Co-designing VR Game Content for Sustainability Education

Daniel Harlow Schlander(✉), Line Højberg Jokumsen, Maja Højslet Schurer, and Anders Kalsgaard Møller

Aalborg University, 9220 Aalborg, Denmark
d.schlander@hotmail.dk, line.jokumsen@youmail.dk, {mhsc, ankm}@ikl.aau.dk

Abstract. In this paper, we introduce a study about primary school students who participate as co-designers in a design and development process of a Virtual Reality (VR) game about sustainability. Utilizing methods like workshops and focus group interviews, as part of a participatory approach, we seek to gain a unique insight into the students' own perspectives and experiences with videogames and how the student actively could integrate their interest and knowledge in sustainability into the game design as co-designers. We initially conducted two semi-structured interviews with educators who are experienced in applying VR in their teaching. Following the interviews with the educators, we facilitated two workshops with six 7th grade students. The students play-tested our initial iteration of the VR-game and afterward helped co-design two new iterations. Having them influence the development of the VR-game, with the notion of "by students for students", showed increased motivation towards developing the VR-game as co-designer. Categorizing, analyzing, and reviewing their spoken word in transcriptions, written, and drawn down ideas - resulted in several applicable ideas and materials for further development of the game. Our findings showed how the students expressed interest in contributing to the sustainability premise of the game. We realized how vast their knowledge was on the subject to begin with, which only led to more in-depth discussions on what contributes to the changing climate. We believe that, based on feedback and the theoretical framework, that the VR-game serves as an efficient educational tool, that can help facilitate conversations about sustainability.

Keywords: Sustainability · Participatory Design · Game Design · User involvement · Design-Based Research

1 Introduction

For the past decades there has been a rising preoccupation with the state of the climate and the environment. The United Nations (UN) has set up seventeen world goals to overcome climate issues and to create a better world for future generations (Global Goals 2023). The world goals serve as a call-for-action and point out exactly where the needs for action are to reduce environmental and climate issues such as global warming, plastic pollution,

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deforestation, and overfishing. We have been particularly focused on two world goals for this study. Goal 12, which describes the need for ensuring sustainable consumption and production patterns and Goal 13, which describes five actionable targets to strive for in order to secure a sustainable future (Global Goals 2023). However, environmental and climate issues are not something that can simply be fixed today, but a future problem for many generations to come (Global Goals 2023). Taking action now is one thing, but making sure future generations have the right tools and insights into sustainable living and climate issues is another important responsibility. Research shows that many teachers find it hard to teach a complex topic like sustainability (Epinion 2021). Epinion (2021) iterates that developing supplementing teaching materials about sustainability is very important.

This paper initiates an exploration that centers on elementary school students' engagement as co-designers in a project focusing on designing a Virtual Reality (VR) game.

Acknowledging the demand for more teaching about sustainability in the elementary school system, led us to design and develop a VR game about environmental issues, bringing in the students as co-designers. Research shows that VR and games in education opens for new possibilities in supporting students' learning, motivation, engagement, and immersion (Holly et al. 2021; Hu-Au & Lee 2017; Istiono & Waworuntu 2021). In contrast to this, research made by Istiono & Waworuntu (2021) shows that learning games are generally less attractive than classic entertainment games. Consequently, we need to implement classic game-elements such as rewards, challenges, characters, and a narrative to keep the students interested in and motivated to play the VR-game but how do we do this in a way that appeals to school students and at the same time introduce them to climate issues?

In this study we apply a Participatory Design (PD) (Sanders & Stappers 2008) method approach where 7th grade students are involved as co-designer in a process of developing teaching materials focusing on sustainability. Using the PD methods, we allow the students to become co-designers so they can influence the content of the VR-game in a way that relates to them and their reality. Pairing the principles of a user involvement method such as PD with the iterative procedural framework of Design-based research (Christensen et. al. 2012), gives us the necessary tools to ensure a solid design, derived from prototyping, theorizing, and collecting empirical data.

In this study we aim to answer the following research question:

- What climate issues interests' students and how do we create and communicate content to students that motivates more sustainable awareness and action?
- How do we include students in a co-design process of a VR game with focus on how to support the students in expressing their ideas and perspectives?

2 Background

In the following section we will briefly summarize research about user involvement through PD, game design, student's perspectives, sustainability teaching and VR to provide the necessary background to understand our study and co-design workshops.

2.1 The Need for Sustainability Teaching Materials

Research shows that teachers worldwide find it important to teach sustainability, but many teachers find it difficult despite a rising importance in both international and national policy (EducationWeek 2023; Epinion 2021; Shift Insight 2022). Epinion, a Danish consulting company that also covers a wide range of research fields, did an extensive research project back in 2021, surveying 1.396 elementary school teachers who taught any science-, culture, language, or practical subjects, on how they incorporate sustainability teaching into their classes (Epinion 2021).

The Epinion (2021) report shows that 66% of the teachers agreed that sustainability should be a part of the curriculum. Furthermore, agreeing that students should have the belief that their actions matter and that the teaching should focus on motivating such behavior and create discussions about what sustainability is (Epinion 2021). More than half of the teachers in question took inspiration from the UNs 17 world goals for a sustainable future (Epinion 2021). They would also look for sustainability media content to illustrate the complex subject, such as movies or documentaries.

As part of a pre-study, we initially conducted two semi-structured interviews with educators who are experienced in applying VR in their teaching. In the interviews the educators indicated that; teachers besides consuming illustrative content, would use hands-on teaching such as; going to a local water stream to research ecosystems or catch and cut up a fish to see the microplastics. These examples indicate that teachers would go unconventional routes to teach the subject.

The Epinion (2021) report also shows that 77% of the teachers in question expressed difficulties with incorporating sustainability in their classes expressing how it is very time consuming to prepare materials. They felt inadequate in their abilities to teach such a complex subject. Epinion (2021) stresses the importance of making sure proper educational tools are available. The Epinion (2021) report shows 30% of the teachers felt the same.

Shift Insight (2022), a consulting educational market research and analysis company, sent out a survey in 2021 to 500 teachers in the United Kingdom asking how they felt about teaching sustainability. The results from Shift Insight (2022) varied a little from Denmark, having 85% of the teachers agreeing on sustainability is an important subject to teach and only 55% of them think they haven't received sufficient training or tools to do so. EducationWeek (2023), a news and information company about education, recently published an article, in collaboration with the Smithsonian Science Education Center, about the lack of sustainable awareness and teaching in schools, in comparison to countries like France, Canada, India, and Brazil. Although the consensus about the importance of sustainable teaching was similar to the mentioned countries – the competency and knowledge to teach was at 37% compared to 78% in Brazil (EducationWeek 2023). Allocating time to teach about sustainability also proves to be an issue as only 20% manage to do so. Compared to 84% in France or 80% in Brazil (EducationWeek 2023).

2.2 Students' Perspectives

To develop educational tools about sustainability that can help support students in believing that their actions matter and motivate them towards such behavior, we propose including students in the design process.

Often in the past, scholars and researchers in the field of educational research have not sought young people's perspectives (Joerdens 2014). However, young people are no longer considered mainly as research objects, but rather as people with their own opinions and capabilities of offering advice about their lives (Lundy 2018). When studying a students' perspective and social participation, it does not suffice to discuss the topic from an adult's point of view but also from participation and the lens of the student's perspectives (Karlsson 2020).

Therefore, we argue that it is relevant to focus on the concept of participation when studying the students' climate issues interest and how we can co-design a VR game that effectively communicates content to motivate sustainable awareness and action.

In line with the UNs Convention on the Rights of the Child (Lundy 2007; United Nations 1989), young people have the right to have a say, and to have their opinions considered, when decisions that affect them are made. Students' perspectives can strengthen the information about the topic being studied because they can provide new knowledge and different views from those of adults (Biggeri et al. 2018). Listening is not only about the spoken words but also listening to the students' creative ways of expressing their views and experiences (Clark 2017). The students are experts in their own life and that is why we can't assume to know their answers (Clark 2017). Warming (2019) describes an inherent challenge of getting 100% access to a students' perspective as we cannot feel their emotions or be inside their thoughts. Listening, taking notes, and transcribing the spoken word comes with an inherent interpretation problem. Their perspective will always be a representation of our interpretation of what they are trying to express (Warming 2019; Warming et al. 2023). Thus, to ensure that the perspective of the students is directly included we suggest a participatory approach where the students participate as co-designers in developing a game about sustainability through participatory workshops. The approach is inspired by the findings from a study about PD for serious game development by Khaled & Vasalou (2014).

2.3 Participatory Design and Game Design

The PD design method aims to cooperate with the people who, in one way or another, is going to be the end-user of the product. PD gives various ways of which the co-designer or creator, can represent their peers, skills, and unique insights (Bødker et al. 2022). PD has been used in a variety of design processes, serious game-design being one of them. Khaled & Vasalou (2014), two researchers in the game development industry, present observations made from attempting to apply existing PD methods of brainstorming and storyboarding to their serious game-design process with children.

In the study they asked children to play an early game prototype and to create storyboards of potential game narratives. While children provided a wealth of information that was used to improve the game, they often proposed ideas well beyond the learning

objectives of the game, including violent and competitive mechanics that conflicted with the very purpose of the game being designed (Khaled & Vasalou 2014).

Working with a younger audience as co-designers in their study, raised questions like; how should we incorporate children's taste in games when working in highly specific domains? What should we do when the end-users themselves do not understand the domain? How should we proceed when the game design ideas provided by children are inappropriate? (Khaled & Vasalou 2014). Throughout their studies, they came across challenges with mismatched ideas and high abstraction tasks showing that the co-designers needed knowledge of both domains and a basic level of game-design literacy.

The co-designers displayed active participation by generating numerous ideas to tackle the game design challenges presented (Khaled & Vasalou 2014). While Khaled & Vasalou's (2014) analysis did not emphasize idea quantity, the workshop showcased the co-designer's engagement through their eagerness to surpass the given tasks.

PD introduces fresh possibilities for both serious game designers and players. Drawing on experiences with established PD methods for game design ideation, Khaled & Vasalou (2014) formulated an innovative PD approach to guide ideation, aligning with the core concerns of serious games – domain expertise and procedural (Khaled & Vasalou 2014). Their findings lead to three pivotal considerations for involving children in PD for serious games. Children demonstrated optimal co-design participation during the intermediate phases of game design. In the initial design phase, when domain content and pedagogical theory were undecided, the open-ended boundary objects Khaled & Vasalou (2014) employed lacked the required theoretical framework to assist participants in devising specific and applicable ideas. Conversely, the more focused boundary object employed in subsequent workshops triggered inventive concepts that aligned with the game's educational goals (Khaled & Vasalou 2014). The attributes of boundary objects employed in PD for serious games should be assessed considering their role in supporting and inspiring ideation. In the later stages of the design process, designers are better positioned to create boundary objects that encapsulate the essential theoretical foundations and scaffolding to empower children in generating impactful ideas (Khaled & Vasalou 2014).

3 Theoretical Approach to the Game Design

To theoretically support the students' ideas and the game development of the VR-game we use Barab et al.'s (2011) theory about transformational play, to create a connection between content, person and context in the VR-game inspired by real climate issues. With transformational play every experience in the game change something inside the player, which the player can take into the real world (Barab et al. 2011). In that way the students can take the knowledge and experience about sustainability into the real world and hopefully use this knowledge to make a difference for climate change. With the introduction of Ryan and Deci's (2000) self-determination theory (STD), we aim to ensure that the students feel competent to act as co-designers, autonomous in their decisions and having a feeling of being involved in a greater good, being a part of something bigger. STD also translates into the game design as we strive to make the

gameplay feel autonomous, challenging within reasonable difficult and emphasize the need for a common actionable goal to ensure a sustainable future. We chose to make a VR game as the sense of presence in VR enhances the first-hand experience of the game, and thus provides the foundation for knowledge-transfer to the real world (Winn & Windschitl 2000). Furthermore, VR can provide opportunities for supporting the students' learning effect, their motivation, engagement, and concentration (Holly et al. 2021; Hu-Au & Lee 2017). This gives the students some control to define their own way of learning (Holly et al. 2021; Hu-Au & Lee 2017). Giving the player a sense of autonomy in the decision making of the game is key to keep them engaged and explorative. Autonomy ensures that every decision made, leaves a feeling of responsibility and ownership (Ryan & Deci 2000). Since VR appeals to more than one sense, it also attracts a broader group of student types. Students learn by developing and interacting with the content, then reflecting over their own learning. Holly et al. (2021) points to virtual labs, designed for active learning, as helpful in teaching students about complex subjects in a playful manner. Feeling competent is not only about always being able to solve the task at hand, first try. It is about having a baseline feeling that you can do it if you put your mind to it (Ryan & Deci 2000). Making sure that the player is being fed positive affirmations, reassuring their competency, will in turn leave the user feeling competent and thereby motivated to face the presented challenge.

To support transformative play and to strengthen the game development we also use Deterdings (2015) model of 'Schematic of a skill atoms' (Fig. 1), which describes the challenge model and a list of game-elements that are key to in developing a game. The challenge model is a visual representation of what a player must go through to complete a challenge in the game (Deterding 2015). As shown in Fig. 1 the 'Schematic of a skill atoms' contain these six points:

- Goals – What are the goals to win the game?
- Actions – What can the player do to achieve the goal?
- Challenge – What challenges must the player overcome to achieve the goal?
- Objects – What objects can help the player achieve the goal?
- Rules – What algorithms and user-defined rules are in place for the player's actions to achieve the goal?
- Feedback – How is the process expressed in the game? Could be a reward.
- Motivation – How is the player's engagement and interest in exploring and continuing to play the game maintained? (Deterding 2015).

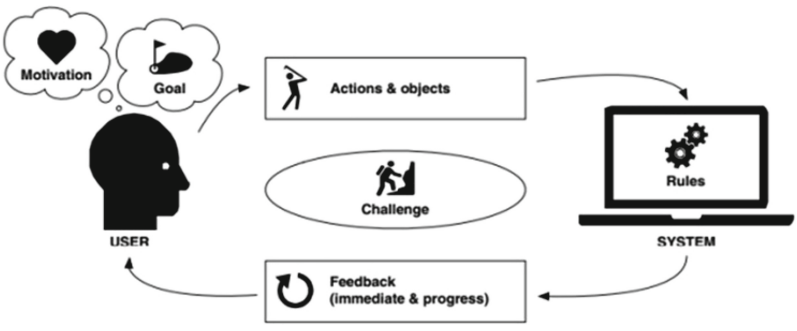

Fig. 1. Model of 'Schematic of a skill atom' (Deterding 2015, s. 314).

4 Research Design

4.1 Methodology

A combined approach of DBR (Christensen et. al. 2012) and PD (Sanders & Stappers 2008) is employed, recognizing the need for iterative development while ensuring our users' involvement and providing them the right tools to voice their opinions and knowledge.

DBR uses a four-phase model we use to frame the whole process from start to finish (Christensen et. al. 2012). We start by looking at the context for our study, based on research and the empirical material gathered from our interviews. Going into phase 2, the "LAB-phase", we use the collected data and chosen relevant theories from phase 1 to develop our design-framework and principles. Next, we start making the first prototype of our VR-game, ready to be tested in phase 3. The intervention phase is testing the feasibility, effect, and legitimacy of the prototype design (Christensen et. al. 2012). Taking notes on how to improve the design and looking out for new research or theory to support the redesign. The final phase, reflection, is an analysis of how robust the design is put up against other contexts (Christensen et. al. 2012). Does the design relate to a more general use, other than the context intended.

PD presents two ways of user involvement - co-creator and co-designer (Sanders & Stappers 2008). Co-creators are typically involved in everything from the beginning until the end of the design process. They co-create any backend coding, framework or UX for example. The co-designer-role is characterized as an advisory role, meaning we as the creators will extract ideas and design-oriented inputs from our co-designers (Sanders & Stappers 2008).

In this study start we by using the DBR to get knowledge around the subject and to create the first prototype of the VR game based on theory and initial research. In the workshops we applied a more PD-oriented approach where the students as co-designers further developed the VR-game.

The PD method was introduced to help the students express their thoughts and viewpoints regarding their concerns related to climate issues in the workshops. We decided, given the age and limited time we had with the students, that we would introduce them to the design process as co-designers in the LAB phase of the DBR-model (Christensen et. al. 2012). Co-designers' primary role in the process is sharing ideas and thoughts, and in our case, visual representations with the developers (Sanders & Stappers 2008). Based on the students' experiences, perspectives, and ideas, we developed the second prototype, which the students in the intervention phase tested and evaluated.

4.2 Workshops

In this study we used two workshops to gain insight about the students' ideas, perspectives, and experiences. The aim of the workshops was to engage the students in sharing knowledge and creative problem solving (Ørngreen & Levinsen 2017). This as part of a co-designing process of a VR game that could effectively communicate content to motivate sustainable awareness and action. Both workshops were built on the DBR-model. In phase one we collected empirical data from existing research and interviewed two

educators who have experience with implementing VR as a teaching method. Based on the empirical data, we designed a prototype to play-test and further develop through PD and a continuous semi-structured interview format with our co-designers. In phase two of the DBR-model the lab-phase we utilized the workshop method to further gain insight into our target demographic audience.

We invited six 7.th grade elementary students from a local school into two workshops. This target audience were selected because at this age the students start to address issues about sustainability and climate problems through classes such as biology, geography, and physics/chemistry. Furthermore, young people in the age of 13–14 years can think abstractly, logical, critical, and problem solve (Kuhn 2009). The goal with involving the students were to support them, through co-designing a VR-game, to express their ideas and perspectives on sustainability and climate problems, as they know which games and game-elements capture their interest and motivation.

In workshop 1 the students play-tested the first prototype which was more a VR experience more than a VR-game, we developed it inspired by interviews with two educators who are experienced in applying VR in their teaching. We used CoSpaces Edu (2023) to create the prototype and future iterations of the game. In Fig. 2 a collage of the first prototype is shown where the students were presented with plastic issues. We chose not to add any game-elements to the first prototype because we wanted the students' ideas and perspectives on how we could create a game they would want to play.

Fig. 2. The first prototype of the VR-game.

When developing a learning game, it is important to consider how the game can ensure learning, motivate, and simultaneously challenge the player (Deterding 2015; Hanghøj 2019). To ensure the learning element in the VR-game we use Gyldendal's educational platform. This platform is a well-known tool for Danish teachers to draw

inspiration from when preparing the educational material for their classes (Gyldendal's digitale læremidler, n.d.).

After having play-tested the VR-game in workshop 1 the students further developed the VR-game with their ideas and perspectives. In the co-designing process, we provided paper and pen which allows a more creative expression and ensures that all our participants could contribute on their own terms (Clark 2017; Spyrou 2011). Some of the students' drawings were in such detail and perfectly within our intent and theme of the game, that we transferred them directly into the game.

Throughout the idea-generating phase we positioned ourselves as researchers, curiously asking into their experiences with sustainability, games in general and more specifically into their ideas and inputs to the VR-game. We tried to minimize the inherent power-balance between student and researcher by working on a relative and trustful bond between us (Spyrou 2011). To understand their ideas and perspectives we asked the students a lot of questions, which helped us narrow down what game designs/elements motivates and encourages them to play VR games and video games in general. Filtering through the many ideas presented by the students in workshop 1, we had to establish a few criteria as to what could be made in our given timeframe. In the exchange process of all the students' ideas we looked at; What is possible and not possible in the program we use? How does the learning content and game-elements interact? How does the VR-game become fun for the students and how can teachers see opportunities in using the VR-game in their teaching? This way we sets up clear boundaries for what could be designed. Based on the students' ideas, perspectives, and drawings we developed a second prototype.

In workshop 2 the students play-tested the second prototype. The second prototype consisted of a world selection screen with four different climate issues (Overfishing, global warming, plastic pollution in the ocean and forest fires and deforestation.), two minigames to the plastic world in the VR-game and a questionnaire to test their knowledge and the ability to roam relatively free in our virtual world. They also further developed and co-designing some new ideas and inputs to a third prototype such as a main story about a time traveler from the future who must travel back in time and make a difference for the climate to save the earth. This narrative has been included in the third prototype.

4.3 Data Collection and Analysis

During the workshops we would take notes and record the discussions between the students, Furthermore, we keep the different design artifacts created through the session for inspiration. The recording of the sessions got transcribed and categorized through the thematic analysis by Braun & Clarke (2006). We use the six phases in the thematic analysis to process our data (Fig. 3).

By using the thematic analysis, we have pointed out three overall themes in the data collation. These themes are Game design and students' perspective, learning design and sustainability. The notes gave us context clues from certain times in the recordings, describing certain emotions or reactions the co-designers might have had to playing the game.

Phases in the thematic analysis	Description of the analysis procedure
1. Familiarising with the data collection	Read and re-read the transcribed the data, notes, and drawings from the workshop.
2. Generating of initial codes	Looking for noteworthy details of the data noting initial notes and codes noteworthy details of the data notes and codes.
3. Searching for themes	The code is organised into initial themes.
4. Reviewing themes	The themes from phase 3 are reviewed. Some of the themes may have to split up while others remain as they are.
5. Naming and defining themes	The themes are named and defined by identifying the essence of each individual theme.
6. Producing the analysis paper section	Analyses the theme selected by relating them to the research questions.

Fig. 3. Phases in the thematic analysis (Braun & Clarke 2006)

5 Findings

The workshop sessions provided insights about what interested students and what they knew about sustainability and climate change. It also offered opportunities to discuss these topics and introduce more knowledge to the students laying the foundation for the focus on sustainability in development of the game. Often these conversations would be initiated from questions about the student's drawings. In the following section we will provide examples of how the game design process facilitated conversations and learning opportunities about sustainability. The examples also show how design artifacts such as the drawings helped support these conversations.

5.1 Game Design and Student's Perspective

In workshop 1 the students use their experiences with video games to come up with their take on which game-element they find fun, interesting, and motivating and which ones they think should be included in the VR-game.

"Student 1: Zombie apocalypse! That's when the plastic runs wild!

Student 2: Plastic apocalypse!

Student 1: There is a main quest about saving the earth and a lot of minigames where you must sort and remove the plastic as fast as you can. [...] Like Fruit ninja where you chop plastic bottles over. Then you must fight against the plastic!"

(Extract of interview with the students in workshop 1).

This shows how the students have helped co-design the VR-game using their experiences. Student 1 describes an idea for the VR-game's plastic world inspired from a video game he knows - Fruit ninja. In this way the students use their knowledge and experience to co-design a game they want to play.

"Student 5: He is from the future, so he knows that's going to happen and he is coming to stop it.

Interviewer: Okay, so the avatar has a time machine?

Student 5: No, it's yourself. You're the person who knows what's going to happen and that's why you travel back in time. You know that if it continues the world will end.

Interviewer: It sounds like the whole basis of the game.

Student 5: Yes, all of it!

Interviewer: Then it's just before you must start on a planet where everything has gone wrong.

Student 5: Yes, a backstory! You start in a world where things are destroyed and there are disasters everywhere. Then you press on a button and go back in time. [...] He has lost his family. The only job he has is: Save the World! So, what he saw in the future, it is not going to happen.

Interviewer: The starting scene could be a time machine that just spawns in the middle of a desolate place where there's no green anymore and the scene is drying up. It's not a nice place to be in. [...] But just before it's all 100% over, he manages to take the time machine and go back and save it all.

Student 6: Uh! Uh! Uh! (Starts to draw a time machine)

Student 5: Because he already knows what is going to happen. He's from the future!"

(Extract of interview with the students in workshop 2)

While some of the students immediately shared their ideas and thoughts about their idea's others were more reserved. During one of the observations a student drew a plastic monster. The student did not initially say much, but viewing the drawing and asking questions regarding it helped to get him talking and helped us to understand his ideas.

"Interviewer: It's that an avatar?

Student 6: No

Interviewer: A boss?

Student 6: YES! (Laughing). With health-bar and XP!"

(Extract of interview with the student 6 in workshop 1)

Based on the drawing and the conversation with the student we implemented the character into the VR-game. The drawing and the implementation are shown in Fig. 4. When we presented the group of students to this new addition, at the second workshop, it was like a shift in their perception of what was possible to implement for the next iteration.

Fig. 4. The Plastic Boss from one of the minigames

5.2 Learning Design

During the workshops we also discussed the learning aspect of the games and how the games could be used to teach others about sustainability and climate changes. According to the students, games are a good way to learn, because they are doing something they are interested in and therefore learn more according to themselves.

"I like to play games, so when I play a game and learn in the process, I will learn more than if I did homework in books. I'm not interested in books. I'm interested in games." Quote of a student.

One of the students brought up the negative connotations concerning classic learning games during workshop 1. The following transcript is a snippet of the conversation we had about it.

"Interviewer: Remember, we are developing an educational game. It's not a game you play at home, like you play 'Five Nights at Freddys'.

Student 1: Why not? Why can't it be a fun game? Why can't you play it at home?

Interviewer: So, it's about making a game that we say is a game where you can shoot zombies. But we're not saying it's plastic zombies out on the sea...

Student 1: And it's a learning game… You just can't associate it with a learning game. They shouldn't think: "Oh, it's a learning game".

Student 4: That's right. When people our age hear it's a learning game, we think: 'Oh for fuck's sake'.

Interviewer: So, what I hear you say is that we can make a mixture? We can make something where there is some learning in it, but it also needs to have some game-elements from entertainment games?

Student 2: Yes! For example, mix a shooting game into it or something like that."

Extract of interview with the students in workshop 1.

This extract shows that the students agreed that learning games are boring. This made us think about how we present the learning part in the VR-game and how we can make it a fun game for the players. *"It's like if you need to give a pill to your dog and you wrap it in a piece of ham."* said one of the students, implying that if it had to have a learning component, it would have to be somewhat hidden. The conversation that followed resulted in an insight into how we could implement a narration that supported the learning component but still felt like a traditional entertainment game. Istiono and Waworuntu's (2021) research on learning vs. entertainment games also supports this initiative. Their research concludes that game-elements like rewards, challenges, character, and narration are the driving factors in why kids like entertainment games better (Istiono & Waworuntu 2021). Having a format such as a beginning, a middle and an ending, allows the player to immerse themselves in the game better. Which is why, by the end of workshop 2, we started co-designing a narrative about a time traveling character (the player) and a time machine (Fig. 5).

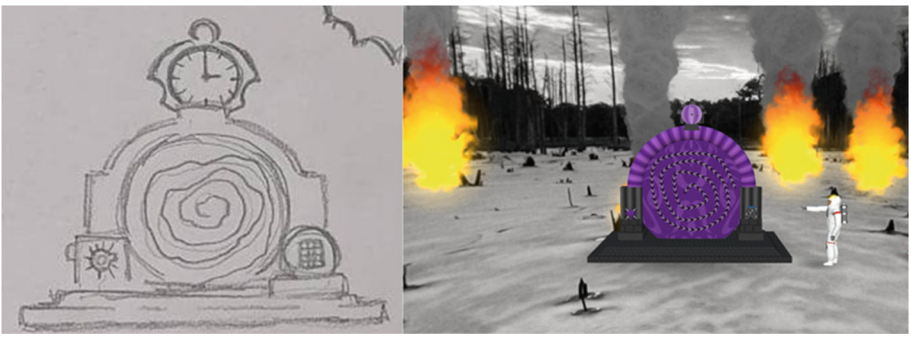

Fig. 5. The VR-games time machine

5.3 Sustainability

To find out what climate issues interests' students we had a dialogue with the students in workshop 1 about sustainability and climate change. To our initial surprise, the students already knew a lot of things about sustainability. One even brought up Power-to-X, which is a relatively new concept involving transforming carbon monoxide into usable fuel for planes, cars, trains etc. The students shared their knowledge- and gave their inputs, about which climate changes they found important to have in a game about sustainability. During the dialogue, one of the students decided to draw portals for each of the climate change we discussed, see Fig. 6.

Fig. 6. Portals of climate change in the VR-game.

The four portals shown in Fig. 5, is a collective representation of the different climate problems that the students were interested in. From left to right, Overfishing, global warming, plastic pollution in the ocean and lastly, forest fires and deforestation. Each portal represents a new world with its own challenge, knowledge to be obtained and games to play. These four portals represent climate change issues of which the students are interested in and create more awareness on sustainability. We talked with the students about overfishing, how the coral reefs suffer, ecosystems are destroyed, and self-sustaining breeding cycles are being heavily affected by it. On the topic of global warming caused by CO2 emissions, the students talked in great lengths about the impact the industry has on the CO2 emission. One student went into detail about the aluminum factories, talking about the lengthy process of digging it up, washing it, melting it, and

processing it in the end. Continuing the conversation about CO2 emissions, the forest fires were brought up by a student. Which in turn led to another conversation about deforestation, or the industry cutting down an inconsiderable number of trees, destroying the homes of animals and ecosystems. At this point, after discussing the different potentials of creating awareness about other climate problems, coming back to the world we were focusing on, the plastic pollution, it seemed to have sparked new ideas for the game.

One student asked why the game wouldn't be about stopping the plastic from getting into the ocean in the first place, instead of trying to pull it out. This of course sparked a conversation about the logistics and economics in building a disposal facility in a small village in a third world country. This would also spark a new idea that involved a recycle-grenade that would blow the plastic into fragments that could be used to upgrade the players weapons/tools to defeat the plastic boss (Fig. 4). One student compared it to Minecraft, a building game where you harvest/destroy natural resources like trees or iron 'blocks' to gain its materials to ultimately upgrade your tools, armor, or weapon that you wield.

5.4 Game Development

In the developing process we have tried to include as many of the students' suggestions as possible. Based on all the students' ideas and suggestions in both workshops we have transformed the first prototype from workshop 1 to an actual game with game-elements. We have used Deterdings' (2015) model of 'Schematic of a skill atoms' to develop the foundations of the VR-game in the shape of goal, action, challenge, objects, rules, feedback, and motivation.

The goal of the VR-game is to save the planet and learn about sustainability in a fun way. The VR-game is based on a narrative. Action is when the player travels back in time to save the planet. The player is faced with four portals, each with its own climate change. The challenge is to solve these climate changes by playing various minigames e.g., in the portal about plastic, it's the minigames about removing and fighting trash. To add learning into the VR-game there are some objects in the form of facts and information about sustainability and the world's current and future climate problems. The player can use this knowledge to answer a quiz in each portal and take the knowledge out in the real world. The game also contains rules, such as limitations to where the player can walk, which objects can be interacted with and how many pieces of plastic you need to destroy before completing a mini game. VR is not a very social technology as you can, in most instances, only experience it on your own. Our VR game is to be considered as more of a conversation starter and generally speaking a supplement to the existing sustainability teaching. This allows the students to experience the game for short amounts of time and then have a discussion about the content presented with their peers and teacher. With the theme of a handful of NPCs we introduce gives the player a feeling of being a part of something bigger and helps to motivate the player to play the VR-game. The competent feeling is induced by the rewarding elements and feedback of the VR-game in the form of high score and voice-over, sound, text, and images that tell the player how a challenge has been completed.

6 Discussion

In this section we will discuss our findings from the previous section with focus on students' perspective on learning games, Co-designing game development and Sustainability in education.

Our findings show that students' perspective has had a major impact on the design of the VR-game, particularly the students' drawings. Involving young people in the design process comes with a necessary discussion about the extent of which they participate, how much influence overall they will have and how we interpret and analyse the inputs that we get. In this study, we position ourselves as the game design literate, inquisitive about their experiences and curious about how they view learning games and by the end, ask if they have any ideas for the game at hand. Every idea or thought on learning games was paired with questions like *"Can you see that working in our game, in some capacity?"* or *"Is there any way we can brainstorm a way to incorporate exactly that game element you like into the game and add a learning element to it?"* - really trying to push the abstraction level of their creative thinking. Giving the students the focus on what the boundaries were and guiding their idea generating stages in the right direction, is something Khaled & Vasalou (2014) deemed crucially important.

Khaled & Vasalou's (2014) research presents two major challenges involving children as co-designers. One being the lack of domain knowledge and the other a general deficiency in game-design literacy. In the beginning of the first workshop, we had very open-ended boundaries set for what the children could contribute with. Big game elements like open-world multiplayer ideas that would require too much time playing the game, pushing the balance between a conventional entertainment game and a learning game, way too much to the entertaining side or just plain out of theme with the game. We procedurally started to set more boundaries, yet still leaving some space for new takes on how the game could completely pivot - within the sustainability theme. As previously mentioned, we wanted to allow their abstract thinking to be free, which led to ideas such as stopping the plastic from ever going into the river in the first place, by setting up recycle stations - which in turn showed a lack of domain knowledge of how the infrastructure of the country didn't permit such a thing. Then the idea of having a futuristic narrative came in, tying the whole objective of the game together with a classic game element (Istiono & Waworuntu 2021).

Khaled & Vasalou goes into detail how children do not possess any game design literacy, on the contrary, we learned that the children had already had some experience, designing their own learning game through a project in Minecraft. They were well intune with most of the elements from the intrinsic skill atom's table, such as action, goals, rule settings etc. (Deterding 2015).

Knowing we wanted to make a VR game about sustainability meant for elementary school students we asked our first research question; *"What climate issues interest' students and how do we create and communicate content to students that motivates more sustainable action and awareness?*

Our findings shows that the students in general are interested in taking care of our planet. We must recognize that their domain knowledge of sustainability and climate change exceeds our expectations. Even though they have only started to receive education in sustainability the same year as our study. Their current domain knowledge gives an

insight into how many different sources of CO2 pollution they already are familiar with, as well as their level of reflection about what the future may hold.

37% of Danish school students answered in a survey that they worry about climate change in such a way that it affects their everyday life (Ritzau 2023). These numbers show that just over a third of the students worry about their future. When children and young people are regularly made aware of the climate crisis, for example in the media, and they hear and see that the planet is beyond saving, they lose hope and become afraid (Ritzau 2023). There must be given space to these concerns, but students must also gain a sense that they can do something to influence climate change. Therefore, it's important to focus on sustainability and teach students about it in school. Epinion (2021) stresses the importance of making sure proper educational tools about sustainability are available. This is where our VR-game comes into play. We already knew the learning potentials from visualizing and simulating experiences from higher education. Letting elementary school students put on VR headsets in order to visualize a complex concept such as sustainability and climate issues, proved to be a potent educational tool. To ensure the connection between the individual, content, and context, we used transformational play (Barah et al. 2011) to turn their input about climate change into gaming experiences that potentially could transform into values that the students could carry into the real world.

Sustainability is a topic you hardly can avoid hearing about. The students are no exception. Discussing sustainability in the workshops, seemed to peak their interest even more when paired with designing a game around the topic. We initially asked ourselves; *"How do we support the students in expressing their ideas and perspectives?"*. DBR is already very user-centered, as phase one is all about collecting data, not only through existing research but also through talking to users and other creators of similar work. Then the testing phase ensures the validity of the design by testing out different iterations with the user-group. Pairing this method with PD, giving the users, the students, a voice and influence in the overall narrative and design of the game – meant that we could efficiently incorporate their inputs and ideas directly into the game, backing it up with our own theoretical framework through DBR. Furthermore, it created a sense of ownership for the students as we progressed and they could see the changes being made, inspired by their own contribution from one workshop to another.

7 Conclusion

Our findings indicate that the PD approach combined with the LAB and intervention phase of DBR in our study are viable methods for projects centered around user engagement and cooperation. The co-designing role of the students has been significantly influential for the game development process. The students were considered experts in their own domain, allowing them to share their ideas and perspectives in a semi open boundary environment. Furthermore, we made sure to give them all equal opportunity to be heard - both verbally, in writing and visually, by drawing. We can also conclude that the visual representations of the students' ideas have been significant in both how the game looks, and how the content is presented.

Without the involvement of the students, we believe that the VR game would have been a more traditional learning game, focusing on the visual representation of a climate

issue along with some infographics that would spark discussions within the traditional teaching method. Instead, we now have a concept of a VR game that has game-like elements, which on a subconscious level teaches the student to be more action-driven in securing a sustainable future. Furthermore, the students expressed how working with and creating learning material is highly motivating for self-educating on the given subject.

We believe that the VR-game has the ability to contribute to teaching about sustainability as a supplementing tool to the traditional teaching method. The VR-game contains age-appropriate learning, inspired by the curriculum the teachers are teaching from. The goal is to spark conversations around sustainability, in- and outside the classroom. Discussions about how to act in a sustainable manner to prevent some of the presented climate issues in the VR-game. Based on our research, we can see an expressed need for learning materials that helps teachers concretize and visualize a complex topic as such. By implementing motivational elements such as feedback- and progression systems in the game, showing the students that action can make a difference.

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