Benni's Forest – a serious game on the challenges of reforestation

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Fig. 1: The serious game *Benni's Forest* faces you with the main challenges of managing your own reforestation project.

***Abstract*—Many people think of reforestation projects as one-dimensional, simply consisting of planting trees. In reality, a reforestation project takes into account a wide variety of factors, of which the three most important are *improving soil quality*, *reducing fire hazard*, and *ensuring the prosperity of the community*. We posit that a simplistic view on such projects is detrimental for a more committed and serious societal awareness and support of sustainable reforestation. Therefore, it is desirable that more people have a better understanding of the interplay of these factors, as they will likely become more involved in reforestation projects. We present *Benni's Forest*, a serious game aimed at increasing awareness of the challenges of reforestation projects. *Benni's Forest* is a simulation game, in which the player is responsible for a reforestation project, balancing its various factors over the years, deciding on *what* to do *when* and *where* on the terrain, e.g. fertilizing, planting trees, or digging fire ditches. Meanwhile, adverse events, like wildfires or illegal logging, threaten your progress, creating a tension that gives the player a vivid experience of the complexity of the project. As you progress, several scores indicate the quality of your performance, most notably a biodiversity score, representing the amount and variety of trees in the forest. In this way, players receive clear hints to strategize and face each situation with the appropriate measures to grow a biodiverse forest. We evaluated *Benni's Forest* conducting a survey amongst players. The results confirm both an increased understanding of the challenges involved in reforestation efforts, and an increased sense of engagement of players with such projects.**

***Index Terms*—Serious games, Games for change, Sustainable development, Reforestation, Rainforest**

I. Introduction

Biodiversity worldwide is declining, and that is partly due to the deforestation of rainforests. Biodiversity is important to humans for many reasons: economic, ecological life support, recreational, cultural and scientific [1]. Around 1 million animal and plant species are threatened with extinction within the next decade if nothing changes [2]. Next to containing deforestation, reforestation projects play an important role in safeguarding worldwide biodiversity.

Reforestation projects involve a huge amount of effort. Their success strongly depends on weather, pests and weeds, as well as on continuous maintenance. Proper reforestation could easily take more than 100 years if no humans were steering and helping it [3].

There are many factors that add up to the complexity of reforestation processes. For example, a local community can be tempted to plant a single, non-diverse tree species for quick money, but that will not prevent biodiversity from declining. Moreover, fire prevention measures need to be taken, because of the high fire risks in and around the forest. Prior forest fires usually leave the ground unfertilized and exhausted. Re-fertilization of the ground is then necessary, which also takes some time.

Because this is a global problem, it is crucial to increase its worldwide comprehension and awareness. People from all over the world will benefit from healthy rainforests, even without them realizing it. To get more people involved in reforestation projects, they need to better understand these difficulties [4]. This can be achieved by using advertisements, presentations at schools and businesses, on-site visits to rainforests, etc. By exposing people to their complex challenges, rainforests might become a more important topic in people's lives, and some might be moved to invest in supporting reforestation projects.

Games often challenge players by immersing them in all sorts of simulated situations, e.g. to attempt changing their attitude [5], [6], or to raise understanding for complex prob-

lems [7], [8]. We therefore posit that a serious game in which players take on the manager role of a reforestation project, can be an effective way of increasing their awareness of the complex factors considered in such projects. This leads us to the following research question: *How can a game improve the awareness and engagement of a player regarding reforestation projects?*

To answer this question, we designed and developed *Benni's Forest*, a management game in which the player is in charge of decision making in a reforestation project, aimed at achieving a healthy rainforest within a few years; see Figure 1. Among other tasks, the player has to fertilize the ground, decide where and when to plant which tree species, and take fire prevention measures.

To further focus our answer, we sought the advice of an NGO specifically dedicated to reforestation projects: Masarang Foundation[1]. Eventually, we decided to center our target group on potential donors for the the foundation activities: a group of (young) professionals typically keen on managing, with some financial means, and scarce time. This specific motivation and context was instrumental for some of our design choices, as described in Section III.

II. Related Work

This section surveys relevant research work related to both reforestation and serious games.

A. Reforestation

Reforestation has been extensively studied, regarding both its intrinsic necessity and its successes and failures. Stanturf et al. mention three approaches to reforestation [9]:

- The process of returning any kind of forest cover, to increase either economic productivity or carbon storage. This kind of reforestation is satisfied with planting a chosen monoculture that grows fast and densely, and is not concerned with diversity in flora and fauna.
- The process of returning the forest to the state it was before there was a disturbance event. This kind of reforestation is focused on planting as many native trees as possible. Completely returning to this state can take many years.
- The third approach is taking aspects of the two previous processes to create a biodiverse forest with some economical output and most of the original species, but also introducing exotic species that may be more suitable than the original species.

Which approach to take is dependent on both environmental and social aspects. If an area can regenerate naturally, the cost of restoration is low, although the costs of protecting these areas may be significant. If there are remnant patches of natural forests that need to be protected, buffer strips should be planted around them to protect them from further disturbances, enlarge their effective areas and soften the edge effects (the highest priority is given to remnants with endangered or vulnerable species). Similarly, if there are remnant patches of natural forests with roaming fauna, there should be corridors planted between them to facilitate movement of species and genetic exchange between isolated populations. Forest corridors can facilitate animal migration as a response to climate change. Forests can stabilize steep erosion-prone soils. Moreover, the ground areas between land and river protect erosion-prone soil, act as filters to limit sediments reaching waterways, and can act as corridors for species movement. Areas subject to sheet erosion and with compacted soils should be reforested to reduce erosion and increase filtration capacity. In areas prone to salination, this can recharge groundwater by increasing evapotranspiration, thereby increasing the depth of the water table and decreasing salinity problems. Coastal protection zones can be planted to decrease storm impact. Finally, in urban areas forests improve recreational opportunities.

A difficult aspect of doing reforestation correctly regards how the results are analyzed. Since most reforestation is funded by foreign donors, results are narrowly based on criteria set by the funding agency. These criteria are usually metrics associated with ensuring that the funding has been applied in the manner intended rather than trying to achieve broader, longer-term outcomes. These funding goals set are often focused on simple criteria, such as planted area and initial tree survival, and generally focused on the short-term stages of projects. However, it is at least as important to highlight the long-term effects of reforestation, to gain a better view of the profits of the reforestation [10].

It is difficult to guarantee the success of a reforestation project. Several stages need to be carefully planned to grow a healthy, diverse forest that can sustain itself. Goals and multiple stages must be defined and both the short- as well as long-term results need to be considered [10].

B. Serious games

Serious games are games with other purposes beyond entertainment, such as education, health, persuasion, etc. Serious games are a good medium to educate and inform people about a certain topic. One study compared four different teaching mediums (text, video of the game, the game itself, and a hypertext version of the game) and found that interactivity is a critical factor in media-based learning. They concluded that even though initially most people saw games unfit as a learning medium, it had the most positive effect on knowledge gain, interest in topic, enjoyment, and self-reported learning [11]. Therefore, serious games are often very suitable for informative purposes, for example when one intends to arouse players' interest in a certain topic while providing an entertaining experience.

There have been various serious games made with the goal of informing players about environmental issues, often trying to change their attitude or view on a certain topic. Examples of this are *Veganity, your journey*, proposing players to consider more sustainable diets for environmental reasons [12], *Reto Global*, a game made for a museum exhibition to support climate change awareness [13], and *Hydro Hero*, also made for

[1] https://https://masarang.eu/

a museum, to educate children on the environmental relevance of water maintenance [14].

Several games have also been proposed to inform and educate people on the topic of reforestation, each with different purposes and tackling different environmental topics. Madani K. et al. surveyed serious games on environmental management. Of the analyzed games, environmental education only covered (8%) of the researched games [15]. Another study analyzed 31 different environmental games, of which only 3 games (less than 10%) were about environmental forest protection, and none directly about reforestation [16]. There is, therefore, ample room to use serious games to inform and educate people about issues such as reforestation in an environmental context.

Several common pitfalls have been identified that game designers should take into account, expressly in environmental topics [17]. The most important regards focusing too much on the environment-only perspective, and failing to properly address the economic and financial advantages of environmental conservation. A game should provide an accurate representation of reality, while at the same time highlighting the advantages environmental conservation projects have. For example, not only is there a biodiverse forest that is inhabited by many animals and improves the overall health of the soil surrounding the area, but produce grown from the trees also gives the local community an economic advantage.

III. Game Design

This section summarizes the rationale behind the main design choices of *Benni's Forest*, including its core mechanics.

A. Main design principles

Accessibility and strategy are the principles overarching the design of the game. Keeping the game as low-threshold and accessible as possible will keep players engaged as they progress through the game, allowing it to optimally reach the intended audience. At the same time, by stimulating decision-making and forming a strategy, the player engages with the key elements of successful reforestation. To clearly identify and properly integrate these elements in the game, we were quite fortunate to count on the expert advice of Masarang Foundation staff.

Because the ultimate purpose is to make people aware of the challenges of reforestation projects, the game places players at the manager role: they can use their own ideas and personal vision of reforestation to play the game, and whenever they fall short in some manner, they will perceive that through a variety of logical consequences. The variety of possible actions available requires players to devise a strategy, and in this process, they improve their comprehension of the overall reforestation objectives. For example, if a player thinks they can just plant trees without properly preparing the ground, it will quickly become clear that trees will not grow on infertile soil, and that this aspect needs consideration in their strategy. Likewise, when a player does not invest in fire ditches or fire-resistant trees, the chance of bog patches of the forest burning down increases, and the player might need to start over again. Moreover, when the importance of prosperity for the local community is neglected, the local community might cut down part of the forest for their own profit.

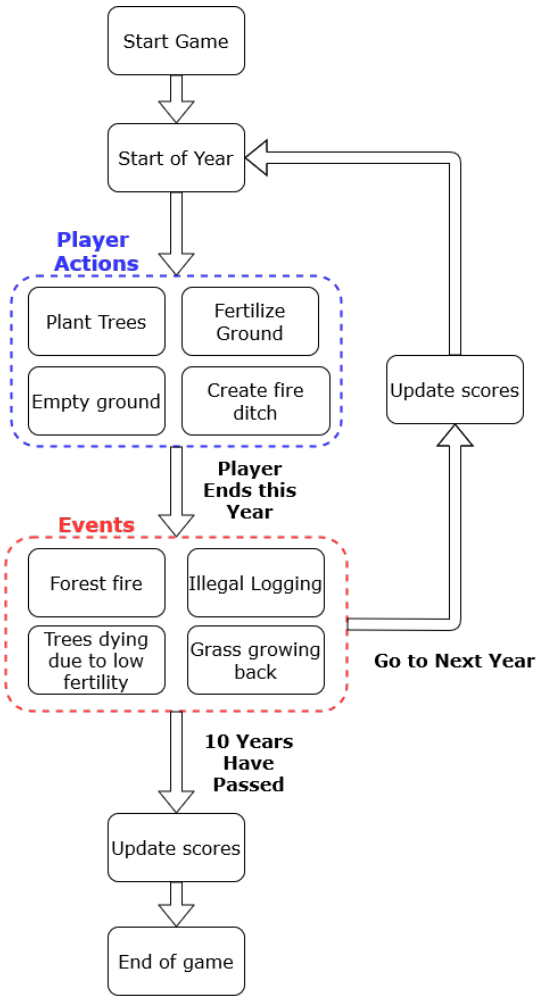


Fig. 2: The main game loop.

The game offers players a God-view over the entire world, allowing them to have an overview of the forest and, therefore, of the impact of their decisions. In our experience, if players directly see whether their actions have a positive or negative impact on the environment, they will better realize what they should (not) do to create a healthy rainforest.

The game was made turn-based, with a turn representing one year, to mimic the cycle of seasons, which strongly determines reforestation projects. In addition, this allows players, who may vary wildly, to play at their own pace, taking their time to choose and implement their strategy over the years. In this way, we believe *Benni's Forest* is made more accessible and can better serve its varied target audience.

B. Game Synopsis

Benni's Forest is a management game aimed at raising awareness about reforestation. It is set in the land surrounding Temboan Beach, in Indonesia, with the goal of regrowing an

area of the local forest, called Benni's Forest. The player is a project manager, aiming at restoring the land to a healthy and biodiverse rainforest. For this, the player has to make a variety of choices to steer the reforestation process. First of all, the biodiversity needs to be increased, which can be done by choosing from the four types of trees available to plant, each having different effects. Secondly, the player has to keep in mind the chance of forest fires: though they cannot always be prevented, the player can limit the extent of fire spreading. Thirdly, the player has to keep in mind the welfare of the local communities surrounding the forest, else they might disregard the reforestation efforts and start logging the forest.

C. Game mechanics

The main game loop is depicted in Figure 2, also indicating the basic game mechanics of *Benni's Forest*. For each year cycle, the player can execute a variety of actions. Players have a limited budget to spend each year. By limiting the amount of resources per turn, the game presents a realistic facet of the real world: only a limited amount of work can be done in one year.

When a year passes, a number of events that took place can be reported, thus simulating rainforest occurrences in real life. The player has a total of 10 years to restore Temboan Beach. In the real world it likely takes a little bit longer, but having too many years has the risk of boring the player.

1) Player Actions: A player can execute 4 types of actions:

- Plant trees: one of four different tree species.
- Create a fire ditch: prevent forest fires from spreading.
- Empty ground: remove grass, dead trees or tree stumps left behind from illegal logging, so that new trees can be planted.
- Fertilize ground: improve the quality of the soil, the soil has three levels of fertility; low, medium and high.

These actions are an approximation of what a reforestation project in real life entails. Mostly, the player will be left free regarding the order of actions, only two restrictions are put in place to sketch a realistic scenario: (i) you can only plant a tree on ground priorly made empty, and (ii) you cannot fertilize ground directly after a tree has been planted.

2) Tree species: There are four different tree species a player can plant. Each of them covers a distinctive function that trees in a rainforest serve in the real world. The three functions are prosperity, biodiversity and fire-resistance. The prosperity value (P) ranges from 0 to 2, where 0 is for trees that have no prosperity value and 2 for trees that add a lot of prosperity, biodiversity (B) ranges from 0 to 3. Fire-resistance (F) is indicated by a percentage, the higher the percentage the bigger the chance a tree will catching fire. These values are based on playtesting. The four tree species are:

- Sugar palms, which are good for prosperity, decent for biodiversity and significantly fire-resistant.
- Fruit trees, which are decent for prosperity, are good for biodiversity and catches fire quickly.
- Native trees, which are very good for biodiversity, do not add prosperity and catch fire quickly.
- Legumes, which fertilize the surrounding ground over by one level each year, are decent for biodiversity, do not add prosperity, and catch fire fairly quickly.

For the prosperity, biodiversity value and the chance of catching fire for each tree, see Table I.

Tree name	P	B	F
Sugar palms	2	1	20%
Fruit trees	1	2	80%
Native trees	0	3	80%
Legumes	0	1	60%

TABLE I: Parameter values of each tree species. P = prosperity value, B = biodiversity value, F = chance of catching fire

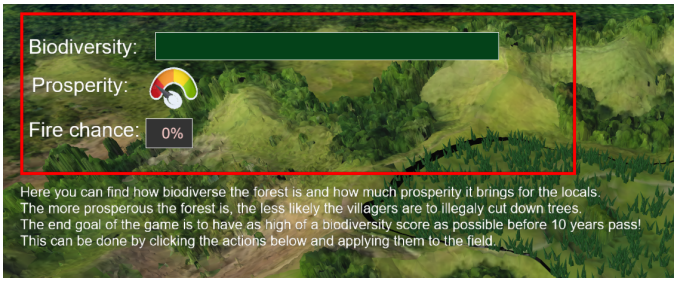
3) Events: To have the player experience some of the challenges of reforestation, four types of events can occur in the game which regularly also happen in real-world reforestation projects, and hinder them the most. The player needs to make the right decisions to either prevent these events from happening or at least to limit their damage:

- Forest fires: a forest fire spawns at a tile in the forest with the highest chance to catch fire and spreads to adjacent tiles. By placing fire ditches or planting fire-resistant trees, the player can prevent fire from destroying too much of the forest.
- Illegal logging: when the prosperity of the forest is low, locals may cut down trees to make a profit. If the forest is prosperous, the chance of this happening decreases, since the consistent income from the forest outweighs the one-time income from the logging.
- Tree death due to low fertilization: trees planted on infertile soil, have a small chance of surviving; fertilizing the ground increases that chance, eventually ensuring tree growth. Trees on ground with low fertility have a 20% chance to survive until the next year, medium fertility 40% and high fertility 100%, showing the player the importance of fertilizing ground.
- Grass growing back: in the real world, if land is unattended for a while weeds will grow back, hindering trees to grow there. In the game, when a piece of empty ground is left unattended for two years, grass will grow back.

The chance of forest fire increases each turn, balanced such that the player will always get one fire and can expect two, given by the formula below.

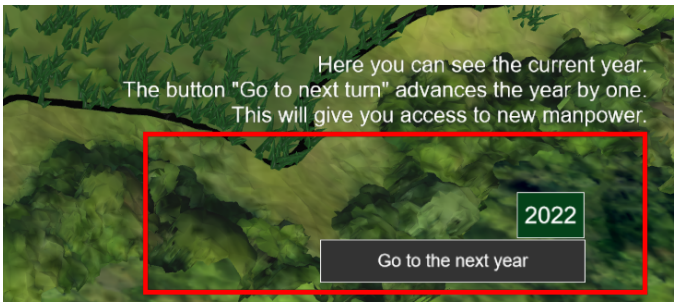
$$f = min(1, max(0, (t-2) * 0.3)) \quad (1)$$

f is the chance of a forest fire occuring and t is the number of turns without a fire. The first two turns are exempt from a forest fire because otherwise the player had no time to prevent them. To calculate the ilegal logging chance, the prosperity value of the forest is used. There is an expected prosperity value, which is the prosperity the local community expects from the forest and the actual prosperity value of the forest,



(a) The scoring area, with tutorial overlay

(b) The action area, with tutorial overlay



(c) The progress area, with tutorial overlay

Fig. 3: Various areas of the game interface.

the difference between those two values is used to calculate the ilegal logging chance. The exact formulas are shown below.

$$p_e = min(max(t-2,0)*6,40) \tag{2}$$

$$p_d = max(0, p_e - p) \tag{3}$$

$$l = \frac{p_d}{p_e} \tag{4}$$

p_e is the expected prosperity which takes into account t turns, p_d is whether there is any defficiency between p_e and prosperity p and l is the chance that a tree will be illegally cut down. The values determining p_e have been refined through playtesting to have a balanced playing experience. For example, the first two turns the game will not activate the event, after which the expected prosperity ramps up, giving the player a grace period to start a forest and avoiding confusion for if they would be punished with the event without having a chance to avoid it.

4) Scoring: To indicate how well the player is doing, there are two different scores being tracked and displayed:

- Biodiversity: the main score of the game; the goal of the player is to get it as high as possible.
- Prosperity: this score has 4 levels (very low, low, medium, and high), indicating the current economic value of the forest for the local communities.

The biodiversity score is based on the diversity value of the planted trees and on their age. Old trees are better for biodiversity than younger trees since they will create sunlight layers in the forest, ensuring different types of plants will grow. The formula is:

$$biodiversity\ score = \sum_{i=0}^{N} B_i \cdot \lceil \frac{A_i}{3} \rceil, \tag{5}$$

where N is the number of trees, B_i is the biodiversity score of tree i and A_i is the age of the tree. A total score above 80 is seen as a good biodiversity score. This value was balanced through playtesting so that it is reasonable to achieve a good biodiversity score in the amount of turns given.

The prosperity score is the sum of the prosperity of all planted trees. This prosperity score is used to update the Illegal logging chance as explained in *3) Events*. The formula for the prosperity value is given by

$$prosperity\ score = \frac{\sum_{i=0}^{N} P_i}{T}, \tag{6}$$

where N is the number of trees, P_i is the prosperity score of tree i and T is the total amount of tiles.

5) Game interface and graphic style: The game interface provides the player with the tools to interact with the game environment, and it consists of three main areas:

- Scoring area: displays the biodiversity and prosperity scores of the forest, as well as information over the fire chance (see Figure 3.a).
- Action area: presents the player with the choice of actions to select from, as well as the remaining manpower for the current year (see Figure 3.b).
- Progress area: displays the current year, and allows for year advancement (see Figure 3.c).

Benni's Forest takes place in a virtual version of Temboan Beach, an actual ongoing reforestation project. To give the player the feeling that they are actually reforesting Temboan Beach, the game provides a 3D view on the environment. We use a LIDAR scan of Temboan Beach[2], and define a virtual tile-based grid on top of it, that can be filled with trees, grass or fire ditches. This choice for world visualization seems very adequate for conveying how impactful the reforestation project can be on the landscape.

At the end of each year, a report will pop-up informing on the events that have taken place during that year. According to the different choices made by the player, these events can

[2]kindly provided by the Masarang Foundation

(a) The game world, after ignoring fire risks: a part of the forest has burned

(b) The game world, after neglecting community prosperity: multiple trees have been cut down

(c) The game world, after neglecting ground fertilization: planted trees die due to a lack of nutrients in the soil

Fig. 4: Various game world states, after adverse events have taken place.

largely vary, including forest fires (see Figure 4.a), illegal logging (see Figure 4.b), and trees dying due to low fertility (see Figure 4.c).

6) Implementation aspects: Benni's Forest is a web-based game since we wanted it to be easily accessible. It was implemented using Babylon.js, Webpack, and Typescript. Babylon.js is a web rendering engine for 3D worlds. It also has built-in functionality for animations and creating UI elements, making it a good framework for building this game. Babylon.js supports both JavaScript and TypeScript. We chose Typescript because it has better debugging tools and it does typechecking during compiling instead of runtime. Webpack is a module builder that combines our modules into one static file and minimizes it, which makes it more efficient and easier to host. The game can be played online, at https://bennisforest.gitlab.io/bennisforest/.

IV. Evaluation

A. Method

To evaluate how successfully *Benni's Forest* achieves its goal, a survey was linked on the score screen after a playthrough, asking the player to review their session.

In order to gather enough participants for the evaluation each author asked people in their personal network to playtest and fill in the survey. In total 21 players responded, necessarily having played the game in its entirety. Playtime was not recorded. This population consisted of people that are 18 years or older.

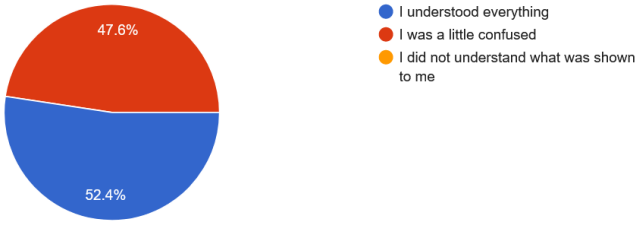
The survey assessed whether they:

1) had understood the complexity of reforestation in the game?
2) had learned something new about reforestation?
3) would be more likely to get involved in a reforestation project?

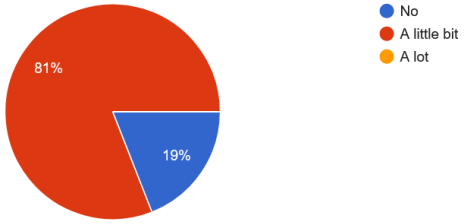
B. Results

The main results of the survey can be found in Figure 5. At the beginning of the game, 47.6% of the players were a little bit confused. This is partly natural, since most players did not know much about reforestation. However, at that moment the tutorial overlay was still lacking, which could also explain part of the confusion. In fact, participants indicated that an extra test round in the beginning would help with learning the basic game mechanics, including some better explanation of the fertility aspects.

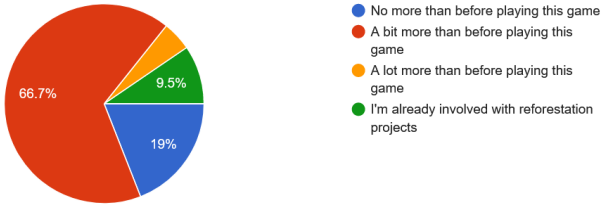
Most participants (81%) indicated that they had learned something new about reforestation. The most mentioned topic they learned about were (i) that some trees are fire resistant, and (ii) that ground fertility is important when planting trees. Participants also indicated that they underestimated how much planning reforestation requires. None of the participants indicated that they learned something about the importance of sectioning the forest with fire ditches, nor of the interplay between the forest and the prosperity of the local communities. Two thirds of the participants (66.7%) indicated they are a little bit more engaged with reforestation projects than before playing the game.



(a) "Did you understand the complexity of reforestation in the game?"



(b) "Did you learn something new about reforestation?"



(c) "How likely are you to get more involved in a reforestation project?"

Fig. 5: Main answers to the evaluation survey.

C. Discussion

The survey indicates that a majority of players did learn something about reforestation and that they are a bit more engaged with reforestation problems. They learned about multiple aspects of reforestation such as fertilization and the importance of biodiversity. However, it seems the game mechanics about 'forest prosperity preventing illegal logging' and 'grass growing back on abandoned parcels' did not work as convincing as biodiversity and fertility.

A main current limitation of *Benni's Forest* regards some lack of clarity and of explanation, about a few aspects of the game, e.g. the working of fertility. The forest fire mechanic also lacked some clarity, and it wasn't always clear where would the fire spawn. In some cases, players did not build fire ditches at all and hoped they would get 'lucky' and fire spawned far away from their trees. This limitation could be almost completely solved by creating a more comprehensive

and visually richer game tutorial, including e.g. voice and animations.

V. Conclusion

Our research question was: *How can a game improve the awareness and engagement of a player regarding reforestation projects?* We presented *Benni's Forest*, a serious game that we designed and developed expressly with this purpose. In this game, the player assumes a manager role in a reforestation project, and is commissioned with growing a healthy and biodiverse rainforest at Temboan Beach, in Indonesia. The chosen game mechanics requires the player to strategize and decide about a variety of actions, which are instrumental in any real-world reforestation project. By having players freely choose their actions, and learn by experience from the results of those choices, they acquire a deeper understanding of the ongoing processes, and potentially realize the worth of engaging in existing reforestation efforts.

From a preliminary game evaluation, we concluded that more than half of the participants learned new elements about reforestation, and that a large majority felt more engaged with reforestation projects than before. The importance of biodiversity and of fertility was among the aspects they learned the most about.

Benni's Forest gives players a valuable experience of what it is like to manage a reforestation project, with the complex challenges and real-world difficulties involved in such projects. In particular, players of *Benni's Forest* get a hands-on exposure to the most critical aspects of reforestation integrated in its game design, including fertility, fire hazard, local community, and pogon grass.

We can conclude that increasing their awareness, players of *Benni's Forest* realize both the complexity and the value involved in raising a rainforest. A better picture of the challenges of reforestation projects improves understanding of the work that needs to be done. Ultimately, we hope this can lead more people to an increased involvement and commitment in actual reforestation projects. Time will show the extent to which *Benni's Forest* can help Masarang Foundation increase their outreach and activities.

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