Creation of a meaningful gardening game: Increasing players' nature awareness through soil management and plant recognition mechanics

Introduction

Gardening and farming are relatively common themes for videogames. *Farmville* (Zynga, 2009), *Stardew Valley* (ConcernedApe, 2016) and *Caesar III* (Impressions Games, 1998) are examples of successful games with a prominent theme of nature. From farming and life simulators to survival games to management games, a large variety of games about nature are available to players. Nevertheless, it is extremely rare that video games take an approach that is beneficial for environmental education. As noted by Alenda Chang, video games "exert an important influence on how millions of players conceptualize country life, food production, and right relations between humans, animals, and the environment. Contemporary farm games represent an array of missed opportunities to model more meaningful game ecologies" (Chang, 2012, p.251).

Natural heritage sites, on the other hand, have a strong focus on environmental education. According to UNESCO, natural heritage sites can be defined as sites "with cultural aspects such as cultural landscapes, physical, biological or geological formations" (United Nations Educational, Scientific and Cultural Organization, no date). Natural heritage sites are also defined by the Convention as "precisely delineated natural areas of outstanding universal value from the point of view of science, conservation or natural beauty." (UNESCO World Heritage Centre, no date) Digital media has become a popular tool for educational mediation in heritage sites. For instance, the augmented reality game *Histopad* (Normandy Productions, 2013), the virtual reality application *Jumièges 3D* (Art graphique et patrimoine, 2012) or the video game *Le Roi et la Salamandre* (Pinpin Team and Centre des Monuments Nationaux, 2015), have garnered a strong interest from both heritage institutions and their audience.

This leads one to wonder whether or not these tools could also be integrated into natural heritage sites. The possibilities offered by mobile devices seem to be particularly relevant as they could be played in situ. According to Salen and Zimmerman, games, because they allow players' action to be framed as steps toward clear goals, convey meaning more efficiently: "Meaningful play occurs when the relationship between actions and outcomes in a game are both discernable and integrated into the larger context of the game." (Salen and Zimmerman, 2003, p.34) Moreover, the pervasiveness of video games through procedural rhetoric can increase the strength of their intended message (Bogost, 2008, p.125).
The most common approach for cultural heritage valorisation through video game is to use the heritage institution objectives and knowledge as a starting point for the development team (Lelièvre, 2016, p.5). If the development team pursue scientific inquiry while creating the game, it can then be considered a research-creation project (Bruneau and Villeneuve, 2007, p.34). One can then investigate if the same process could be applied for natural heritage as well.

Literature shows than one of the benefits of spending time in nature and interacting with it, is the increase in environmental behaviours and awareness (Ahn, Bailenson and Park, 2014, p.236). ‘Nature awareness’, which includes nature as plants, animals or the landscape, can be considered more specific than ‘environment awareness’ which includes climate change and ecology on a global scale. Following Chandler and Swartzentruber (Chandler and Swartzentruber, 2011) as well as Fisman (Fisman, 2005), nature awareness can then be defined as a person’s ecological knowledge and their awareness of the form and features of their local environment.

Plant blindness, a specific issue, related to the lack of nature awareness, could be a particularly interesting issue to address in a video game. Wandersee and Schussler, define plant blindness as “the inability to see or notice the plants in one’s own environment—leading to: (a) the inability to recognize the importance of plants in the biosphere, and in human affairs; (b) the inability to appreciate the aesthetic and unique biological features of the life forms belonging to the Plant Kingdom; and (c) the misguided, anthropocentric ranking of plants as inferior to animals, leading to the erroneous conclusion that they are unworthy of human consideration” (Wandersee and Schussler, 2001).

Decreasing plant blindness to increase nature awareness has shown to be a topic of particular interest for The Eden Project. It is an educational charity focused on environmental sustainability. They began their activities in 2000, when they completed the restoration of an abandoned Cornish clay pit into a botanical garden. They brought thousands of plants from all over the world and planted them in monumental plastic domes simulating their natural habitats. As of now, their Cornish garden features a dome simulating a Mediterranean environment, and one simulating a tropical environment, with plans for expansion and a whole variety of other activities across the world to raise awareness about environmental issues. It is a natural heritage site.

As part of a research project, it was proposed that we develop, with their assistance, an experimental video game and evaluate its impact after playtest. Our main objective was to answer whether a gardening mobile game could meaningfully promote nature awareness. Our goal was specifically to increase nature awareness and we limited the natural elements present in this experiment to flora, soil, and water resources.

Development of Tevi was also made possible thanks to the Pl@ntnet research project (Goëau et al., 2013), which granted us access to their API for the plant-recognizing mechanics of the game.
The research project was consequently created with a mixed-method (Lieberoth and Roepstorff, 2015), where research-creation provided insight into the creation process and intents, while the playtest allowed for analysis of player reception of the prototype.

To explore this research question in this paper, we begin by undertaking a review of relevant games and literature. Secondly, we present the prototype created using a research-creation methodology to illustrate the hypothesis. The effects of this

prototype are then studied through the analysis of a survey. This paper is concluded with a discussion on the limits and benefits of such an approach.

Games for purpose, learning and nature awareness

The idea of using games to change or influence behaviour is not a new one and the act of play has long been identified by biologists and psychologists as a natural mode of learning (Bateson and Martin, 2013) In recent years there has been a growing interest in exploring uses for games beyond pure entertainment, including for learning, variously termed educational games, games for learning and serious games (Boyle et al., 2016). Interrelated to this, an intersection of environmentally conscious 'eco-media' with video games, sometimes termed 'green games', has developed as some academics and game creators explore the function and utility of games in our understanding of the natural environment (Chang and Parham, 2017).

In 2016, Boyle et al. conducted a meta-study of papers that demonstrated empirical evidence of the learning impacts of playing games, focusing specifically on papers about 'serious games' and 'games for learning' which they identified as being used synonymously within the literature (Boyle et al., 2016). Their study drew on research from the disciplines of social science, science, education, and engineering, and focused on 143 papers deemed to be the highest quality from an initial sample of 7117. They concluded that, in general, serious games tended to perform better for knowledge acquisition than the control condition. Similar findings were reported by another meta-analysis conducted by Backlund and Hendrix (Backlund and Hendrix, 2013).

Among some of their more specific findings Boyle et al found simulations to be the most represented genre among their studied sample of learning games. This should not be surprising as simulations have a long history of use in teaching and training across many disciplines (Arnseth, 2006). Simulations afford learning by allowing the user to interact experimentally and playfully with the simulated system. They may also aid the understanding of a complex system by presenting the user with a simplified version (Bogost, 2006). Digital simulations particularly can capitalise on these affordances; granting the ability to modulate the users' interaction in ways which would not be possible in other media, for example by adjusting the speed of the simulation (Bogost, 2006, p.95).

In his book *Unit Operations*, Ian Bogost discusses simulations at length and highlights cellular automata as being of particular use in the simulation of natural systems. Cellular automata are a system created by a series of rules relating to cells on a grid. Each cell follows the same simple rule set to work out if it is 'alive' or 'dead'. Despite the simplicity of the set-up, cellular automata have been shown to exhibit tremendous complexity of emergent behaviour and produce outputs that can mirror those seen in nature, for example the behaviour of simple lifeforms. Cellular automata, in computer science, are defined as "mathematical idealizations of physical systems in which space and time are discrete, and physical quantities take on a finite set of discrete values." (Wolfram, 1983, p.1).Cellular automata, therefore, can provide an excellent basis for simulations about the natural world and in

particular observing the complex results of simple rules interacting over time (Bogost, 2006).

Many, if not all games contain some element of simulation, a metaphorical mapping between the system described by rules and the presentation of that system to represent something. Philosopher Alfred Korzybski famously remarked that the “map is *not* the territory” (Korzybski, 1958). So too can simulations in games not reach the same level of complexity as the systems they seek to represent. When deciding how to represent something, designers can include, exclude, exaggerate, or minimise various elements. This allows space for rhetoric to be constructed to advance a particular argument. Bogost coined the term ‘procedural rhetoric’ for designing a system in this way (Bogost, 2010). The use of games to advance arguments has already achieved some success with what Bogost’s terms ‘advergames’ (Bogost, 2010) and the ‘newsgames’ of Gonzalo Frasca (Newsgaming.com, no date).

A further tactic that games can employ that has been shown to have a significant positive effect on learning is termed ‘tangential learning’ (Mozelius, Fagerström and Söderquist, 2017). Coined by Floyd and Portnow (Floyd, 2008) tangential learning refers to users continuing to seek information on a topic after having been exposed to it within an engaging, often fun, context. One of the clearest examples of this style of learning would be players becoming interested in various historical periods after playing *Civilization* games, for instance *Civilization II* (Microprose, 1996). The in-game encyclopedia or ‘civilopedia’ in the *Civilization* games prefigured Floyd and Portnows advice to capitalise on the players self-directed learning by including an encyclopedia within the game or internet links to other sources of information that can, but do not have to be accessed during gameplay.

It is these affordances and similar that lead Smith to claim that games could be the “ideal media for ‘green’ or environmental thinking, since the player is consistently expected to manipulate their environment.”(Smith, 2017, p.105). However, as he points out, the procedural rhetoric of many grid-based management games “encode a set of narratives in which nature is the location of resources to be extracted and used.”(p.103). Similarly, in the inherently grid based cellular automata, we can see the dividing up of nature into discrete units of function in a highly mechanised vision of organic life. Despite these and similar concerns however, Alenda Chang and John Pahram share Smith’s optimism that green games could expand the players ecological understanding and awareness, or even move them to acts of environmental responsibility (Chang and Parham, 2017).

In one of the few available studies on nature awareness, Chandler and Schwartzentruber (Chandler and Swartzentruber, 2011) define three types of nature experiences within a teaching context: direct, as in a walk in a forest; indirect, for example visiting the zoo; and vicarious, which includes computer games, books, and film. They show that students with higher incidences of these nature experiences (and by definition therefore higher nature awareness) show a significant increase in science understanding as measured by science grades. The proposed method for this relationship is backward-reaching high road transfer (Salomon and Perkins, 1989) where learners formulate an abstraction for use in a current task by use of past knowledge and experience. These findings are supported by Wandersee & Schussler, who cite specific education coupled with a variety of “personal, guided,

direct experiences with growing plants" (Wandersee and Schussler, 2001) as being perhaps the best way to overcome plant blindness. They add that capturing *one's "botanical sense of place" (p. 7*) via photography of plants helps to recall prior knowledge of plants which can be used to conceptually support the learning of new knowledge in a method highly reminiscent of backward-reaching high road transfer.

In light of this research, the creation of a video game was proposed that would utilise elements of simulation, cellular automata, procedural rhetoric, and photography in an attempt to increase players' natural awareness and reduce plant blindness.

Tevi: A Proposed Solution

The prototype for the management video game for mobile devices, *Tevi,* was developed over the course of nine months. The team experimented using procedural content generation (PCG) for the creation and representation of natural elements and their evolution in real-time 3D as it was considered an interesting tool for this purpose. To complete this research-creation approach, a user study was planned to analyse the impact of the prototype.

In *Tevi,* players are asked to sustain and take care of a garden on Mars. They are provided with seeds to plant on a five by five grid of soil tiles and, as the seeds grow into plants, players support them by either watering or providing nutrients to the soil tiles they are planted on (Figure 1). Players can also use their devices' cameras to take pictures of real plants. Doing so, thanks to access to the Pl@ntnet API, will provide them with a name and basic info on the plant photographed, as well as reward them with some in-game items.

Figure 1: Tevi Main screen

We will here go through the main mechanics describing how they appear in the game.

In order to simulate a natural growth process, the behaviour of each plant is simulated using a model based on cellular automata concepts and by using data provided by botanists at the Eden project. For each plant, the game checks their resources consumption, if their soil has too much water or nutrients, and how many neighbouring plants they have. It also simulates their fruit production cycles, life cycles (how many times they can produce fruit before dying) and how many offspring it spawns in its own and adjacent soil tiles. The game simulates five plants: Banana Plants, Shampoo Ginger, Breadfruit, Sugarcane, and Wild Indigo[1].

This creates a sprawling, autonomously developing garden with plants growing, flowering, fruiting, dying and leaving seedlings to begin the cycle again. If players fail to add water and nutrients, the ecosystem keeps going until all resources from all tiles run out, and nothing can grow anymore until players start feeding and watering the soil again (Figure 2).

Figure 2: Different stages of garden development. The last one being a completely dead garden.

Other than the two soil resources already mentioned, each plant also produces certain ratios of resources. These resources are directly borrowed from the story of the canoe plants (Anderson-Fung and Maly, 2002, p.20): the collection of plants that, it is believed, Polynesian people, brought with them when colonising Hawaii. This is

1 Respectively Musa species, Zingiber zerumbet, Artocarpus altilis, Saccharum officinarum and Tephrosia purpurea.

a selection of 26 plants they judged sufficient to sustain a new civilization. Plants that would provide the five resources considered essential for a civilization: food, fuel, construction, medicine and culture (Figure 3). The game constantly calculates the ratios of production for each of these resources based on the plants currently present in the garden. This system was expected to help players interpret their garden as an evolving organism without accumulating resources.

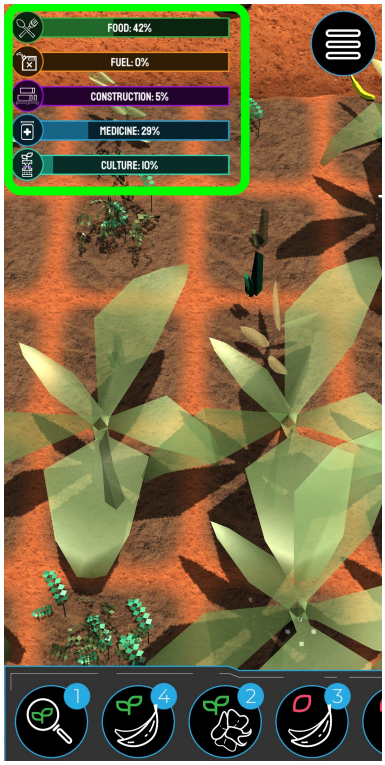

Figure 3: UI showing the garden resources ratios

The Pl@ntnet tool uses a mix of citizen science and machine learning techniques to identify a plant when given a picture of it. Building on techniques popularised by AR games such as *Pokémon Go*, Tevi allows players to bring up the Pl@ntnet menu at any time during gameplay, which accesses the device's camera and allows players to take pictures. If a plant is recognised in said picture, the player is provided with the scientific and common name of the plant, as well as an accuracy rating of the API prediction, and finally a link to the Wikipedia page of the plant. The photo is then stored in the player's in-game plant gallery. Players are rewarded with water, fertiliser or new seeds to plant, for the contribution (Figure 4).

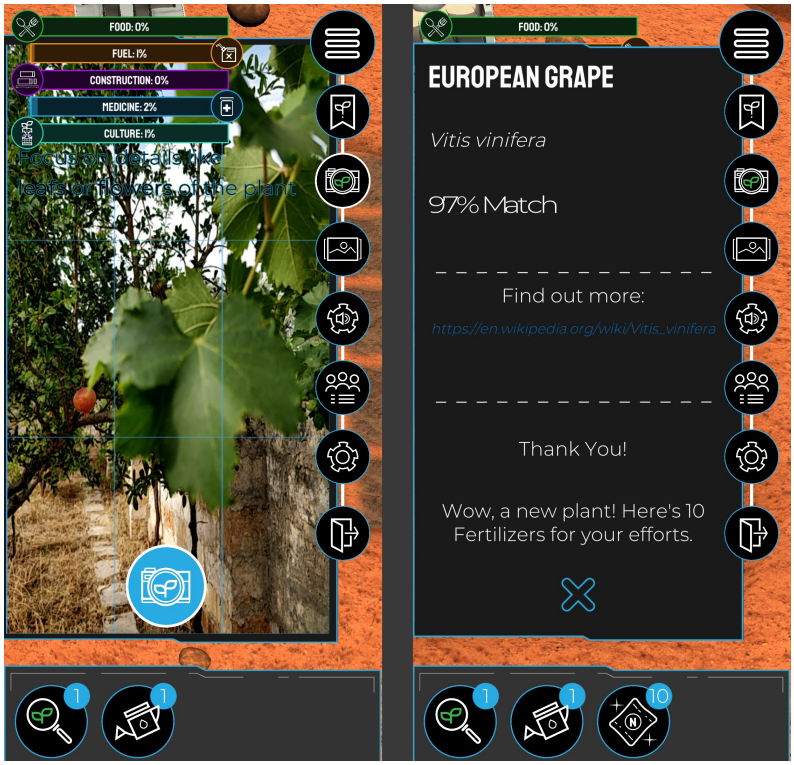

Figure 4: Pl@ntnet menu of the game

Finally, the game delivers a tutorial and some narrative context, through quests, that also reward them with seeds and soil resources when completed (Figure 5).

Figure 5: Quests

Methodology and design process

To conduct this study, a research-creation methodology was chosen, taken from the field of the arts (Gosselin and Coguiec, 2006). Research-creation studies the process of the creation of a work from within, based on the authors' log books and work documents. With this methodology, the study is conducted by the designers of the artistic work themselves. In the case of the research presented here, the research-creation was conducted by the three designers of the games authoring this paper: xxxxxx, xxxxxx, and xxxxxx. A researcher external to the creation process, xxxxxx, was also involved in analysing the results and writing this paper for the sake of critical distance from the project.

Tevi was entirely developed in Unity 3D, with graphic and audio assets created in external software, programming written in C#, and an online database with scripts written in PHP storing players' game interactions and login details. The online database is also used to store player-made pictures recognised as plants and check them against the Pl@ntnet database. It was developed by a core team of three people, all game designers with experience developing in Unity, mobile games, and serious games (Michael and Chen, 2005), with one of them also being a researcher with a focus on heritage site valorisation through games. *Tevi* benefitted from the work of four freelancers hired to produce 2D graphics, introductory cinematics, a trailer, marketing materials and concept illustrations. *Tevi* was developed by the MetaMakers Institute at Falmouth University, and benefitted from consultation from the Falmouth University Games Academy teaching and administrative staff.

Tevi was developed over the course of nine months, with two months of preliminary discussion followed by seven months of active development. The design process was kept loose, and the game design evolved dynamically throughout the nine-month period. User research and outreach for the game was performed throughout the last two months of development plus an extra month when we showcased the game at industry specific events.

The team built on their experience of national heritage sites valorisation through games and the richness of Cornwall's natural landscape to start the project with the explicit intention of creating a digital game able to contribute to the valorisation of Cornish natural heritage sites. This made collaboration with the Eden Project an obvious first step.

From an initial conversation with Eden it arose that the demographic they had the most trouble reaching were young adults (defined by Eden as 18 – 25 years old) who are not necessarily already interested in natural awareness and sustainability. Video games were identified as a possible entrance point to reach them, focusing specifically on successful mobile games (for accessibility and immediacy purposes) (Google, 2019). The design of *Tevi* was therefore inspired by games that the team identified as popular with young adults and mechanically compatible with sustainability themes. Specifically *Clash of Clans (Supercell, 2012)*, *Animal Crossing: Pocket Camp (Nintendo EPD and NDCube, 2017)*, and *Pokémon GO (Niantic, 2016)*.

As part of the preliminary design process, research was undertaken into what are generally recognised as challenges in nurturing nature awareness. Tackling plant blindness was identified as being particularly important among these challenges. As a result, the team resolved to find ways to make plants the central focus of *Tevi*. A need to simulate and educate about sustainable gardening was also identified. This incurred a set of problems related to common approaches in management games: namely a game economy that was capitalistic and exploitative in values (Dyer-Witheford and Peuter, 2009) and focused on getting the higher numbers possible, be it in resources, scores, or game objects. These approaches were found to conflict with ideas of sustainable gardening (Smith, 2017, p.107).
Equipped with this knowledge, a team of Falmouth University's Games Academy researchers and staff was assembled to lead a discussion on designing a game addressing the requirements and early inspirations of the project. The team quickly agreed that the best way to encourage direct contact with plants would be to have said contact be essential for gameplay and achieving the objectives of the game. For this purpose, they identified plant-recognition technology as a possibly useful tool.

The team also agreed that principles of cellular automata algorithms could be used to simulate the natural growth and spread of nature. Through cellular automation, the value of each tile is influenced over time by the values of neighbouring tiles. In *Tevi*, as we've discussed, plants are simulated individually, and the result of their simulation affects neighbouring tiles.

Finally, the team settled for a science fiction theme for the game's narrative. Involving an attempt at escaping Earth's crumbling environment by building gardens on Mars protected by domes similar to the ones found at the Eden Project. The team also discussed the possibilities of introducing an element of cooperative multiplayer by including competing factions each player can join, visiting other players' gardens, and planning real-live events connected to the game at the Eden Project.

This was all the result of multiple brainstorming sessions organised with Falmouth University staff, as well as a continuous unshackled design process that eventually allowed the core team to fully explore possible affordances of games in the context of encouraging nature awareness. Ultimately, through in-house testing, a specific set of mechanics that would be able to work together in a complete product were identified. The most technically feasible mechanics within the development schedule were implemented.

Ultimately, the team was able to develop a game able to encourage nature awareness by keeping its design flexible throughout development and by opening its design process to contributions from advisors involved in the games industry and education as well as Eden Project staff knowledgeable on nature awareness. The development was also facilitated by the direct access to the Eden Project that its staff provided.

Prototype playtest results and analysis

Context of the playtest

As a part of the research project and partnership, the team was invited to present the project from the 16th of February to the 23rd of February 2019 at the Eden project. This was the week of the holiday winter break in the UK, a period used mainly by families to visit the site. The Eden project is a charity and popular destination that attracts more than a million visitors each year (ALVA, 2018), who are mainly families, according to Eden Project's advisors. The project was presented in a room called "The Lab", situated in the "Core" building, dedicated to science and art mediation.

At the Eden project, visitors are encouraged to see a lot of plants, both local and from other areas of the world. Strong interactions with plants, like touching plants or taking leaves, are discouraged for practical and botanical reasons (diseases spread, harming plants, etc.) Gardening is not currently a part of the Eden project mediation of nature.
The visitors can take pictures freely both in Eden Project's gardens and biomes. Plant identification is encouraged through labels next to most plants, guided tours, and occasional non-digital games for children.

The playtest of *Tevi* at the Eden Project was the first public presentation of the prototype. This event was designed to help the researchers of the team to test their hypothesis, get feedback on the game design, as well as testing its technical aspects. Because the game was still a prototype, it was not finished or completely polished and was presented as a scientific experiment to the players. "The Lab" has been designed to show researchers at work. The team consequently used their time there not only to conduct a survey but also to improve the game, which was updated several times during the week.

User research methodology

The purpose of this research was to explore the main research hypothesis through a first sample set. This survey was created as part of the design process and it was expected from the beginning to have a relatively small scale both in terms of the size of the sample and in terms of duration, as it was likely that the players could only be asked to play and answer once.
The survey was done on paper. It included twelve visual analogue scales (VAS, also called graphic rating scales or unipolar line scale) and four open questions (Figure 6). We have chosen VAS as this measure is particularly exact and easy to understand for participants. As described by Daly-Jones, the VAS used in this study is standard. It "consists of a line between two extremes, in the current study between 'Not at all', on the left and 'Very' on the right. Participants were asked to make a mark on the line, which could include the extremes" (Daly-Jones et al., 1997).

Virtual Analog Scale	
Q1	How much did you enjoy the game?
Q2	How easy was it to play the game?
Q3	How much did you like the graphics?
Q4	How proud are you of your garden?
Q5	How happy do you think the plants in your garden were?
Q6	How alive did you feel the plants were?
Q7	How much did you think about your plants' growth process?
Q8	How much did you enjoy taking pictures for your game?
Q9	How easy was it taking pictures for your game?
Q10	How much would you like to play this game again?
Q11	How sci-fi did the game look?
Q12	How much did you understand what made the plants grow in the game?
Open Questions	
Q13	What did you like the most about the game?
Q14	What did you like the least about the game?
Q15	What would you have like to do in the game that was not possible in this version?
Q16	If you did take picture using the app, did you try it in the Tropical Biome? Did it change your visiting experience?

Figure 6: Questions of the survey

The graphical scale questions can be divided into two sets: general and technical questions on the game (Q1, Q2, Q3, Q8, Q9, Q10, and Q11) and questions on nature awareness in the game (Q4, Q5, Q6, Q7, and Q12). Both sets were designed to avoid leading the responders, following the recommendations of Singly (Singly, 2012). It was particularly important to allow the responders to freely answer the open questions at the end of the survey: Q13, Q14, Q15, and Q16. It was decided to leave the open questions at the end to avoid discouraging the responders to answer previous questions, as open questions could be more intimidating and take more time. All of these data can be considered subjective measures according to Landers and Bauer (Landers and Bauer, 2015, p.151). In addition to these questions, the date of the survey was gathered, which was important as the game changed during the week, as well as personal but not identifying information (age and gender). 24 visitors participated in this study. They were aged from 6 to 54, with 7 children and 17 adults, 11 women and 13 men.

The right to get surveys from children was only obtained from the 19th of February onwards. The children filled the survey with the help and agreement of their parents. Completing the study took about ten minutes and was done after a playtest of various durations inside The Lab, mostly on the mobile devices provided by the team, but also sometimes on the players' own devices. In addition to playing, some players received an oral presentation of the game by the project team or Eden's mediators. There was a video trailer explaining the gameplay displayed in the lab. All the responders also received an oral and written explanation on the purpose of the survey.

After arriving, the team was told by Eden mediators that the Lab is generally visited at the end of Eden's visit, after the two biomes and the garden. The team's experience was consistent with that expectation, as the number of visitors increased greatly after 12 pm every day. As a result, it is safe to assume that the players already visited a large part of the Eden Project before testing the game. For this reason, the last open question (Q16) revealed itself not to be useful as none of the

responders had the occasion to test the game in the biomes before coming to the Lab. If they did go afterwards to play the game in the biomes, they did not come back to the Lab to answer the survey.

Results analysis
The game had an overall slight positive appreciation (6.7/10 average on Q1), which increased over the course of the week (Figure 7). This could be explained by the improvements that were implemented into the prototype across the week (bug fixes that notably allowed players to take pictures).

Figure 7: Game enjoyment for each responder, ordered by date

The average opinion of the seven children was higher than the global score (average 8.5/10) and their rating was very consistent, which was not the case for adults. The size of the sample makes it difficult to conclude that the game is appreciated more so by children, but its enjoyment by children is also consistent with observations during the week. It is nevertheless interesting to note that some adults enjoyed it as much as the children and that the need for reading, which required adult supervision, didn't stop children from appreciating the game.

The general appreciation of the game (Q1) is correlated with pride in one's garden (Q4), taking pictures in the game (Q8) and interest in replaying the game (Q10) (above 7). Contrasting this, ease of playing the game (Q2), and understanding of the plant's growth process (Q12) have a low correlation with general appreciation of the game (below 4). The high correlation (7.37) between Q1 and Q10 seems to indicate a consistent behaviour. The low correlation between Q1 and Q2 probably indicated either a disconnection between the game accessibility and how fun it was perceived or players' understanding of the fact that it was a prototype with its technical limitations.

Taking pictures of plants

The pleasure of taking pictures in the game (Q8) shows the highest correlation with general enjoyment of the game (7.4). The plant recognition system through picture

taking was not working properly on the first days of the survey. The score for Q1 and Q8 for each responder, except for the three participants that did not answer Q8, is illustrated by Figure 8.

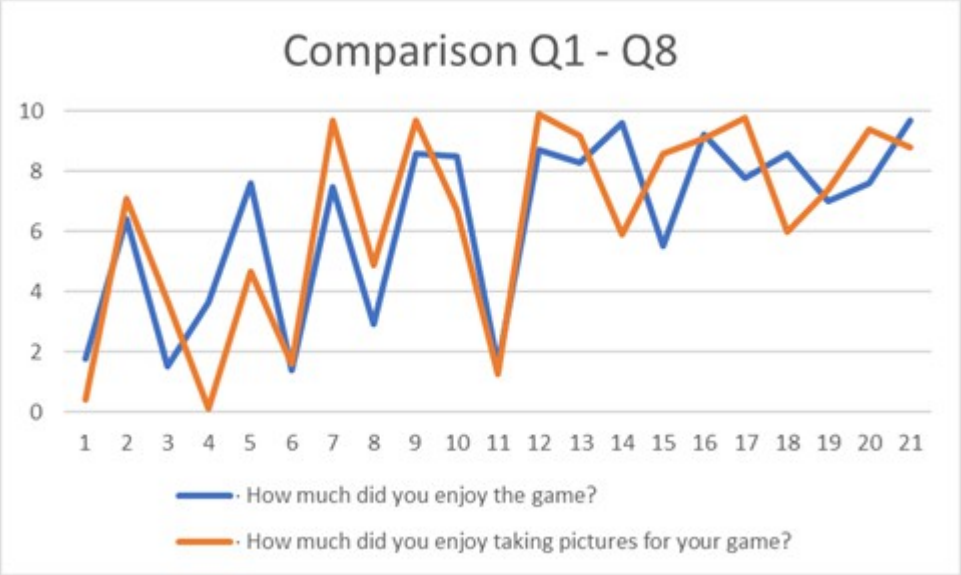

Figure 8: Correlation between picture-taking and game enjoyment

The high correlation leads us to speculate if there is a causal relationship between this feature and the game enjoyment, despite the small size of the sample. The open questions Q13 and Q14 seem to indicate that, at the very least, taking pictures in the game played an important role for some users. Indeed, seven of them noted “taking pictures” as one of the aspects they liked the most in the game. Also, five responders noted that their difficulties with the camera or their inability to take pictures were one of the things they liked the least about the game.
From the development team point of view, the plant recognition system through picture taking was the most innovative feature of the game. Yet, its link with the game was not very tight, as the game was designed not to rely on this feature. The team was indeed initially afraid of not being able to integrate Pl@ntnet properly due to technical and legal reasons. The responders seemed to have considered this feature interesting regardless.

Virtual gardening
Q4 asked users if they felt proud of their garden. This relatively high correlation with game enjoyment (Figure 9) could indicate that the users who appreciated the game also felt some pride in their garden.

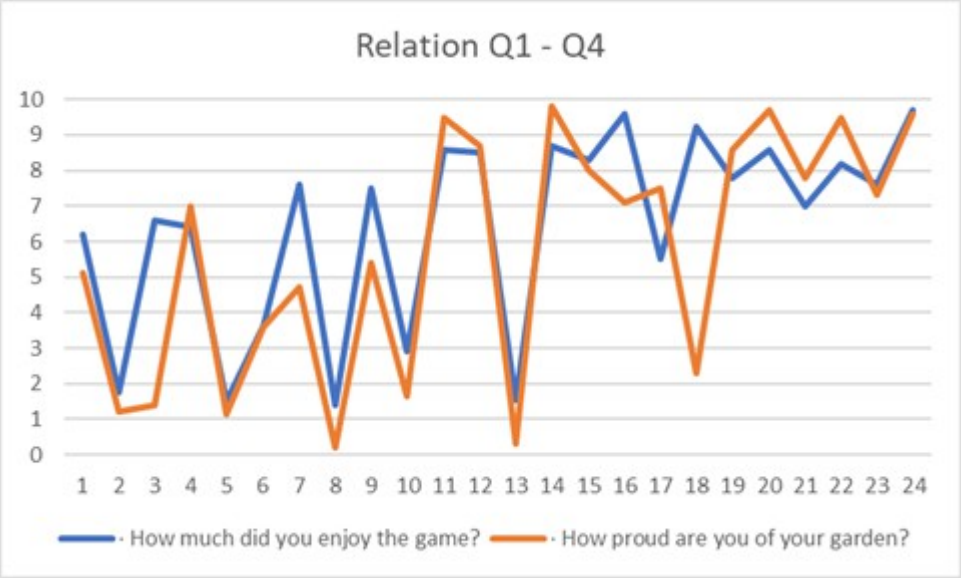

Figure 9: Correlation between garden pride and game enjoyment

No one mentioned directly the state of their garden as something they particularly appreciated in the open question Q13. Rather, they appreciated the process of growth which can be seen in the following comments by respondents:

> “Doing something to make things progress/grow.”
>
> “Watching the plant grow.”
>
> “Planting the seeds”

In addition, several respondents mentioned the bad state of their garden and their inability to make it better as something they liked the least in Q14:

> “No success, despite watering and fertilizing. No visible sign that watering or fertilising is done. Everything dies no matter what I do.”
>
> “I didn't get much fertiliser & watering cans, meaning my plants kept dying :(”

It is then possible that these answers indicate the garden was considered as a place for the action of gardening rather than a space to decorate.

If the virtual gardening offered by the game was considered to be interesting by some players, it seems that understanding of the growth process played no part in it. The correlation between Q1 and Q12 is particularly low (2.79), which should question the pedagogical potential of the game and the use of cellular automata to simulate a growth process.

These conclusions should be nuanced by the scale of our survey as well as the context of this exhibition. It is indeed likely that the responders were already interested and sensitive to nature, at the very least due to their apparent desire to visit the Eden project.

The scale of our survey limits our conclusions, but this study still points us towards several interesting directions: the importance of taking pictures of real plants within a gardening game, the possibility of addressing a broader audience than the initial target demographic, the interest of virtual gardening, and the pedagogical limitations of the prototype.

Discussion

Although the original goal was to design a game for smart device platforms that would promote short-term nature awareness and prevent plant blindness in young adults, the resulting research has opened up several directions/issues for the research going forward.

Managing Contradicting Rhetorics and Player Expectations

Woolbright (Woolbright, 2017) has noted the difficulties of communicating eco-positive messages through critiques of several games. One risk is that players may perceive a sanctimoniously preachy or doom-laden tone about ecological issues which would prevent receptivity to the intended rhetoric. Chang (Chang, 2013, pp.43, 47, 53) has discussed how tensions in *Farmville*'s procedural rhetoric make differ from real farming functionally and ideologically, leading to a disregard (intentional or not) for farming's history and contemporary issues. Smith has also noted that games tend to be a difficult medium for progressive ecological rhetoric and tend to 're-inscribe ideological and cultural norms that are ecologically regressive' (Smith, 2017, p.117). Abstracting these issues or fictionalising them as fantasy risks making very real issues seem like a disconnected fantasy that will never affect a player's real life (Woolbright, 2017, p.94) and emphasising the harsh reality of such issues can be perceived as preachy or negative. The challenge is to encourage a particular way of interacting with nature that is not contradicted by systems within the game. In this case, does the underlying procedural rhetoric of *Tevi* contradict its goal?

The goal for *Tevi* was to emphasise the benefits of plants to both humanity and the individual whilst not sugarcoating the difficulty of co-existing with nature in an eco-friendly way. *Tevi*'s design ethos aimed to avoid a disposable, material approach to the growing and cataloguing of plants in the player's garden. This was intended to guide the player away from adopting capitalist rhetoric that sees nature as a resource to be managed and exploited for a purely instrumental purpose without consideration for the impact on the global or local ecosystem. It's possible, as Smith suggests, that the level of simulation abstraction and goal-oriented nature of games makes games a potentially unsuitable medium for challenging rhetoric that capitalises the natural world.

The team ultimately resorted on relying on using elements they had already agreed to include in the game to critically subvert management games expectations. For example, by aiming to implement what are effectively predatory mechanics commonly referred to as microtransactions but link them to plant-recognition technology. Normally, these systems create a need for in-game resources through game mechanics and, when engagement is maximised, remove free access to said resources, requiring people to instead buy them with real money. Contrary to this, in *Tevi*, players are required to go out and take pictures of real plants. To solve the problem, the team has also theorised the possibility of approaching the game

economy from perspectives that challenge dominant capitalist paradigms, and by reinforcing the idea of plant death not being a fail-state, but something part of the natural circle of life.

Similarly, the team recognised how the tightly structured game economy inertly conflicts with the uncontrollable nature of the cellular automation of the garden's growth. This was designed with the intention of exacerbating their differences and highlighting the need to find a way for the player's control to facilitate the natural evolution of the garden, as opposed to impose their objectives and control over it.

The focus on garden management, in *Tevi's* systems and core game loop, may be undesirable if the goal is to get players to care about the plants they grow as well as balance the eco-systemic processes that preserve species in the long-term. In retrospect it might be worth considering ways in which the fundamental design of the game could be adjusted to incentivise caring for plants, not only virtually but for plants the player might encounter in their daily life. The lowest rated response in the questionnaire was for the question 'How alive did you feel the plants were?' It is suspected that the abstract nature of the simulation brings with it some unintended simplifications that may lessen the degree to which players feel like the plants are living things worth being emotionally invested in.

When asked about what players liked least about the game or what they would have liked to do that was not possible in the tested version, familiar conventions common to games were mentioned that might contradict *Tevi's* message. Expansion of property was often mentioned as a desired feature as was the presence of rewards or the ability to 'use' harvested fruit. The detail of the qualitative feedback is limited but it is clear that a not insignificant portion of players brought expectations of expansion and reward to the game which may be informed by genre conventions or the player's existing understanding of gardens and farms.

Smith has noted that the genre of games that involve resource management and adopt a top-down perspective, sometimes referred to as 'god games' "draw on a philosophical tradition that asserts man's control over nature, and so are aligned with potentially dangerous geo-engineering interventions" (Smith, 2017, p.117). The grid-like nature of *Tevi*'s garden calls to mind resource management games such as *Minecraft* (Mojang, 2011), *Viridi (Ice Water Games, 2015)*, *Balance of the Planet* (Crawford, 1990)(Crawford, 1990), the *Wetlands Restoration Facebook Game(University of Washington, 2012)*, *Per Aspera* (Tlön Industries, Forthcoming), *Civilization V (Firaxis Games., 2010)* or *Settlers of Catan* (Teuber, 1995) and others mentioned above. All of these games challenge the player to make efficient use of limited space, often in order to maximise value from the natural world. It is clear that the systems of *Tevi* align with various farming, gardening or resource management sims but the experience cannot and should not necessarily be clarified with genre labels such as these. The expectation brought about by game genre or 'game grammar' is an expectation that needs to be managed otherwise the player may inadvertently assume the game is about simply maximising nature's output as a genre convention. Any quantification of nature and plants may be something that needs to be reconsidered or avoided when developing a game to promote nature awareness.

There are many games that explore the theme of nature that are not necessarily tied to genres commonly associated with resource management. Examples include *Flower* (thatgamecompany, 2009), *Flow* (thatgamecompany, 2006), *Luxuria Superbia (Tale of Tales, 2013)*, Pikmin (Nintendo EPD, 2001), *Waking Mars (Tiger Style, 2012)*, *Everything* (O'Reilly, 2017), *Abzu (Giant Squid Studios, 2016)*, *Ecco the Dolphin (Novotrade International, 1992)*, and *Mountain* (O'Reilly, 2014). These games, while often fantastical, encourage players to think about the effect of human activity on the natural world. Leveraging the role-playing property unique to games, these games place the player in the role of a non-human organism to experience its perspective. This approach could reframe the player's perspective on nature in similar future projects and has been advocated by Woolbright (Woolbright, 2017, p.91). This brings to the forefront a related discussion of the role of fiction in the game.

Contextualising the Player Experience through Fiction and Characterisation.
It was mentioned in the player feedback that players would appreciate a greater deal of contextualisation with regards to the fiction of the world – specifically characters representing player action. This feedback may speak to a desire to have some sort of player surrogate that might make empathy with the character and plants in the game more likely. However, this runs counter to Woolbright's (Woolbright, 2017, p.98) critique of avatars reinforcing anthropocentric approaches to nature. Likewise, op de Beke (op de Beke, 2018, pp.82–83) sees the focus of the caretaker relationship of environmental awareness as being more a question of context than direct characterisation through an avatar. The question of how the player even knows to be aware of nature and where they should intervene (with care) should be more open-ended than necessarily prescribing a garden-gardener relationship through a fictional character and their environment. Nature should not be framed as other or antagonistic and the game should not posit the player's awareness of plants around them as a special moral position but rather a normal yet beneficial one. Previous research, however, may run counter to player expectations of what the fiction of a game about gardening might be.

During the project, a 'store listing' experiment (Figure 10) was conducted that randomly assigned an artwork to *Tevi's* page on the Google store. The artwork was either a screenshot of the game (Figure 11), an image that contained character artwork (Figure 12) or panoramic artwork with no character (Figure 13). The image with the character artwork garnered the most attention in terms of unique installs and this might reflect what was felt in the feedback during playtesting regarding more of a human presence in the game via characters.

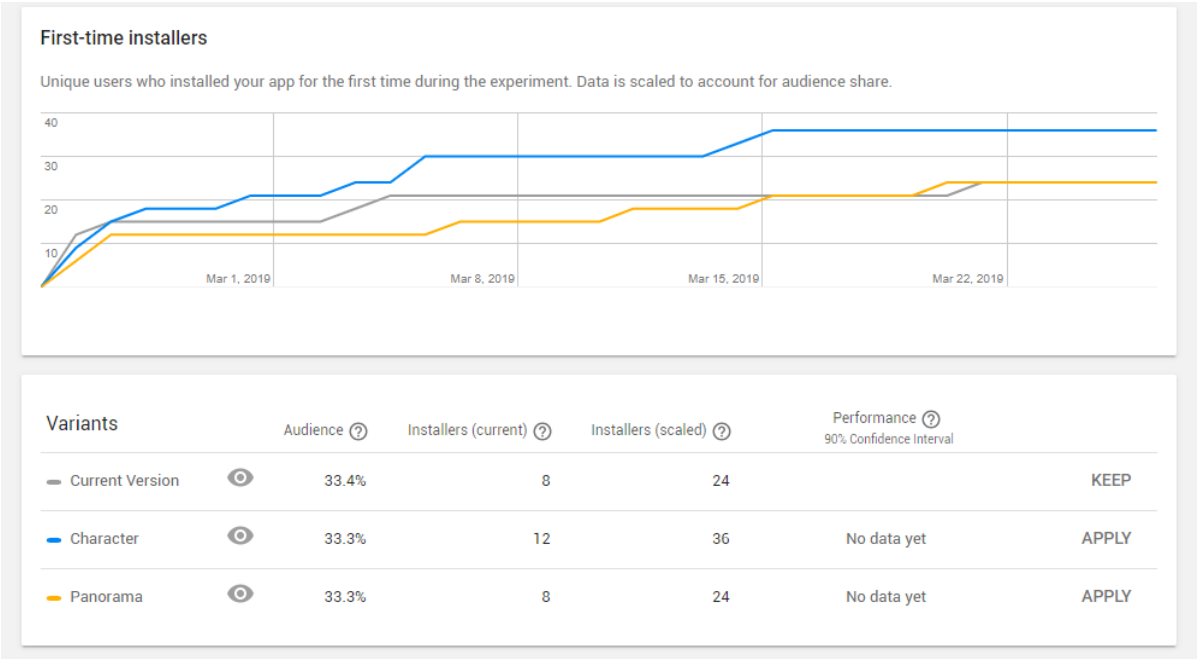

Figure 10: Results of 'Store Listing' Experiment showing the number of installers based on the variant thumbnails for 'Current Version', 'Character' and 'Panorama' shown in Figures 11, 12 and 13 respectively.

Figure 11: Game Page Artwork: Current Version

Figure 12: Game Page Artwork: Character

Figure 13: Game Page Artwork: Panorama

Integrating Subversion and the Benefits of Camera Integration

Players generally did not pick up on the subversive intentions of *Tevi* which is partially down to signalling that the game is satire when managing expectations (discussed above). There is a potential to push the satire further with regards to the futility felt by some players. One participant's comment captured the potential of using frustration to make nature awareness clear: 'Everything dies no matter what I do'. Trying to preserve nature, especially large-scale efforts to prevent global climate change and species preservation are difficult undertakings that the game could satirically represent through frustrating gameplay. In one critique, Woolbright(Woolbright, 2017, p.97) mentions that the opportunity to fail and have serious consequences for environmental failure could be a useful rhetorical tool but

potentially off-putting to a casual audience. A satirically difficult game may not be the most fruitful option if the project is to have widespread appeal and potential for improving general nature awareness amongst the public even if it accurately communicates the procedural difficulty of caring for plants.

As mentioned in the playtest analysis, using the camera integration to identify real-life plant species was enjoyed by many of the participants and could also further a satirical goal. If a player is in an environment that leads to a lack of nature awareness (e.g. urban centres that lack initiatives to preserve natural commons) there is an opportunity to make the absence of plants a part of the game's goal. The camera does not make a distinction between real plants and photographs of plants and so one is able to cheat the system but not without being confronted with the core conceit that they are willingly disconnecting from nature for short-term rewards.

However, the camera would be a good way of redirecting focus on biodiversity of any natural areas the player inhabits. Tying rewards to collection of plant species in a codex was highlighted by players as something they would like to see more of and this desire to collect could be exploited to encourage players to engage with the natural world around them. In the same way that the quantification of nature (via gridding the garden and giving short-term rewards) might subvert the promotion of nature awareness, taking pictures might highlight plants in a way that is closely aligned to nature awareness. When taking a picture of a plant a player must consider their relation to an individual plant more directly and in a way that is unlikely to be exactly the same way every time (as opposed to the repetitive placement of plant assets in a uniform grid). The information they receive about the plant may also be made more unique by time-stamping the date that they took the picture and additional contextual information such as the etymology of the plant's scientific name and additional trivia.

Motivations of achievement-completion, as identified by the Quantic Foundry model of player motivation (Yee, 2015) are strong incentives to play in popular resource management games such as those mentioned above as well as games for smart device platforms that integrate a real camera such as *Pokémon Go*. However, as mentioned above, the framing of the game may reduce plants to nothing more than collectable 'QR codes' in the eyes of players who may quickly forget the semantic nature of the game in favour of focusing on collection for its own sake. This is a criticism sometimes jokingly levied at the *Pokémon* franchise. Ostensibly one is meant to train and care for their Pokémon but the nature in which players capture and store unused Pokémon, coupled with the series' slogan "Gotta catch 'em all", leads to a grim utilitarianism that leads people to churn through and discard Pokémon in a dispassionate simulation of artificial selection. The same dispassion may be a risk for games that aim to give the player a mutually beneficial relationship with non-human organisms such as plants. There are also the risks associated with augmented reality games such as *Pokémon Go* (e.g. trespassing, sudden crowding of public spaces) (Koster, 2017).

The initial success of the integration of the camera is encouraging though and suggests there is something that should be focused on given that most novice players will know how to use a smart device to take a picture. This level of simplicity would be useful in terms of engaging with a broad audience and in a more direct way

in the same way that *Pokémon Go* or Geocaching (Geocaching.com, 2000) have become popular.

The Effect on Long-Term Nature Awareness

Another important question is how the approaches taken here could be developed to change nature awareness in the long-term. The long-term could be considered either as the total duration of playing the game over time (i.e. if the game was publicly available, would nature awareness be changed in the playing population over the time they played it). Or, it could be considered as the general potential for the game (or similar games) to change a player's nature awareness over the course of their life e.g. from childhood to adulthood.

Conclusion

The answer to the research question of this paper 'how could a game for smart devices effectively promote short-term nature awareness for a general audience?' is uncertain. There are several potential paths to promoting short-term nature awareness in a general audience that have presented themselves.

In summary, it is difficult to make general conclusions based on the amount of data we collected however there were several useful findings that came out of the research. Ideally we would have liked to test the game on a larger population of players since this is the primary target audience for promoting nature awareness and preventing plant blindness. However, the most positive response to the project was from children. Although this is not conclusively indicative of a change in the children's short-term nature awareness it does help us describe what might be appealing about future projects with the same goals.

Unexpectedly, taking pictures through the game's interface to interact with plants was generally considered a large factor in players' enjoyment. Although some players noted that they disliked the feature, this could be ascribed to the poor functionality of the feature at the time of testing. The feature was not as well-contextualised with the rest of the game as it could have been and there were numerous technical and legal questions surrounding the feasibility of the feature. However, despite the problems it poses to development, it was felt by the team that this feature was one way in which the game showed the most promise as it guided players' attention toward real plants in their immediate environment and offered a lot of potential for cultivating learning about plants via an integrated codex.

The playtesting analysis showed that the game, in its current state, was not effective at educating players about processes related to plant biology. Instead the game, possibly due to genre expectations, was understood as a basic simulation of gardening which, despite the principles of cellular automata, may have been too simplistic to generate deep engagement with procedural rhetoric associated with nature awareness.

It is clear that this area of research is ripe for investigation along numerous lines of enquiry. The integration of fiction, cultivation of expectations about the game, development of systems to encourage direct interaction with plantlife (such as the camera integration), and the potential for satire are all possible avenues of study.

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