think it was fun to solve it [the puzzle] together. It felt a bit like a game night with a friend".*

In general, cooperation was assessed as an important factor, adding to engagement and fun: *"It is a very necessary element that makes the game fun (...), I don´t think the game would be as fun without it."* However, the evaluation also pointed out some weaknesses in how the game tries to promote cooperation through information sharing and communication. For example, in some scenes, the game requires to describe to the other participant the items one finds in a room or the content of information sheets. One participant explains: *"It was difficult to know how much I was supposed to say, like, should I make a list of all the stuff that exists in this room, or is it enough to give a general description?"*

Playing in the past and the future were both viewed as engaging and interesting, though in different ways. Playing in the past was viewed as engaging especially due to the conversations with the NPCs which continued the storyline. Playing in the future was intriguing thanks to its aesthetics and overall dystopic feeling. It is therefore beneficial to make sure that there is a balance between the game experience on both ends and ensuring that both players have as equal feelings of engagement. The participants also found the storyline and sustainability theme engaging and thought the use of a dystopic future scenario was appropriate and added to the enjoyment of the game.

The students all expressed that they had gained a new perspective and understanding of the connection between sustainability and IT after playing the game and the results indicate that the game overall developed more understanding of sustainability and IT

and the consequences that IT systems might have on sustainability. As one participant stated:*"I see how IT has a greater sustainability impact on other things than I had thought before."* It was also pointed out how the game can help to gain a holistic perspective, *"I feel at the study program, we learn a lot more about implementing environmental measures in the code itself. In the web development course, for example, you kind of get, 'Now we're going to create environmentally friendly code', but it doesn't go further than that. As in, you need to think about the whole picture, not only this line of code. That's something you get more of [in the game], here you get a wider perspective."*

On the other hand, the perceived learning about the five sustainability dimensions and the orders of effect was low. The students reported that it was not easily understood how they could be used as assets in the game. Several of the students found it tedious to explain aspects of the underlying sustainability model to each other and wanted to wait until it became more obvious that they needed them to proceed. This aligns with the worries expressed by the sustainability expert during the evaluation.

Some students expressed that they felt a greater responsibility in how they conducted their work in the future and that they would be more careful in what types of projects they agreed to work on. This can indicate that the game had an impact on the student's perception of their responsibility as IT practitioners. On the other hand, the questionnaire distributed before the evaluation showed that most of the students already highly agreed that they have a responsibility for the systems they are making. The results also show that they thought sustainability should be a priority consideration in IT projects. The students recruited for this evaluation may therefore have been particularly inclined to react in this way to the game experience.

Finally, participants assessed the game as a tool that could be used early in the study to increase students´ awareness about sustainability. One participant pointed out: "*I missed a focus on sustainability a little earlier in the study program …So getting that perspective early, in the first and second year can be good. And especially since [the game] is not that technical, I think it could be a good fit in a first-year subject.*" At the same time, the game could also be used later in the study programme, when students *"might be more aware of their own situation and have more experience with developing systems and working in IT in general…"*

5   Discussion

The evaluation of the game is mainly explorative, having involved only a limited number of students. However, our preliminary experience with the design and evaluation of SustainIT show the potential for using a collaborative game to support learning about sustainability and IT. Various studies indicate that there is a need to strengthen the education on sustainability in the computing curriculum, but that so far, the development has been slow, partly due to different hindrances the educators experience [22]. This is supported by the data that we collected during the evaluation of SustainIT. In particular, the sustainability expert elaborated that major hindrances lay within the educators' available time and resources to implement sustainability in their courses. She also noted that finding a meaningful way to incorporate these topics in different courses can be challenging and that there is a risk of leaving the students

feeling it is irrelevant to their studies. At the same time, students confirmed that they had not had much experience with IT and sustainability in their studies. The evaluation of SustainIT shows that the game properly addresses the identified learning goals and has the potential to be used as a tool in the context of IT education.

Previous research has shown that games have the potential to increase engagement and support learning outcomes [13, 29], and collaboration in games has also been found fruitful [16]. Previous studies also show that the use of games to teach sustainability is promising [5, 8, 9, 14, 20, 23, 24, 26]. The findings of this research further confirm that there is strong interest toward using games in sustainability education and that a collaborative game for sustainability and IT can promote learning outcomes and engagement. The interviewed experts were excited to see these topics put in a game context and thought it could potentially provide value as a learning tool. One of the experts identified the potential for incorporating such a game into a course, although it was noted that there should be some arrangements and facilitation planned around the game to fully exploit the learning potential. The involved students reasoned that games can be engaging, provide motivation to learn, and make lectures more exciting.

In [24] they recommended future research within sustainability games to look into features that promote holistic learning, integrating realistic 3D graphics and intensifying social interaction. This research addresses these recommendations and can therefore further contribute to the understanding of games as educational tools for sustainability. SustainIT as a game concept was received with much enthusiasm and interest from all participants in this study. The concept has been described as fun, engaging, thought-provoking and creative, and the idea of having two players collaborate across two different times was viewed as an interesting concept for an engaging experience. The results of the final evaluation with students also indicated that the game experience had an impact on their perception and understanding of sustainability and IT, and they reported that they felt more motivated to consider sustainability in their future endeavors as IT practitioners. Some of the participants also noted that they felt the game provided a more holistic view of sustainability and IT.

The results of the evaluation revealed that several of the game elements were perceived as motivational and engaging, which therefore can further support the findings in [3, 12, 13]. Collaboration, storyline, and puzzles were particularly emphasized as the most engaging elements and strengths of the game. The game expert emphasized that a strong narrative and collaboration both were compelling features that support engagement. In the final evaluation with students, they saw the collaborative aspect as a necessary element of the game, commenting that it pushed them to go further in the game despite their frustrations with certain aspects. Other aspects that were pointed out as engaging were the escape-room feeling and mystery aspect, and the use of dystopic future scenarios. Finally, being able to make decisions that would affect the game environment also came up as an aspect that was engaging, thus making consequential play another promising game element. These findings help indicate a set of effective game elements to promote motivation and engagement in a collaborative game to teach sustainability and IT. Collaboration was also brought up as a beneficial element for learning, as this can support discussion and reflection, as well as aid problem-solving. Furthermore, the advice sentence mechanic was pointed out as a crucial element for learning since this can help structure the discussion process and make connections between the decisions and the resulting impacts. The context of the

game where the players can see the impacts of an IT project in the past and the future was also seen as a promising component to further learning about sustainability and IT.

The SusAF framework [7] was partly integrated in the game as an optional tool to inform the choice of advice sentences. The study can therefore further contribute to the understanding of how this framework can be used in teaching. The results of the final evaluation revealed that the participants did not intuitively understand how they could utilize the given information related to SusAF, which indicates that the incorporation of SusAF would need strengthening for it to add to the learning outcomes. The participants further suggested that they thought it could be helpful to integrate better the framework in the game, by for example explicitly using it in a puzzle, to further push the player to try to understand and interact with it.

6   Conclusions

The paper presents SustainIT, a collaborative game to teach sustainability and IT. The research explores how a collaborative game could be designed to develop IT students' knowledge about the connection between sustainability and IT. Furthermore, the aim was to challenge IT students' perceptions of the topic. The game concept SustainIT has therefore been designed, evaluated at different stages with experts and participants from the target audience. Combining the various assessments of the game concept indicates that it has the potential as a learning tool for developing IT students´ understanding and perception of sustainability and IT.

We fully acknowledge the limitations of the work, that is still in an early phase. The prototype has been evaluated with a small sample size of the target audience, and one should be careful with generalizing the results. Also, the research has only assessed the initial effect of the game experience but not the long-term effects, only giving insight into the perceived learning and general impression.

As part of our future work, we aim at extending the prototype further and evaluate it with a larger group of students. We also aim to define guidelines for teachers about how to integrate the game in different courses.

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