

EvoEnvi: A Collaborative Serious Game Played On An Interactive Table For Teaching Evolution Using Genetic Algorithms

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Abstract

This research is inspired by Boolean and Joolingen's (2013) Simsketch, specifically their simulation in regarding to evolution. The aim of this research is to create a game in order to induce collaboration amongst the players using an interactive table. In addition, the game's design needs to have an easy learning curve so that the players can focus more on the topic the game is trying to teach, rather than on learning how to play the game. Thus, we created a game called EvoEnvi, that is to be played on an interactive table. The game uses a genetic algorithm to simulate natural selection in a population of prey when being hunted by a population of predators. This research explores if EvoEnvi can increase collaboration between players, in addition to having easy to learn mechanics.

Six groups of two people participated in the experiment where an empirical evaluation was conducted. Two types of data were collected: the observation data, which concerns the participants' interactions with the table and each other and interviews.

From the data collected, EvoEnvi has been shown to have a positive influence on collaboration. In addition, the game itself is easy to understand and has potential to be used for collaborative learning in classrooms.

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1 Introduction

The aim of teachers and educational institutes is to find the ideal way to keep their students motivated and interested in a subject. They have to make sure students do not learn the wrong information and gain wrong ideas while keeping them motivated and engaged with the learning topic. The use of technology, games, and simulations in learning is one such attempt to achieve this. Technology is becoming more and more incorporated into the education system, and beside that educators are trying to come up with fun ways to pass on knowledge and increase motivation. Combining both technology and games has been an increasingly common approach to this. However, the challenge is to make sure that these approaches do not deviate from the subject and do not introduce any misconceptions. Misconceptions are ideas and pieces of knowledge that are incorrect, and can manifest if knowledge is presented in a wrong way and the student thinks about it in a wrong way.

Science is a big part of the school curriculum containing three major sections; physics, chemistry and biology. There are many subjects and approaches to teaching each of these three sections. Creating a simulation to try and address all the topics science covers would be nearly impossible since they are vastly different from one another, despite at times being interconnected. In addition, each topic has to be handled and taught in a different way that corresponds with the material. The question is how to approach teaching on a specific topic and accurately relaying that information to students. This research will focus on the subject of evolution.

Another important factor to know is that different students have different levels and speed of learning. While something might be hard for one student it might be easy for another (Vandewaetere et al. 2011). Therefore, it is important to allow the students to learn at their own pace and not pressure them. There has been development on adaptive technologies in respect to this, however this project will not be an adaptive technology. However, it does aim to allow students to think at their own pace, and come to their ideas with there being no pressure of getting it wrong or right.

In order to help with the process collaborative learning in the classroom has become more popular. Collaborative learning is when students work together and help each other learn through discussion and interacting with one another. Collaborative learning helps with critical thinking and can increase the retention of knowledge (Gokhale et al. 1995).

1.1 Motivation

Bollen and Joolingen (2013) created a program called Simsketch for simulating multiple scientific models, one of them being evolution. In this simulation the students can see how a prey evolves in colour to survive being hunted by the predator. However, the only interaction the players have with the simulation is in the initial stages before it begins. The player can draw their own species and environment before starting the simulation, once the simulation is started the player has no other interaction with it. While the simulation is pleasing to the eye due to its use of colours, it lacks interaction. Interaction in video games can increase motivation and engagement (Reid, 2012). The experiment by Reid aims to expand on this simulation and create a simulation that has more interactive options while it runs for the students to engage in.

In addition to making a simulation interactive, there is another factor that needs to be considered: misconceptions. When learning evolution, there are several common misconceptions that can occur with students (Abraham Joel et al. 2009). According to the paper the common misconceptions in evolution are:

1. that the animals will-fully evolve
2. the variation between individuals in a population is due to the environment
3. difference within a population of animals is due to environmental pressure
4. the change of traits happens to a population as a whole
5. changes to a phenotype to a parent are inherited genetically by an offspring
6. trait variation is caused by genetic drift
7. the chances of an individual surviving are dependent on physical strength
8. dominant alleles are always advantageous.

The above are the main problematic misconceptions that occur when a student is learning about evolution. However, not all of the listed will be taken into account, since they are beyond the scope of the simulation. These misconceptions include misconceptions number five, six, and eight. Five and eight deal with a more specific section of biology which is beyond the scope of the teaching material of these students. In addition to attempt to fix these misconceptions, the simulations would have to be more intricate and more in-depth than what is hoping to be an upgraded version of Simsketch. There will not be a focus on the DNA processes and how genetics is passed. Number six is also not being taken into consideration, since the project will be more focused on natural selection and mutation.

1.2 Research Question

Research in combining gamification and education has increased over recent years each subject is different in its own way and needs a different approach. The aim of this project is to create an collaborative game that deals with the concept of evolution. The questions it aims to discover is:

- Does the design of the game and interactive table encourage collaboration?
- Is the design of the game easy to understand, and does it provide information to the players?

1.3 Structure

In the next section, the report will discuss related work in regards to teaching evolution and gamification for learning. Then it will go onto explaining the core concepts for the simulation, these concepts include genetic algorithms and gamification. The method describes how the game is designed and why. Then the paper will discuss how the core concepts are implemented into the game. The empirical evaluation section will follow, in which we describe how the results were gathered using observation data and interviews. Afterwards, we will discuss the results obtained from the empirical evaluation. Lastly we conclude that the game did induce collaboration and had a simple playable design.

2 Related Work

2.1 Serious Games for Education

According to Yildirim (2017) a student's academic achievement is correlated with their attention, interest and motivation in learning a subject. Gamification is a solution to increase these three factors in order to increase the student's achievement.

"gamification of education can be defined as the transference of game design to the educational process for the purpose of increasing students attention and motivation and improve student achievement and attitudes toward lessons."
(Yildirim, 2017)

They test this out by gamifying the educational processes, such as adding a pointing system, badges, levels, experience points, puzzles and leader boards.

They show that the gamification of the classroom had a positive impact on student achievement along with their personal attitude towards the lessons.

The question is why gamification? Video games have a good reach and appeal to millions of people across the world, focused mostly on students (Mayo, 2009). The question that needs to be asked is; can video games be used as an effective tool for encouraging learning and can they be a successful learning tool? According to Mayo, yes they can. Not only are games fun, but they can adapt to the pace of the user. Different students learn at different rates; therefore, they can go at their own pace. Game based learning has a good potential to aid in the education of sciences, due to their highly interactive nature (Mayo, 2009).

In 2009, Annetta et al investigates the effect of a video game on genetics created by teachers for their students. The students were immersed in the game, and, therefore, the learning environment. Hence, the gaming environment increased their engagement in the learning material. The results they received showed that video games as a learning tool can be motivating and engaging for students of all ages. However, there was not a significant increase in the grades of the students.

The research also points out some disadvantages and problems that can occur within education games. One problem is that the game was created with a high learning curve, where the students spent more of their focus trying to learn how to play the game instead of focusing on the learning material. Despite these problems the paper states that more research needs to be done if such gamification can increase overall grades of the students.

When creating an education it is important to make sure that the game itself is easy to play so that students can focus on the learning topic. In addition the learning topic needs to be presenting in a way that increases engagement and has a positive affect on a students knowledge gain.

2.1.1 Feedback

Feedback is an important part of learning and education (Evans. 2013). Feedback is information given to the student in regards to their performance, actions and ideas in relation to the topic they are studying. It can clarify and give hints to how the student can improve. If they got a question wrong feedback can tell them why it's wrong and how they can fix it. According to Evans (2013) it can encourage a student's independent learning along with motivating the student to evaluate their knowledge and hence increase their own knowledge. However, the research also mentions that feedback needs to be presented in such a way that does not threaten the self confidence of the student, but instead gives information on how to improve and not just a negative response.

On that similar note, Graham et al (2011) also point out that students consider feedback to be poor if it is overly critical (negative) and has no guidance on how they can improve. If they receive no guidance they will not know how to improve and will not learn in the process. Therefore, good feedback has to facilitate learning and guide the student to better results.

2.2 Serious Games and Evolution

Abraham, Joel et al. (2009) state, even after given instructions, that students can still develop misconceptions about evolution. Therefore, traditional instruction is not enough to prevent them misconceptions from developing. They attempt to resolve this problem with their own game. In their game, the students play as a crab feasting on snails. They have to click on the snails to eat them; the number of clicks required is dependent on the thickness of the snail shell. The snails through simulated evolution will develop thicker shells, therefore being harder to kill. They proved that their simulation was able to decrease the occurrence of common misconceptions within the students and they also had a small increase of knowledge gain.

Figure 1: Simsketch Example (Bollen and Joolingen, 2013)



As mentioned earlier, the main motivation for this project was SimSketch (Bollen and Joolingen, 2013). SimSketch (Figure 1) is a drawing-based education program for primary and secondary education. It has several different simulations, including traffic, cogwheels and evolution. Each one allows the user to draw the environment where the simulation will occur. In the evolution simulation, the user has to draw the prey, background and predator. The background can be several different colours if the user decides to or just be composed

of one colour. Before they can begin the simulation, they also have to select the correct labels for the prey and predators they draw on the scene. Once this is completed, the simulation can be played. The predators and prey travel around the screen on the environment, once the simulation is played. The prey will start to multiply with the mutation of colour changing. Each new individual has a new colour on the screen. The predator hunts the prey using its eyesight. This means it will eat the prey that is most noticeable in colour compared to the environment. Once the simulation has run for a time the prey should be almost invisible on the terrain.

This project will expand on this simulation idea. It will use the colour changing aspect along with some other features. What will also be added are more interactive options. so that the player has more to do then draw the scene.

2.3 Evolution Games

Unlike the previously mentioned games and simulations there are some games that were not built for education purposes but do deal with the topic of evolution. Some of these games have been considered by some teachers to aid in teaching despite not being made for this.

2.3.1 Spore

One such game that had its game-play based on evolution is the game Spore (by EA games). In this game the player starts of with a small simple cell creature in the water and has to eat food, meat or plants (depending if it's a carnivore herbivore or omnivore). By eating food you collect DNA points which allows you to 'evolve' your character through mating. The evolving processes takes you in a character creation screen in the game where you can add certain elements to your species, such as a different mouth, spikes, fins and so on. These things you can add help you navigate in your world and survive. There are 5 stages in the game, the cell stage, creature stage, tribal stage, civilisation stage and the space stage. The first two stages (cell and creature) are the ones mostly focused on evolution of the players creature. At the end of each phase the game shows you the development and evolution of your creature through its life.

Figure 2: Spore (Maxis 2008)



This game has been considered by some educators to be used for teaching evolution to children. (Bean et al, 2010) The game was considered for this due to several of its attributes. One such attribute is that the game allows the player to place themselves in an active learning situation within the games world, giving the player control and freedom of creativity.(Oliveira et al. 2018) However this game can introduce a various number of evolutionary misconceptions to children. One such problem of spore is that the player chooses the mutations themselves and can choose when they occur within their creature, which in evolution occurs at random and is not controlled. According to Bean et al. it is not an accurate scientific representation of mutation. While spore can induce interest in the topic of evolution and introduce the basic concepts teachers need to take great care if and when using it as a teaching tool in order to avoid misconceptions.

2.3.2 Niche

Recently a game called 'Niche' has been released, or it's full name 'Niche - a genetics survival game'.

In this game you are in charge of a populations of a species called nichelings and the aim of the game is to explore the different islands along with breeding, in order to get a population that can survive. In the user interface the player can view the genetics of each individual niche and how it helps them survive. For example, inheriting big ears allows them to cool of quicker and therefor they can survive higher temperatures.

Figure 3: Niche (Stray Fawn Studio 2017)



Unlike with spore, this game deals with a more in depth concept of inheritance using alleles and dominance, co-dominance and so forth. The option of mutation is available, however, unlike in Spore you can choose two mutations for each individual that can occur in their offspring. This does not mean that the mutation will definitely occur, only that there is a chance. The choice of what mutation occurs is still a slight deviation from how mutation works in the real world. Unfortunately, the fact that this game is still new there are currently no existing researches about it and how it can affect the player's thoughts on evolution. However, there might be some potential within the game.

From personal experience the game might be too complex for younger ages, due to its learning curve. There are a lot of factors needed to take into consideration with every decision you make. However, it is a fun game that may increase interest in evolution. In addition, unlike previously mentioned simulations and games this game takes a more in depth look at how genetics work. While this project will not focus on genetics it is still a fairly interesting game to look into.

2.4 Collaborative Learning

For teaching, both collaborative and competitive learning can be beneficial for the student's learning. (Plaas et al. 2013) However, collaborative learning seems to have a more positive affect on students in comparison to competitive learning. According to Gurnee et al (1968), students found collaborative learning to be more pleasant then competitive. In general when it comes to teaching and learning collaborative learning is preferred. (Laal et al, 2013)

In comparison to competitive learning, collaborative learning has shown to

be more effective with students increasing their productivity. (Laal et al. 2012) According to the same research it was also better for the social lives since with collaborative learning people form supportive relationships. This is because, with collaborative learning the students support and help each other with ideas and reasoning while with competitive they work against each other. This is why this research aims to create a collaborative game instead of a competitive one.

Collaborative learning is a beneficial learning tactic because it can increase critical thinking and enhance problem solving skills. (Gokhale et al. 1995)

"collaborative learning fosters the development of critical thinking through discussion, clarification of ideas, and evaluation of others' ideas" (Gokhale et al. 1995)

Collaborative learning has also shown that it is able to motivate students to take a more active role in their learning experience compared to when working alone. (Laal et al. 2012) Laal et al list that Collaborative learning also has social and psychological benefits. The social benefits are that students develop a social support group for learning with a positive atmosphere. In addition, the collaborative learning can increase self esteem along with reducing anxiety.

2.5 Interactive Tables

One such way of inducing collaborative learning is the use of interactive tables. Interactive tables are one of the central focuses of research for collaborative learning (Wigdor et al. 2006). Combining technology and learning in most cases deals with one person with one computer and individual work. While with an interactive table, the information and activity can be presented to a group as a whole as Wigdor et al explain. A shared display such as the interactive table can help students interact with each other in a natural manner (Bachour et al. 2010). Buisine et al, also states that the spatial configuration of the interactive table can encourage communication along with increase motivation. The broad surface of the table creates an environment where students can socialise and discuss ideas, it even decreases social loafing. (Buisine et al. 2012). Social loafing is when one student contributes less to the discussion or group work due to other students doing most of the work. The interactive table has also shown that it decreases social loafing within groups and increases participation within students. (Buisine et al. 2012) Buisine claims that the novelty of the technology and the attractiveness of it increases motivation within the students and therefore, increases participation.

Interactive table's are a promising direction when it comes to increasing collaboration and motivation in learning. That is why this research will be using an interactive table.

3 Core Concepts

3.1 Evolutionary Computation

Evolutionary computation is a section of computer science that is a collection of algorithms that were inspired by the biological processes of evolution. These algorithms are used for modelling other aspects in the world such as business and economy. The algorithms work with a given initial population of n items within an environment with limited resources and/or competition. The fitness value is part of evolutionary computation and it is attached to each of the n individuals of the population. This value is affected by the resources/competition in the environment. It determines which individuals will survive and pass on their characteristics, and which will die. The ones that survive create a new generation that contains the surviving characteristics. The paper will mostly make use of the genetic algorithm.

3.2 Genetic Algorithms

Evolutionary computation was inspired by the overall concept of evolution, while the genetic algorithm was more specifically inspired by the process of natural selection (mutation, crossover and selection) which is the focus of this paper (Eiben et al. 2015).

A genetic algorithm consists of 6 steps; initialisation, evaluation, selection, crossover, mutation, and repetition. Each one of this will be further discussed in the coming sections.

Here is the pseudo code of a genetic algorithm that explains how the 6 steps work together:

```
Initialise n population;  
Evaluate fitness value of each n individuals;  
while Termination condition is false do  
    | Select parents to produce offspring;  
    | Crossover genetics from parents;  
    | if Mutation occurs then  
    | | Mutation Occurs in Child;  
    | end  
    | Evaluate each new child;  
    | Generate new population ;  
end
```

Algorithm 1: Genetic Algorithm Pseudo Code

This whole algorithm repeats itself over from the evaluation step on-wards for the different individuals/generations.

It is the most widely known technique of evolutionary computation because it is a simple model and not overly complex. The advantage of a Genetic Algorithm is that it does not get stuck in a local optima. Local optima, in mathematics is called the best possible solution to a problem. In the case of evolution not getting stuck in local optima is beneficial because when it comes to natural selection there is not such thing as the perfect solution.

3.2.1 Initialisation

The initialisation phase occurs at the start of the program, it serves to create the initial population that will be handled within the algorithm.

3.2.2 Evaluation

This phase deals with the fitness value of each individual of the population. It evaluates each individual's fitness level to be used further on in the algorithm. This is an important part of the algorithm since the fitness value is what determines what occurs in the next steps.

3.2.3 Selection

The fitness value is passed onto the selection phase to separate the individuals of a population depending on whether or not they will continue to exist or be destroyed. It will also select which of the individuals will produce the offspring. These two different selection methods are called **Survivor Selection** and **Parent Selection**.

Parent Selection is dependent on probabilities. Individuals with a better fitness value have a higher chance of producing a child than the individuals with a worse fitness value. The reason for making even the 'worst' of the population able to breed is to prevent the algorithm from getting stuck in the local optima.

Survivor Selection occurs when a new individual is created. A genetic algorithm works with deciding and choosing which individuals will make up the different generation dependent on the individual fitness value. This selection will in most cases choose the individuals with a better scoring fitness value.

3.2.4 Crossover

Crossover (also known as recombination), is the part of the algorithm that takes the information that can be passed on to the child from both parents. It can create multiple offspring with different combinations of information derived from the parents. Deciding which part of information is inherited from which parent is done using probabilities and will always occur. Therefore children can both inherit 'bad' or 'good' characteristics from parents. This means that just because the parents have a good chance of survival it does not mean that the child will inherit the best characteristics and have a high survival rate like the parents.

3.2.5 Mutation

Mutation, unlike the previous phase, does not always occur, but has a chance of occurring within each child during their creation. It modifies one or more of the characteristics passed on from the parent. It can occur in random moments and whether or not it occurs is unbiased. The reason for having mutation in a genetic algorithm is to provide the population with 'fresh blood' as Eiben and Smith phrase it.

3.3 Gamification

Gamification is the use of game elements in other activities. One example of this is gamifying learning materials by introducing competition between students or a pointing system with rewards. Gamification is more commonly known as a reward-based system (Nicholson. 2015). However, reward based systems are mostly useful for short-term changes and are not as useful in the long term. If the goal is to affect someone in the long term with gamification, using a purely reward-based system can even be damaging. Nicholson creates a recipe to create *Meaningful Gamification*:

- Play
- Exposition
- Choice
- Information
- Engagement
- Reflection

Play is the freedom of the user to explore and fail within a set context.

Exposition is the act of creating a world or story where the users have the feeling of control over the world they are in or story.

Choice is act of giving the user (player) power over the system they are engaging with. This will cause the user to have a positive sense of self being along with feeling more empowered and therefor more engaged with a system.

Information is the idea of allowing the user to learn about the real world using the system and come up with their own conclusions. This is because the user will have a more positive mental outlook on what they were doing since they were able to achieve something. In this case gain knowledge.

Engagement is used to encourage users to participate in the activity that is gamified. This is important due to the fact that the users will have a more positive sense of thinking when they feel connected to the system.

Reflection is the part of gamification that encourages the user to think about what they saw in the system and possible connect it to past knowledge/experiences. It is one of the more powerful tools in gamification that can leave an influence on the user after use.

4 Method

4.1 The Game: EvoEnvi

This simulation will focus on presenting the interaction between a population of prey and a population predators in an environment. This is inspired by the SimSketch environment. The game will consist of a prey and a predator population, the predator population will affect how the prey population evolves over time.

4.1.1 Prey

The population of prey in the simulation is the population that will be used by the genetic algorithm. At the start of the simulation there are n individual prey, however this number will change due to the genetic algorithm killing some individuals while having others reproduce. Each prey has three attributes that affect how they look and move within the environment. These three attributes are colour, size and speed. The individual prey differ from each other as a result of these three attributes. Each individual also moves around the terrain, this

movement is affected by their speed, otherwise the pattern is random so that they spread out across the environment.

The model of the prey will be in the shape of a rabbit for this version of the game, the reason it is given a specific model is to make the environment more realist and playful looking. The choice of rabbit is because it is a well known animal.

4.1.2 Predator

The predator population m will stay constant throughout the simulation since they will not be used by the genetic algorithm. This is because the player's interaction will influence the predator population behaviour and we wanted to the game to focus on the evolution of the prey.

The main role of the predator is to hunt the prey in the environment. As in the real world, predators target the weakest prey to hunt and kill. How they hunt is influenced by the player's choices. There are three hunting methods that the player can choose. The three methods; vision, speed, and strength. The player can only choose to use one hunting method at a time for a hunt cycle, so combining hunting methods is not possible in this simulation. The reason for this is because we want to make the changes obvious per hunting method, in addition it would have been to complex and time consuming to make combining methods work with the current system.

How the predators move around the environment is dependent on whether or not they are in a hunting cycle. While hunting, they will 'chase' the prey and on contact the prey will die. If there is no hunt cycle in progress, the predator will walk around the environment until the hunt cycle is triggered.

4.1.3 Food Source: Bushes

The environment also contains a food source for the prey, bushes. The reason bushes were incorporated into the game was to control the population count of the prey. When testing the genetic algorithm in the game, two situations would occur. Either the prey would over population or they would die out. The first attempted solution to this was to add an age limit to the prey, where they would die after a certain amount of time. However, this solution did not fix the issue and therefore bushes were incorporated.

The population size depends on the amount of bushes in the environment. There are two limits dependent on the number of bushes, the minimum number of prey individuals and the maximum number. If the prey population is below the minimum limit it triggers mating season, which makes the prey reproduce and

increase the size of the population until it reaches the maximum limit. If the prey population is above the maximum limit, starvation occurs where the prey slowly dies out until the population number is below the maximum limit. This is because if there are more bushes there is more food to support a larger population of prey. However if there is less food, the population can not feed itself and therefore some prey individuals will die of starvation. The prey that will die first are the large ones, since the larger prey need more food to survive than the smaller ones.

The maximum limit is calculated by the number of bushes multiplied by five. The minimum was the maximum limit take away four. This gave a small range for the population number to vary without the risk of over population or the population dying out.

The players can control the amount of bushes the environment can have, this was added to allow the player more control and add another interactive aspect to the game. However there is a minimum and maximum amount of bushes the player can have in the environment. The reason for these limits is to prevent the players from over populating the environment or from the prey from dying out.

The age limit was also removed because there was a chance that the time limit might pressure players into making quick decisions and we want to allow students to think at their own pace.

4.1.4 The Environment

The environment is the area in which the prey and predator will interact on. The player can alter how the environment looks by changing its colour. They can do this as long as there is no Hunting Cycle in progress.

The secondary role of the environment is to provide camouflage for the prey. If the predator is hunting using their vision prey that blend into the environment will survive. In other words, prey that has more similar in colour to the environment will survive. The reason the player can change colour is so that they have more control over the environment. In addition to that it makes the game more colourful and playful.

The environment spans across the whole screen, it was designed this way so that the players can have a large area to look at along with giving the prey and predators enough room to interact.

4.1.5 Life Cycle: Prey

The life cycle of a single prey starts at either the beginning of the game or at the prey's birth. While the prey is alive it can go through several processes. It's fitness is evaluated when it is born and at the start of a hunt cycle, this evaluation depends on the hunting method. Once the predators are done hunted, in other words once the targeted prey is killed, mating season begins. During this the surviving prey are paired up to produce offspring. If a specific individual has already bred during the hunt cycle they will not breed again during that mating season. This is done to prevent from having one individual parenting most of the new generation. Mating season can also occur when a bush is added, as described earlier.

The prey can die in two different way either by being hunted by the predator or due to starvation from lack of food.

From here on-wards, the population of prey will also be referred to as rabbits since that is the model being used for them. In addition the population of predators can be refereed to as wolves.

4.1.6 Hunting Cycle

The Hunting Cycle is where the genetic algorithm is used, because it selects individual prey to be hunted depending on their fitness level and then after selects individuals to produce offspring for the next generation. Per hunting cycle each wolf eats two rabbits, this was done in order to prevent the wolves from eating too many of the rabbits or too little which would impact how fast the population evolves over time.

To begin the Hunting Cycle the players must first select a hunting method from the three options; speed, strength and eyesight. From Bollen and Joolingen's SimSketch, we use the idea of the prey population being hunted depending on their colour and the environment. However, the two extra attributes and hunting methods were added so that the game can present a wider variety of options to the player and add diversity to the game.

Once the hunting method is selected, the player can trigger the Hunting Cycle by pressing the button '*Hunt*'. During this cycle the prey are hunted and killed by the predators. Once the predators are done hunting, it checks the population number compared to the amount of food available in the environment. In all cases there will be more then enough food for the prey and this will trigger mating season, however the check is still there in case by some chance the population is over the limit.

```

Initialise  $n$  population of prey,  $p$  population of predator;
Evaluate the fitness value of each  $n$  individuals dependent the hunting
method;
while  $p \neq 0$  prey available for hunt do
|  $p$  chases prey;
end
breeding season occurs;

```

Algorithm 2: Hunt Cycle Pseudo Code

During this cycles the buttons are inactive because the player should be paying attention to what is occurring in the environment. It also prevents too many events from occurring in the environment, since it might present too much information to the player and we want them to focus on what occurring during each hunting cycle.

4.1.7 Mating Season

There are two instances where mating season can occur; During the hunting cycle and when adding bushes.

The amount of pairs selected for a mating season is dependent on; how much more prey the number of bushes can support and the number of offspring per couple. A pair of rabbits can have from one to three children, because it adds variance to family sizes. While in nature rabbits can have up to fourteen babies, this number is too large to implement into the game, since it would cause over population. Through testing we found that varying the number between one and three babies caused enough variety in the game without over populating the environment.

Each offspring inherits the three attributes from either parent (Discussed in more depth in the Genetic Algorithm Alterations section).

During mating season the player cannot start a hunting cycle or add/remove any bushes. This is because we want to avoid having too many events occurring in the environment which might cause players to be overloaded with information.

4.1.8 Interaction: Prey and Predator

This section will describe how the above will come together. The main interaction is between the prey and the predator. This is affected by the hunting method, chosen by the player. For each of the three hunting methods there is a corresponding prey attribute the wolf hunts by. If the predator hunts using their eyesight, the prey they hunt depends on how much an individual prey's colour

differs from the environment colour. They will hunt the prey that is the least camouflaged. If the predators are hunting using their speed they will target the slowest prey, since they will be easier to catch than the faster prey. Lastly, the strength method corresponds to the size of prey. The bigger they are the harder they are to catch, therefore, smaller ones are easier to catch and will be targeted.

With the different choices players make they should see how the prey population changes over time due to natural selection. When they are hunted by their colour difference, the prey's population should slowly diverge to a population that has a similar colour to the environment. If the colour of the environment is changed, they will start dying out, and different coloured prey will pass on their colour to their offspring and once again the colour of the population will change. Whilst with speed the population of the prey will become quicker and lastly if the choice of hunting is strength, then the size of the individuals of the prey population will become larger.

4.2 The Recipe For Gamification

Lastly to be discussed in this section is how the above choices try to be their own recipe for the game.

The player is given the freedom to explore how their choices affect the simulation. These choices also give them power and control over the game and its world. This covers the **Play**, **Exposition** and **Choice** part of the gamification recipe.

Information is the next important ingredient and a detrimental one since the aim of the simulation is to teach the player about evolution. The information given is how the population of the prey develops to survive against the predator depending on the environment and the predator's hunting method. Hopefully, the player will be able to connect the dots of information given and learn something new which would give them a sense of accomplishment. At the same time, the elements introduced can also induce **Reflection** about the topic of evolution.

Lastly, the **Engagement** ingredient. The elements of control, different colours and interactivity will give the player a sense of engagement.

5 Implementation

The game was created using the Unity engine version 2017.3.0f3. The game was designed to be played on an interactive table. The game is played on the Ricoh

Interactive Table 55” (learning edition).

5.1 Interactive Table

The game will be played on an interactive table. The reason for presenting it on an interactive table is because it has shown to facilitate collaboration (Wigdor et al. 2006), which is the goal of this research. Another reason is that it is a novel way of playing games and might be more interesting than a usual computer.

5.2 Genetic Algorithm Alterations

In earlier sections the notion of genetic algorithms and gamification for learning has been described. This section will discuss how the two are implemented to make a fun evolution game for students. This section is divided into six segments, in order to describe how the simulation will work. Due to the gamification element introduced there are some alterations that we do to make the algorithm work for what this game aims to achieve. The algorithm will now be described in detail on works for each phase.

5.2.1 Initialisation

The initialisation phase will create the initial population of n prey in the environment. Each prey has three attributes that can affect their fitness value. In this phase each individual prey will have randomised values of the three attributes they contain. This is done so that the players has a variety of different prey on the screen at the start, which allows them to see how they can differ from one another.

The three attributes are size, speed and colour of the rabbit. Each one of these are randomised from a range of values. The code chooses a random number from the given range of floats which is a variable in unity.

- For size the range is 0.25 to 1.5.
 - The lower limit is to make sure that the rabbit model does not get small and therefore not visible to the players.
 - The upper limit is to make sure that the rabbit model does not become too large for the environment.
- For speed the range is 2 to 20

- The lower limit is to make sure the rabbit is not moving so slow so that it seems like it's not moving.
- The upper limit is set so that it is not too fast for the wolves to catch.
- For colour each colour value was randomised from the RGB (Red, Green, Blue) colour values.

In the real world a species doesn't start out with all random population. However, the game needs a starting point and it is done like this as to give the player a nice overview how the prey can vary in the game.

5.2.2 Evaluation

This section is one of the sections with alterations for the game, these alterations were done in order to make it more suitable for the play-style of the game. The fitness value to be used in this phase is dependent on the hunting method of the predators.

In nature a population of prey adapts to survive, in this case survive being hunted. They adapt in such a way that increases their fitness and hence their survival rate. In an attempt to mimic this, the prey population is affected by the hunting method set by the player. There are three hunting methods a player can choose; speed, strength, and eyesight. If a predator hunts using their speed, the faster prey will outrun it and survive. Using strength, bigger prey will survive since they are harder to catch. Lastly, if a predator is using it's eyesight to hunt it will hunt prey that is not camouflaged with the environment therefore, prey which blends into the environment will survive.

The fitness values is dependent on the colour difference between prey and environment, **or** size, **or** speed, depending on how the predator hunts. The evaluation is done for every individual at their creation. It also goes through this step when the player chooses to start the hunt.

5.2.3 Selection

The survivor selection happens when the wolves begin to hunt. In nature, predators will hunt the prey that is easiest to catch, in other words prey with the lowest fitness. In the game the predators will hunt and eat the prey with the lowest fitness scores since they are the easiest to catch.

Once the predators are done hunting or if a bush is added, mating season occurs. During mating season several prey can be selected and paired up to produce offspring. However to be selected the prey has to have survived the

hunting cycle. All the prey that are alive have a potential to produce offspring. However, the number of parents to produce offspring varies depending on the amount of food in the environment. This is the parent selection of the game.

5.2.4 Crossover

This section deals with how the offspring are created using the attributes of the parents picked in the selection phase. As said earlier each individual prey has three factor values, which are inherited from their parents.

Each of the three attributes is inherited from either parent at a random. Each factor is inherited from either parent, therefore the child can have the size and speed from one parent while being the colour of the other. Each factor of the child is independent of the others and the choice of one does not affect the other attributes. The child has an equal chance of inheriting a factor from either parent. While, this is not how it works with genetics due to dominant genes, the focus of this model is not genetics but natural selection, therefore this research will not deal with dominant genes.

The size of all prey is kept short on all 3 axis (x,y,z), we do this to avoid the model of the prey from being deformed. It is also more visually clear which prey is bigger when all three axis are affected the same way.

The colour crossover is done for each individual colour of the RGB spectrum. What this means is that the child does not inherit the exact same colour from one parent however it inherits each of the RGB values separately from either one parent or the other. What this means that it will pick, the red value from parent one or two and give it to the child. It will do this for the green and blue values as well. This was done instead of selecting the colour from one parent because, the prey inheriting the whole colour from one specific parent the population diverged to one colour. Even with mutations occurring within the environment this was a consistent problem. Increasing the percentage of mutations caused the the population too vary too much and made accomplishing the challenge difficult. However, when the prey inherited the colour from it's parents by having it inherit red, blue and green separately this problem no longer occurred.

Lastly, speed, the prey inherits the speed value from either one of its parents.

5.2.5 Mutation

With each child born there is a small chance of a mutation occurring, which will cause the factor that is mutated to be different then from its parents. A

mutation can occur after the crossover phase. Each of the three traits have a possibility of mutation, one mutation occurring will not lower the percentage of the other occurring. This will cause the population to have some variance and prevents the population from diverging into a super population that has no weak prey.

```
Initialise  $n$  population prey,  $v$  number of attributes for each prey;  
Select individual  $m$  from  $n$ ;  
Select individual  $d$  from  $n$  where  $d$  is not  $m$ ;  
while there are  $v$  attributes to go through do  
    | Select  $v$  from either  $m$  or  $d$ ;  
    | if mutation occurs then  
    |     |  $v$  is replaced with the new mutation value;  
    |     end  
end  
Create child  $c$  and add to population  $n$ ;
```

Algorithm 3: Mating Season Pseudo Code

It also mimics how mutation works in the real world. Mutations occur at random and can be advantageous or disadvantageous for a species, and that is what the game tries to mimic by using this.

5.3 Interface

Figure 4: Game Environment: Challenge mode



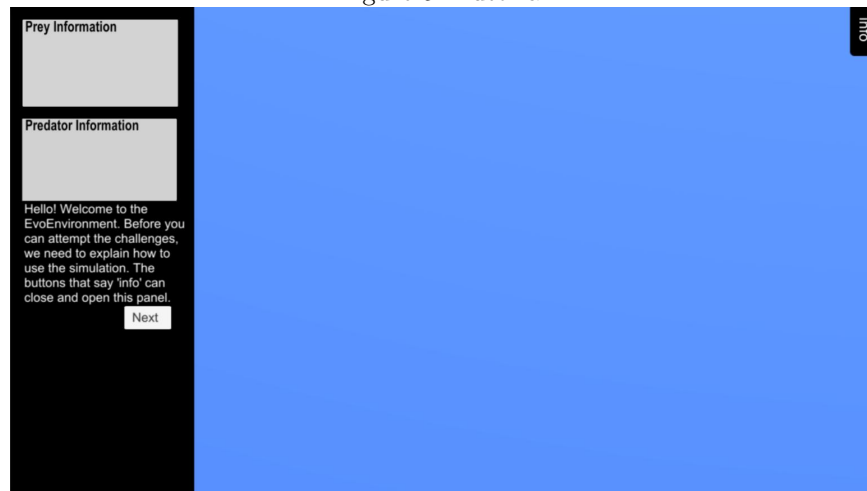
The 3D environment is the main information source of the game. It is where the prey and predator will interact. The environment spans through the

whole of the screen as seen in Figure 4.

The reason the 3D environment spans the whole screen is because we wanted to take advantage of the size of the screen given by the interactive table, and give the users a large enough view of what occurs in the environment.

Figure 5 shows the start of the tutorial. On the side of the screen is the information panel.

Figure 5: Tutorial



The information panel contains the textual information and the buttons for playing the game. To open the panel the button that says *'info'* needs to be pressed. This button is available on both sides of the screen to make it usable for the interactive table and allow the players to stand where they please. However, only one panel can be open at a time. It was designed this way to see if this would encourage players to communicate more since they have to share the panel.

5.4 Feedback

In the literature review section we briefly discuss why feedback in education will be useful. This simulation will have its own feedback for the students to learn from.

5.4.1 Textual

The user interface presents textual information to the user. The information given through text is:

- Size of prey and predator population.
- Number of bushes in the environment.
- What mutation occurred when a child is born
- If mating season, hunting cycle or starvation is occurring.
- Hunting method currently selected

This information is feedback on how their choices affect the simulation. Most of the feedback in the user interface is neither negative nor positive but simply presents information for the student to think about.

As seen in figure 6, the information is presented on one side of the table on a panel along with the buttons.

Figure 6: EvoEnvi Textual Feedback



5.4.2 Visual

There is another form of feedback within the simulation, which is the main feedback. This is what will be called visual feedback no text is involved here.

Instead the feedback is dependent on the what is occurring in the environment seen in Figure 7. This visual feedback is given using the prey's size, speed and colour. The user will be able to see these three attributes of the prey and how these attributes within the population are affected by their choices. This visual feedback should motivate the user along with the textual feedback to reflect on what is happening within the simulation.

Figure 7: EvoEnvi Visual Feedback



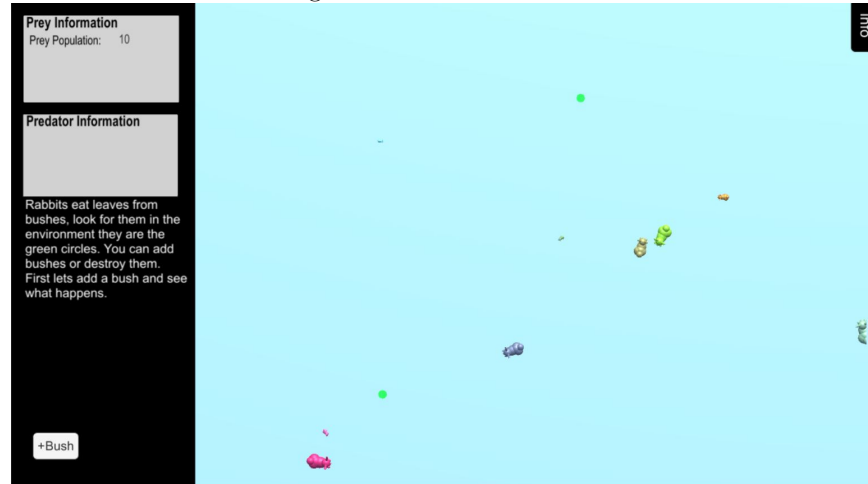
In Figures 4, 6 and 7 you can see the different coloured rabbits and their different sizes. While it is not visible in the image, while playing the game the rabbits speed is also visible. An important visual feedback is the hunting markers. These hunting markers were added with the aim of aiding the players in seeing what occurs when the wolves are hunting.

5.5 Tutorial

The game is split into two sections; the tutorial and challenge section. The reason for making the tutorial is to introduce the players to the core concepts, such as the game elements and the buttons. This was done so that the players can focus more on how to complete the challenges and their strategies without spending extra time to figure out how each element works.

The buttons and information are not all visible at the start of the tutorial, as you can see in Figure 8. This is so that it can introduce the elements of the game one by one in a linear manner. The reason it is done in this way, is to not over burden the user with too much information at once. Each of the buttons will be shown on by one as the tutorial progress as seen in Figure 8.

Figure 8: Tutorial: Button



The tutorial also has the two panels available. With the tutorial, however, at least one panel is open at all times and cannot be closed. This is because during the tutorial information in the environment is not as important, since the goal of the tutorial is to show how the interface works and therefore the focus is on the buttons and how the user can interact with the game.

5.6 Challenge

The challenge mode was added in order to create a goal for the players to ward towards to. This is done to see how the participants will interact when they have a common goal. The four challenges are:

- Create a population of large rabbits.
- Create a population of fast rabbits.
- Create a population of rabbits with the choice of your colour.
- Create a population of rabbits of one colour that are all large.

The reason for the first three challenges is to allow the players to experiment and figure out how each of the hunting methods affects the rabbit population. The last challenge is referred to the impossible challenge, however, it is not impossible but more difficult to achieve then the previous challenges. It is added in order to make the players more aware of how mutations works.

For the challenges, the game checks the average value for the population against a threshold set, to see if the players have completed the game. The reason for using averages is because it is easy to calculate for a varying population size and it was easy to set thresholds for. For size and speed, the average fitness of the population has to be above the set threshold. For the colour of the rabbits, the average has to be below a threshold. This is because for colour the difference of colour is calculated between the colour of the rabbit and the environment. Therefore, we want the value to be as small as possible.

Earlier, in Figure 4 it was shown how the game looks in challenge mode with both panels closed. The reason both panels can be closed during the challenge section is to give the players a better and larger view of what happens in the game since it is the main source of information.

6 Empirical Evaluation

This research is a usability study and aims to explore how students will collaborate and interact while playing the game. What we aim to explore is to see if the game positively influences collaboration between participants. There are two data types we gathered from the empirical evaluation; observational data and interview data. The observational data will show how the participants physically interact with each other, along with how they communicate. It will also show how the participants interact with the game. The reason we also do the interview data is to get more in-depth information on the participants opinion in regards to the game.

The experiment has three main steps it goes through.

- The Tutorial
- The Challenges
- The interview

Each one of these steps will be discussed further in the following sections.

6.1 Setup

Each experiment is done in groups of two. The reason for this is because collaboration involves a pair or a group working together to achieve a goal. Having a bigger group for each experiment is also an option, however for easy monitoring we decided to keep each group a size of two.

At the start of the experiment the two participants are told to stand at opposite sides of the table. As seen in the figure below.

Figure 9: Experiment: Starting position



The figure shows three people, the person in the centre is one of the researchers and moved away from the table to take notes after this image was taken.

The reason for this was that so all groups start of in the same way. The reason we start that at both ends of the table is so that the participants are standing face to face which is a natural position for communication. However the participants were told once they start playing that they were free to move around the table as they wanted. This was done so that we could observe what positions around the table were preferred by the participants.

Before then game begun, the group was also told that the game was made to teach about evolution. Once the game begun, Any further instructions were given by the game. The reason for this is to observe if the game itself gave enough guidance for the players to understand how to play the game and collaborate with one another without outside influence.

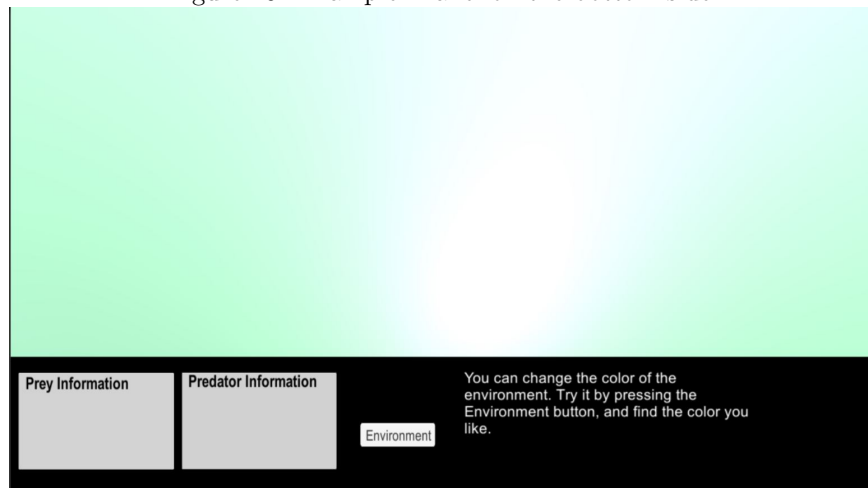
Once the experiment is completed both subjects were interviewed separately. They are interviewed separately because we wanted each individuals opinion about the game with no influence from the partner. It also allows us to gather more information from each participant and avoid one partner answering all the questions.

6.2 Playing The Game

6.2.1 Information Panels

During the game, the information and buttons needed to play the game are presented on a panel to the side of the screen as seen in previous figures. The reason that the panel is placed on the left and right sides of the screen is because if they were placed on the top and bottom sides they would cover more of the screen as can be seen in Figure 10.

Figure 10: Example: Panel on the bottom side



In order to give the player a bigger overview of the environment while still having the panel open, it was decided to have the panels available on the left and right side of the screen. A person on either side of the table has access to the panel.

6.2.2 Tutorial

The aim of the tutorial is not to give away how the game works, but rather to introduce how the user interface works and the mechanics of the game. It presents the information and the buttons available one by one to the users. The tutorial will be presented to the participants after a small introduction to the game. It leads the students through the main elements of the game by introducing them one by one. First, it introduces the population of rabbits, spawning the corresponding model. The first interactive factors that are introduced are the environment modifying buttons. The first is the environment colour change, and then the bushes are introduced. Both adding and destroying a bush can

be done once during the tutorial in order for the student to see how it can affect the environment and to keep the tutorial from dragging on too long. Once the student is done with the food source the predator population is introduced. Finally, the last and most important part of the simulation is introduced. The hunting cycle. In the tutorial one hunting cycle is run for each of the hunting methods, to show the players how they can select them and start the hunting cycle. Once all three hunt methods have been explored the student can click the button to start the challenge mode.

6.2.3 Challenges

Once the tutorial is completed the game goes onto the challenge section of the game. The scene starts with both information panels closed and the options to open either of them. On the panels where the tutorial was previously presented the challenges are now presented instead. There are four challenges in total for the participants to complete. Each of the challenges require the participants to discover how the different hunting methods work and how they affect the population of rabbits. The four challenges are as said earlier:

- Create a population of large rabbits.
- Create a population of fast rabbits.
- Create a population of rabbits with the choice of your colour.
- Create a population of rabbits of one colour that are all large.

The first three challenges are simple, each one requires one of the hunting methods to be used to cause the population evolve into the corresponding challenges. The first one requires the players to discover that the strength hunting method eliminates small rabbits. The second challenges requires the discovery that the speed hunting method eliminates the slow rabbits, while challenge three requires the discovery that both the environment and the eyesight hunting method affects which coloured rabbits are eaten.

However, due to time limitations of the participants, interventions were needed during the challenges. This was mostly due to mutations which would cause the challenges to take longer to complete. After the first group had this issue occur, it was decided that if a challenge takes over 10 minutes, we would interfere and go onto the next challenge.

6.3 Interview

Once the game was complete both participants were interviewed separately. The questionnaire contained over twenty questions, the questions focused on the players experience with the game and their communication with their partner. The main questions asked in the interview are listed in Appendix A. However, there were additional questions asked at times by the interviewer when needed in order to get more information from the participant.

7 Discussion of Results

In total, we gathered observational data from 6 different groups, and collected interviews from 12 people in total. All participants were students from Utrecht University.

7.1 Interpretation of the Interface

7.1.1 Tutorial

Observation Most groups went through the tutorial smoothly. This was noticeable through how quickly they went through it. With each instruction, the participants easily grasped and noticed what they had to do in order to proceed to the next step. All groups but one completed the tutorial, under 5 minutes. Group 6 took around 6 minutes, but this was due to the fact that one of the participants was dyslexic and therefore, took a longer time reading the instructions. The only moment of slight confusion, that occurred during the tutorial, was with group 2. It occurred when the game introduced the bush feature and the players were instructed to add a bush. One player from group 2 tried to add the bush by clicking on the environment instead of the button. However, this was quickly resolved because his partner pointed it out to him that the button needs to be clicked.

One piece information, presented by the tutorial, was missed by the participants. This was that they had two panels available on the table. The first piece of information presented by the tutorial was that the panel could be opened by the other side as well. Groups 1, 4, 5 and 6 all went through the tutorial without opening or testing out the second panel during the tutorial. Group 3 did not realise this was possible at the start of the tutorial but did, however, open the second panel midway through. Lastly, group 2 was the only group that realised that they had two panels available at the start of the tutorial, wince they tested out the panel opening button when prompted.

Interview During the interviews, all of the participants were asked about the tutorial. All participants found the tutorial useful and easy to understand. The most common reason why it was easy to understand, was due to its simple step-by-step design. Subject 1 from group 4, said that the controls were introduced one by one in a concrete and concise manner, which made the tutorial easy to navigate and gave her a better understanding of the game. In addition, multiple subjects said that the tutorial gave them enough information to tackle the challenges without giving away the answers.

However, two participants thought that the tutorial was not necessarily needed. One participant's reasoning for it was that the buttons had simple features and therefore could have been discovered during gameplay. The other participant said that it was because she gave her partner the controls, though she admitted that she thought her partner got more information out of the tutorial than she did.

On the other hand, other participants commented that if the tutorial was not there, it would have taken longer to play the game since they would have needed more time to figure out. For example, subject 2 of group 3 also commented that without the tutorial it would have taken longer to figure out the challenges, since she and her partner would first have to figure out what the buttons do before attempting the challenges. Subject 1 from group 2 claimed that knowing how the buttons work gave her a feeling of certainty on how to play the game, which she said was good.

Discussion From the above, we can see that the tutorial is useful, it does not take too long to complete. In addition to this, it gives a basic understanding of the game, which was the goal. The players were able to easily grasp the concepts presented during this section of the game. Therefore, the tutorial and its design fulfils its role of giving the player enough knowledge to tackle the challenges. However, there is room for improvement. More specifically, in regards to making the players aware how the panels work, since it was obvious that most of the groups were not aware of the panels worked during the tutorial.

It is also important to keep in mind that the target age group for the game is much younger than the participants, in the experiment. While the tutorial and game might be too simple for the participants, for a younger audience the tutorial might be necessary to avoid possible frustration and inefficiency.

7.1.2 Challenges

Observations The challenge section of the game starts with both panels closed, giving both players a full view of the environment. This caused some initial confusion with the groups, since the majority of them did not realise you can open and close them during the tutorial. Due to this, the participants

started to look around the interface before seeing the *'info'* button in the 2 corners of the screen. Once either partner noticed the *'info'* button, they would try it and figure out that that they could swap panel sides, along with being able to close both panels.

One action that occurred in all groups while doing the challenges, was that they would constantly select a hunting method before pressing the hunt button. They did not need to re-select a hunt method if it was the last method pressed, however all groups consistently re-picked their hunting method.

Another observation that occurred in the groups that closed the panels to watch the environment during the hunting cycle, was that they would sometimes not open the panels when the cycle was complete. It seemed as if they did not notice that the cycle was complete and that they had to go back to the panel to perform the next action. The same was noticeable with group 2, when one of the participants asked the other if the hunting cycle was over before opening the panel to check if it was.

Another issue that occurred in regards to the textual information in the panel was with group 6, where subject 1 selected the speed hunting method and then did not notice that his wrist selected the size hunting method right before he started a hunting cycle. Under predator information it would say what hunting method was selected, however neither subjects noticed this. This cause confusion in the group, since they did not notice that the hunting method was not what they had originally intended it to be.

Interviews During the interviews, all participants were asked if they looked more at the panels of the environment in order to see how they were progressing. All participants claimed that they mostly referred to the 3D environment for information, this was also noticeable when groups 2, 3 and 5 closed the panels in order to see the whole environment. Three participants (Subject 1 from group 2, subject 2 from group 4 and subject 2 from group 5) admitted to not looking at the textual information on the panel at all. The rest of the participants, however, said that they did occasionally look at the textual information even though they preferred the visual. Subject 2 from group 2, subject 1 from group 4, both participants from group 5, and subject 1 from group 6, found that they looked at the panel if they felt like they needed extra information and said it can be useful at times for a little extra help. All the participants had similar reasons for preferring the visual information. It was because it contained most of the information needed to complete the challenges. They also said it was more visually pleasing to watch and that it was more interesting than reading text.

However, during group 1's experiment, they both commented that they thought they had completed the first challenge when they had not. They commented that this was because they thought the term large rabbit was ambiguous and that their idea of large did not match up with what the game considered large. The participants pointed out that they weren't sure how big the rabbits had to be in order for the challenge to be completed.

A similar incident happened to group 6 during the third challenge, where they had to make a population of rabbits of one colour. To complete the challenge, the population had to be camouflaged to the environment colour. The participants thought they had completed the challenge, since to them the population was the same population as the environment. However, the colour differed from the environment, so the game did not label it as a completed challenge. These were the only two times where there were major issues with the feedback, which caused frustration.

In regards to the hunting markers, all participants said that they were useful. Subject 2 from group 2 said that the markers helped because the feedback of what type of rabbit was being affected was immediate, and he liked that he did not have to wait to long for this feedback. He also found that it helped him anticipate possible future failures or successes. All participants found that it aided them in understand what groups of rabbits were being hunted and helped them connect the dots. Subject 2 from group 3 and subject 1 from group 5 also commented that they thought it was fun to trace the wolves while they were hunting their marked prey. Subject 1's, from group 4, thoughts were in line with that of the other participants, however they found no need for the markers to be colour coded. They said that the markers could all be one colour since they believed it would still give the information of what type of rabbits were affected without having different colours.

Discussion The visual feedback given by the game presents useful information, that allows the players to understand what is happening depending on the decisions they make. The textual information could be useful at times, despite the fact that not everyone made use of it. At least one person in each group did admit to glancing at the information panel for extra information.

Every participant found the visual feedback interesting and said that it contained the most information. It was easy to understand and provided guidance for the player to be aware of their progress in the game, however there are a few features that should be improved upon.

The feedback for if the hunting cycle is complete is not obvious when the panels are both closed. This was noticeable when the groups, mentioned earlier, would not open the panel when the hunting cycle was completed. If the panel was open they would almost immediately notice that the cycle was complete, since the buttons would visibly turn on, however if the panels were closed they did not see this occur. An idea to improve this feedback feature is to have one of the panels open automatically once the hunting cycle ends.

Another improvement, is to make it more obvious to the players which hunting method is currently selected, since, as seen with group 6, it can cause confusion. One possible solution is to deactivate or '*grey out*' the button of the method that they selected. This would also fix the issue where the groups consistently re-picked a hunting method even when not needed.

7.1.3 Discussion: Interpretation of the Interface

Both the tutorial and the challenges were designed to be easy to understand and give the player feedback on how they were progressing. It was made easy to understand how to play the game by adding a step-by-step tutorial, which allowed players to focus more on figuring out the solutions to the challenges rather than figuring out how to play the game. The challenge section focused more on giving feedback. It gave sufficient feedback for each of the groups actions and allowed them to plan their next step. Feedback for some elements, such as if a cycle was complete, need some improvement in making it more obvious to the players. The issue described above in regards to ambiguity of size is not solely related to feedback, but to how the checking system was coded for completing the challenges.

7.2 Collaboration

7.2.1 Panel Availability

One aspect of the game was that only one panel with information and buttons was available at one time at one side of the table. The panel could be flipped between participants on either side of the table. Unfortunately, during the tutorial the participants were not aware that they could make the panel switch sides.

Observations To solve this issue, some groups opted to walk over to the other side of the table to read the tutorial, such as group 1, group 4 and group 6. During the tutorial all groups, with the exception of group 6, the person closest to the information panel read out the information to their partner. All participants confirmed with their partners if they wanted to perform a certain action. This did not occur with group 6, since one of the participants was dyslexic and her partner admitted in the interview that she did not want to pressure her to read out loud.

In group 3, subject 1 started reading in a soft voice when she starting reading out loud, but gradually increased in volume. As the game progressed, she was visually and audibly more confident when communicating with her partner. This was noticeable due to an increase in pointing to what was happening in the table and an increase with how much she communicated with her partner.

Interview When questioned if having one panel available was a problem while playing the game, all participants disagreed, except for subject 1 in group 5. This participant found it a problem during the tutorial because her partner is

dyslexic and she did not want to force her to read the instructions out loud. Initially, subject 2 from group 1 admitted that having one panel made him scared of stealing control away from his partner. However, he did later admit that it caused him to voice his actions and reasoning more to his partner before taking any action and therefore felt encouraged to talk more. Subject 1 from group 2, subject 1 from group 3, Subject 1 from group 4 and subject 2 from group 6 all said that only having one panel available encouraged them to talk more because they wanted to confirm and receive permission from their partners before performing any actions in the game.

Both subject 2 from group 5 and subject 2 from group 6 commented that they believed that if they had two panels available to them, that they would have felt less inclined to confirm their actions along with providing reasoning for their actions with their partner.

Subject 1 from group 3, during the interview, admitted that she was a fairly shy person in general. Despite that, she did enjoy working with her partner. She said that having one panel encouraged her to talk more than if two panels were available and thus it helped her become less shy and more confident with talking while her partner.

Discussion From the above it is shown that having only one panel of information and controls can have a positive affect on collaboration since it increases discussion along with explaining the reason for their actions. Before completing the actions, participants waited for their partner to agree with their ideas or present their own if they did not agree.

7.2.2 Challenges

Observation While attempting the challenges, participants discussed different actions they wanted to take and why they thought it would lead them to completing the challenge. Groups 4 and 6 were the two groups with the most obvious disagreement between participants in regards to solving a challenge. However, the disagreements increased discussion in both groups.

Interview Subject 2 from group 2 and Subject 2 from group 5 both mentioned that having the same goal as their partner, also encouraged them to talk more and share their strategies and their reasoning behind it. Subject 5 from group 4 also noted that as the challenges got more difficult, he found himself communicating more with his partner. He noticed that disagreements occurred between them and therefore felt more compelled to back up his arguments. On the other hand, Subject 1 from group 6 initially claimed that her communication with her partner was bad since they started to disagree with each other. However, she also noticed that the disagreements did indeed increase communication with her

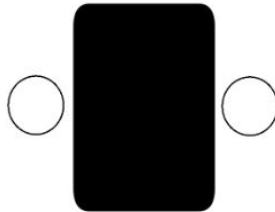
partner and therefore retracted her earlier statement.

Discussion Having a common goal has a positive effect on collaboration since it encourages the participants to share their ideas and strategies.

7.2.3 Interactive Table: Positioning

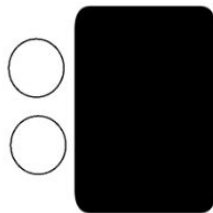
Observation Figures 11 to 13 are the three different standing positions that occurred within the 6 groups while playing the game.

Figure 11: Standing Position around the table



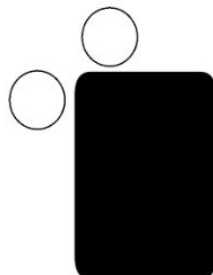
Groups 2, 3 and 5 stood around the table as shown in Figure 11.

Figure 12: Standing Position around the table



Groups 1 and 6 stood around the table as shown in Figure 12.

Figure 13: Standing Position around the table



Lastly group 4 stood around the table as shown in Figure 13.

Interview Both subjects from group 2, and subject 2 from group 3 all commented that standing on opposite sides of the table felt more natural for conversing with their partner and this had a slight effect on inducing communication. On the other hand, subject 1 from group 1 found that standing opposite from his partner felt competitive and therefore chose to stand next to him. The subject might have felt that way because he is more used to playing video games on a television screen with his partner where they are sitting next to each other on a couch.

Lastly, group 4 stood in the position represented in Figure 13. Subject 1 from group 4 moved to stand on the shorter side of the table which the panel covered. When questioned as to why, they explained that they felt that it gave them more control over the game. All other subjects had no comments in regards to their standing positions.

Discussion From the above we can see that standing across from one another can encourage communication, since it is a natural position for two people who are having a conversation. Despite that, there were two groups that decided to stick to one side of the table. In the first group it was because it felt competitive to stand on opposite sides. However, it is important to keep in mind that group 1 was a pair of long term friends. In addition to that, subject 1 from group 1 also claimed that they had felt awkward during the experiment, since they were being filmed and watched. Due to that, there is a chance they also felt less awkward if they stood next to each other.

The interactive table provided the freedom for participants to move around the screen and stand where they feel comfortable. In most cases it was face to face, which felt natural to communicate. Unlike computer and other gaming consoles, the table allows the participants to stand where they want, while still being able to see the whole screen. The fact that the participants can choose to

stand where they felt comfortable can help with collaboration, however, more testing would be recommended to test this.

7.2.4 Social Loafing

In related work, social loafing was mentioned where interactive tables were shown to decrease the chances of this occurring.

During the experiment subject 1 from group 6 was visibly less inclined to contribute to conversation. This was noticeable because subject 2 initiated most of the discussions between them. The way subject 1 slouched and talked, it was evident that he did not have any interest in playing the game. During the interview he also admitted that he did not really feel like communicating with his partner and that the reason why he did talk more than he would have usually was because his partner started talking to him.

This shows that even if one partner is not inclined to talk with the other, the game has potential to increase contribution from this person. Hence, it also has a potential to decrease social loafing. This can also be seen with subject 1 from group 1, who was less willing to contribute because she was shy, but the game encouraged her to discuss with her partner.

7.2.5 Discussion of Collaboration

For the reasons presented above, the game has shown that it encourages collaboration between its players. It does this by creating a natural, communicative environment in which participants can stand in a way that makes them feel comfortable with communicating. Having one set of controls also encouraged the participants to communicate with each other, because participants wanted to include their partners in the decision making process, along with having a common goal to work towards presented by the challenges.

7.3 Discovery

Interview One common word that appeared frequently during the interviews was the word *discovery*. While the notion of discovery is not part of our research question, it is important to mention, since it was a recurring reason during the interviews as to why the participants enjoyed playing the game. Multiple participants said that they enjoyed that the game allowed them to discover and solve the puzzle on their own. Subjects 1 from group 2, both participants from group 3, both participants from group 5, and subject 1 from group 6 all brought up the notion of discovery in their interviews as a reason for enjoying the game. Subject 1 from group 3 and subject 1 from group 5

further explained that the discovery aspect that game gave them a feeling of satisfaction when they discovered the right strategy for the challenges.

The design of the game has shown potential to allow students to discover information at their own pace and give them a sense of satisfaction and hence increase engagement and motivation. However, currently this study does not hold enough proof for this and further experimentation is needed.

8 Discussion

8.1 Limitations

One issue with the game is the way the mutations are currently implemented. Mutations occur at random and this has been simulated in the game with a random number generator. This has, at times, lead to frustrating gameplay, since some of the in-game mutations would make a level harder to complete and more time consuming. While for some groups challenge 1 took a minute or two to complete, for others it could take over 5 minutes. This caused some of the participants to express their frustration while playing and and made them confused about why the game kept working against them. This is a problem, because frustration can reduce a player's fun and immersion in the game, which can have a negative impact on motivation.

Group 1, when interviewed, revealed that they had felt awkward and shyer than they usually are, due to the fact that they were being watched. Subject 1 pointed out that it made him not be as communicative and vocal as he usually would have been. None of the other participants made this claim. However, it is important to bear in mind that while being watched or recorded, people might behave differently than under normal circumstances, because this might proved different results due to different behaviour.

The target audience for this game is preteens of 11 to 12 years of age, before they enter Dutch high school. However, the experiment was performed with university students. While the university students might have found the game easy to complete at times, it is important to keep in mind that this might not be the same for younger ages.

A limitation of the interviews was that at times participants seemed to have a tough time giving reasoning to their answers. This occasionally led the interview in circles, and not all questions were answered to completion by all participants. This means that some participants did not always give reasoning to their answers, while others did.

Another limitation was introduce due to the time at which the experiments

took place. The participants were taken from a university during examination time and most expressed concern to how long this would take. This became an issue mostly when the mutations made the challenges longer than they should have been. At this point, the participants would ask for an intervention since they were running out of time. The intervention included simply setting up the next challenge for the participants instead.

8.2 Future Work

There are several features that could be added to the game to make it more diverse and fun. One such idea is to have multiple populations of predators and prey in the environment. This opens up the game to more diverse challenges and increases the size of the game.

Another possible addition to the game is to allow players to select the species of prey and predator they want in the environment from a pool of animals to increase the diversity of the game experience. This would also increase the feeling of control that players have over the environment and increase their sense of freedom. To further increase the size and playability of the game, additions to the environment can also be introduced, such as different environments with different colours that affect other attributes than colour. Participants also felt that the bushes did not have enough of an impact on the game to be interesting, so making them have a bigger effect on the population would be a good fix.

Another change that should be made to the game is to increase the emphasis on the fact that players can switch between panels during the start of the tutorial. While there is a small textual indicator that you can switch panels at the start of the tutorial, people did not often realise they could do this until the challenge section started.

In addition, small alterations or fixes might need to be made to the random generation of mutation to prevent the game from getting frustrating. However, there might be a trade-off between that and keeping it as close as possible to how mutations work in the real world.

Participants often stated that a sense of discovery is what made the game interesting. It could be beneficial to add more elements in the game to be discovered. Some previous suggestions might have a potential to aid with this.

In regards to testing and getting a better idea of the potential of the game is to test it on the students from the secondary education. In addition, a text on how different personality types collaborate during this game would also help with this. Subject 1 from group 3 is shy and took some time to get comfortable with expressing some ideas, while in group 4, subject 1 had a more controlling personality type. It would be interesting to see how the two of them play the game together and if the design would be able to encourage both of them to

equally contribute to the discussion, along with seeing if two shy people would eventually grow more bold and active with each other.

9 Conclusion

In conclusion, the game has shown potential in inducing collaboration between its players, due too to it's use of an interactive table, setting challenges for the players and having only one panel available at a time.

The game is simple and easy to learn, which allowed the participants to focus on figuring out how to solve the challenges. The feedback presented in the game was also useful and it was sufficient for the participants to be able to solve the challenges.

The game and interactive table have shown a lot of potential in regards to inducing collaboration between the players playing the game and hence, as discussed in previous work, will increase learning by inducing critical thinking.

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A Interview Questions

1. What is your overall impression of the game?
2. What aspects of the game do you like? Why?
3. What aspects of the game did you dislike? Why?
4. What features do you think would make the game more interesting/fun? Why?
5. What features do you think should be added for the game to be more usable on the table? Why?
6. What features of the game do you think are not needed? Why?
7. Did you enjoy working with your partner? Why?
8. Did you enjoy using the interactive table? Why?
9. Was the tutorial easy to understand and navigate through? Why?
10. Was there any part of the tutorial that was specifically helpful and/or not helpful?
11. Did the tutorial help with the challenges?
12. What was your reasoning/strategy for each of the four challenges? Why?
13. Did you notice anything specific in your communication with your partner?
14. Was the information on the panels useful and how often did you read them?
15. Did you prefer the visual or textual feedback? Why?
16. Which of the three attribute changes with the rabbits was most visually obvious to see the changes happening in the rabbit population?
17. Were the hunting markers useful? Why?
18. Was it a problem that only one of you could read the information panel? Why?
19. Did having only one panel available encourage communication?
20. Did you want to move around the table?
21. Is this game and interactive table something you would have enjoyed using while learning?
22. Is there anything else you want to share about your experience with the game?

B Experiment

B.1 Group 1

Group 1 consisted of two male participants who are long time friends. At the start of the experiment both subjects were quiet. They did not notice that the information panel can be opened at either side of the table, therefore one of them moved to stand next to his partner. The two participants stayed close to each other during the experiment, only moving along one side of the table. At the start of the experiment they communicated with each other in quiet voices. Both participants pointed out things in the environment. They both shared one panel and did not open the other during the tutorial. Instead the subject closest to the panel would read out the instructions presented to his partner. Their conversation picked up as they played the game, usually after being amused with how the predators and prey interacted with each other.

The challenge section starts with both panels closed which caused some slight confusion between the two subjects, until they noticed the two small buttons. At this point the participants were aware that they could open the panel at either side of the table. Despite being aware that they have access to the panels from both sides the two subjects decided to stay on one side of the table.

Both participants increased in communicated with one another as they tried to complete the challenges. During these discussions, most commonly during the hunting cycles, they would point to the different elements in the table that corresponded to what they were saying. While they were playing they exchanged jokes and the amount of laughter increased as they continued to play the game. In addition, as the game progressed they started to move away from their huddled positions. One subject did all of the button pressing while confirming his actions with the other and discussion why they wanted to perform a certain action. This was not always vocal, sometimes a nod or an exchange of glances was enough confirmation for the other to complete an action.

Their tactics for solving each of the challenges was audible in the discussions between the two subjects. In the first challenge they discussed the different ways the population can be affected by size, it induced a lot of discussion about how the rabbits were affected by hunting method. To figure this out, their first tactic was to play around with the features of the game. If they had a theory why it would work, they would discuss why they believed it would work and then test it if both agreed. Once they made the connections and confirmed them with each other they were able to complete the three challenges.

During the experiment of this group and intervention occurred during the

first challenge, since it was taking too long to complete. They had to make a population of large rabbits, however they created a population of rabbits that was mostly one size but were just below the threshold for being considered large by the game. Whilst it would have been possible to get larger rabbits due to mutations this group was unlucky, and when a size mutation occurred a small rabbit spawned in most cases. Since it was taking too long to get the right mutation, the participants were allowed onto the next challenge.

B.2 Group 2

Group 2 consisted of a male and female participants who had just met for the first time.

Unlike the previous group this one was more energetic while playing the game. At the start of the tutorial both subjects noticed that the panel was facing one way so one subject ran to the other side so that they could both read the panel. After doing this, however, they then proceeded to discover the button that opens the panel on the other side but closes the one facing them, at which point they both ran to the other side laughing. They proceeded to do the tutorial by both standing at one side of the table. They talked about the information presented in the tutorial. One subject tried to press the rabbits and got attached to them, claiming she did not want them to die. They did not press go onto the next step of the tutorial unless both of them had confirmed that they were ready to. In addition, they also read the information presented on the panel out loud to each other along with pointing out what they saw in the environment. Once the hunting methods were introduced in the tutorial this group already started to make connections about which hunting method affected which factor of the rabbits. At this point they both mentioned natural selection.

Once the challenge section started, the fully exposed environment caused the subjects to move to opposite sides of the table and stand facing each other. At this point they realized they could both open the two opposing panels at their own choice. This group, however, did not move to stand at the same side but rather stayed at either end of the table. Before either of them pressed any buttons, the subjects would discuss what they wanted to do and why. The subject who had the panel would ask for confirmation and permission before performing an action in the game. Once they realized they could have both panels closed, every time they started the hunt cycle they would close the panel to watch the 3D environment. There was no communication about who would have the panel open when they were both closed. In most cases the participants did not swap the panel until a hunt cycle was over, in that case whoever opened the panel first would have it until the next cycle. In addition they sometimes closed both panels when discussing what to do next while looking at

the environment. However, there were points during the experiment when male subject encouraged his partner to take control of the panel.

One noticeable thing about their interaction with the buttons was that they would select the method almost every time before they pressed the hunt button, even if the method had been selected previously. They were seemingly unaware that if they wanted to hunt using the same method that they did not need to select it again and only press the hunt button.

The participants shared their ideas and reasoning for their actions, in addition to further tactics and future steps to be taken in case the first one did not work. The tactics they used for each of the challenges was that they tried to figure out how each hunting method worked. They did this by testing out the methods on the table and once the connections were made they used the corresponding hunting method to complete each challenge. With the third challenge, before they tried to use a hunting method, they decided to first change the environment color to fit the population. In other words, they first checked which color was most prominent in the rabbit population, matched the environment color and then selected the hunting method. One subject even vocalised her preference to when the rabbits for different coloured rabbits, claiming she found it boring when they became a more similar in colour. During the impossible challenge, the participants noted the occurrences of mutation. For the last challenge they used the information they learned from previous challenges and applied it here.

During the experiment one of the subjects accidentally quit the game by placing her palm on the *Quit* button. Which caused the game to quite the challenge. The game was restarted and placed on the challenge on which the group was attempting before the mistake.

B.3 Group 3

The third group consisted of two females who were also strangers to one another.

Unlike the previous group this one was more subdued. This was obvious by how they handled the tutorial part of the experiment. One subject started reading the tutorial to the other in a loud and clear voice. The subject on the other side of the table notices the *info* button on her corner and pressed it, causing the panel to swap sides. That's when they realised they could switch panels and the second subject had a chance to read the tutorial. Unlike the other subject her voice was a lot softer and harder to hear. During the tutorial the quieter subject allowed the other subject to do most of the talking. However that changed as the game progressed, with the quieter subject becoming more vocal and expressive. Once again the game proved to be amusing as the participants started laughing at how the prey and predator interacted.

The participants read out information from the panel to one another. Whoever had the panel open was in charge of reading the instructions out to the other. During the first two challenges one panel was kept open, until the third challenge where they switched control of the panel for the first time. In addition during the third challenge they closed both panels and continued to do so every time the hunt cycle was started. Occasionally during the cycle one of the participants would open the panel to check on some information in order to contribute to a discussion or prove a theory they had.

While slow at first there was discussion between the two subjects. The first major discussion occurred when the tutorial presented them with the button that changes the environment color. They discussed which color they should settle on and whether the other liked the current color and agreed on it. The second major discussion occurred when the hunting methods were presented in tutorial. The subjects noticed the markers the pointed out which prey was being hunted and had started to discuss how the hunting methods are affecting the population. They used what information they gathered from the tutorial to complete the challenges presented. Each subject asked for confirmation when presenting an idea or an action to the other; there was no action done unless the both participants agreed to it. The interaction between the two subjects became louder and more open as the game progressed and the quieter subject started contributing to discussion more often.

The tactics this group employed to complete the challenges were similar to those of the previous two groups. They used the information they gathered from the game and then tested out their theories. The theories they had for each challenge and why they thought their theories were correct, were discussed between the two subjects before testing it out. They discussed possible other theories to try out as well before completing an action. Each theory was tested by trying it out in the environment. Once a theory was confirmed (for example, wolves hunting using their strength would eliminate the small rabbits), they used it to complete a challenge.

B.4 Group 4

The fourth group was also composed of two strangers that had met for the first time during the experiment, one male and one non-binary.

During the tutorial they stuck to one panel, and both participants stuck to their side of the table. Subject 1 had the panel facing them and read out the tutorial to their partner. Neither subjects realized that they could alternate the panel between the two of them during the tutorial (since neither tried to do it at the start of the tutorial), they realized this when the challenge section started up. Subject 2 switched the panel to his side and instead of switching back and fourth, subject one moved to stand at the side where the panel was

located on the short side of the table at the corner. Similar to previous groups described, this group also had a tendency to re-select a hunting method before pressing hunt, despite it already being selected.

Despite being strangers, this group was full of energy. This was shown by their tone of voice and and actions. Both subjects voiced their thoughts and opinions to the other. They discussed some of their theories or what they saw in the tutorial and later on used it to make connections to how to complete the challenges. This group had a similar tactic for completing the challenges as the previous group. However, subject 1 expressed their impatience over having to do a hunt method multiple times at which point subject two said: "Evolution doesn't happen overnight."

Subject 1 agreed with this statement and agreed to try out one method several times. For challenge two not a lot of discussion occurred since they both agreed on the correct method on how to complete the challenge. Each time one of the subjects presented an idea what to do in the game, they gave a reason to why they wanted to perform an action, in addition to then asking for permission to complete an action. However, there was one occurrence where a discussion broke and subject one grew impatient at which point they performed an action without asking or waiting for permission to do so.

B.5 Group 5

The participants in this group were two females who are close friends.

At the start of the experiment, when presented with the tutorial, the panel was initially facing subject 1. The two subjects quickly switched sides on the table, so that subject 2 can read the information instead. This is when subject 1 mentioned that subject 2 was dyslexic. Subject 2 read the tutorial, but unlike previous groups where the participants usually read the information out-loud this one read to herself, while subject 1 tilted her head to read the information for herself as well. Despite not reading out loud to one another, subject 2 would wait for confirmation from their partner before going onto the next step of the tutorial. These were not always verbal confirmations, sometimes it was a hum or a nod of the head. Subject 1 tended to dominate most of the discussions, but did not make any actions unless subject 1 was in agreement. During the first challenge where the goal is to make a population of large rabbits, subject 1 misread the challenge as "*create a large population*". Despite being wrong, subject 2 did not correct the other despite having a different idea and instead tested out what her partner wanted to do. Eventually they realized this was the wrong tactic and through more discussion switched to the right one.

Their tactic to complete the challenges mirrored the previous groups. They discussed actions and theories they had in addition to testing them out in the environment.

When it came to interaction with the panels, during the tutorial they did not switch panels. However, throughout the whole game, they seemed to overlook some of the information presented in the panels, such as mating season. Mating season is shown on the information panel when it was occurring yet the two subjects did not notice that and were initially surprised about the appearance of more rabbits. Most of the time when they glanced at the panel was to use the buttons. During challenge three they also closed both panels to get a bigger view of the environment.

An intervention also occurred with this group due to a challenge taking too long to complete. This was caused by the randomness of which the mutations occur. In the intervention the subjects were put onto the next challenge.

B.6 Group 6

Group 6 consisted of a male and female participant who are acquaintances.

At the start of the tutorial subject 1 noticed the panel was facing subject 2, subject 1 then proceeded to walk onto the other side of the table to see the tutorial and stood directly in front of the information panel. Both subjects then proceeded to read the tutorial for themselves silently. Initially, not a lot of discussion occurred. The only communication that occurred were one word answer on whether or not one of them could go to the next step of the tutorial, in addition they also took turns pressing the button for the next step. About a minute after starting the tutorial subject 2 started to read the instructions out loud to her partner. As they progressed through the tutorial, both subjects started to become more vocal and subject 1 took more control over pressing the buttons. Once the hunting methods were introduced in the tutorial, subject 2 started discussing what she was seeing in the environment. Both subjects showed amusement at the interaction between the wolves and the rabbits. Subject 1 showed more initiative and started most of the discussions during the experiment. There was even a major disagreement in this group which caused them to delay doing any actions and discuss why the other one might be wrong. Despite this, they decided to test out subject 1's theory even though they were both unsure if it was correct. Once it became clear that this theory was not working they tried out another one. In most cases subject 2 shared ideas while subject 1 pressed the buttons.

When it came to using the panels, neither of the subjects moved from the original panel position. At one point subject one pressed the button that allowed him to flip panel to the other side of the screen but he returned it to the original position and both participants stuck to one side of the table. Despite the buttons showing up one by one in the tutorial, the participants failed to notice the "*add bush*" button initially and tried to spawn a bush in the environment by pressing the environment directly until they noticed the button. They also failed to

notice that the information panel showed what hunting method was currently selected. At one point, subject 1 selected a hunting method but accidentally used his wrist to select another one, which he failed to notice. This caused some confusion over how the game works, since they were certain it was hunting using one method when it was actually another method. Another mishap with the buttons that occurred was when subject one started a hunt cycle with a hunting method she did not want, in her panic she pressed quit and quit the game thinking it would stop the hunt cycle.

Their tactic was similar to that of other groups until the hunting method mishap described above. This confused both participants and caused them to just try out different things until they finished the challenge, which sparked some discussion between them.

C Interviews

C.1 Group 1

C.1.1 Interview: Subject 1

Overall Impression During the interview the subject admitted that he found the game fun, due to its inter-activeness. He claimed that, when learning in school, the teachers just gave you the information, while with the game you explored the information for yourself, which made it fun. In addition, he also enjoyed the table for its novelty and found the experience to be different then from using a computer. On the other hand, an aspect of the game which was negative was how long it took to complete a challenge due to the mutations interfering. At times they thought they had completed a challenge when the game said they hadn't (the rabbits were not the right size, since the mutations that occurred were disadvantageous for them).

Interactive Table Subject 1 enjoyed using the interactive table due to it's novelty's and inter-activeness.

Tutorial The subject found the tutorial easy to navigate due to its step by step set up and simple English. However, he also pointed out that it did not give any direct hints to how to solve the challenges. In addition he commented that he thought maybe there was no need for the tutorial, since the buttons functionality was easy to understand. This was a bit contradictory response since he claimed he wished the tutorial helped him with the challenged but not with the mechanics of the games.

Interface When asked about the interface of the game, the subject said that he preferred the 3D environment over the textual information presented on the panel. This is due to the 3D environment being more obvious with presenting the information than the textual information. When asked if the panel was useful he said that it was due to it containing the buttons mostly, otherwise if he wanted information on the prey and predators he depended mostly on the 3D environment. The markers that appeared during a hunting cycle were also useful in aiding the subject in figuring out how the different hunting methods worked.

Collaboration Both participants in this group are close friends, and tended to work together on projects and play games. He added that sometimes only brief hints or short discussions are needed between them because they have good synergy. He also commented that he preferred standing next to his friend rather than across since it felt less competitive. However, he also noted that they both felt awkward during the experiment due to the filming and the setting and therefore they both were less inclined to talk.

An interesting fact that popped up during their discussion while playing the game was that this subject was colour blind. When asked about this, the subject said it was no problem to play the game since his partner aided him by telling him the different colour's. It is also interesting to point out that during the experiment, the subject decided to take over changing the colour of the environment despite the fact that the other subject had been in charge of the button until then.

Additions to the game When asked for any additional features that the game should have, subject 1 suggested the addition of another prey and predator population to play with in the environment.

C.1.2 Interview: Subject 2

Overall Impression Subject 2 liked the game over all. He said that what he enjoyed was the control over the rabbits population and that after a few hunt cycles you can make your own population. He also enjoyed how you can control the hunting and the environment. In addition he commented that he thought that evolution was nicely represented in the game.

Interactive Table The subject found it fun to use the interactive table, due to the fact that it was different from using a computer, and he also commented that it was a lot more visual due to the large screen.

Tutorial Subject 2, found the tutorial easy to understand due to its simple explanation of what the buttons do. He also mentioned that, despite having done the tutorial, it still took some time to understand how each of the methods worked during the challenge mode. However, he did note that that was part of the game.

Interface In regards to the interface, the subject preferred the 3D environment as feedback over the textual information presented on the panel. This was noticeable during the experiment since looked more at the 3D environment. He also confirmed during the interview that he did pay more attention to the environment then the information on the panel. He said he occasionally glanced over to the information panel to check on the population of rabbits, that was because he did not want to count the rabbits manually. When asked if having one panel with controls and textual information was a problem, he declined since it was a fairly large panel and he did not feel the need to look at it apart from when he was using the buttons. He also found the hunting markers useful during the hunting cycle since it aided in visualising how the hunting method affects the prey immediately. To this subject, colour was the most visually obvious attribute that could change with the rabbits.

Collaboration When commenting on the communication with his partner he said that he always enjoyed working with him since they were friends and it was therefore easy to work with him. Working with a partner during this game aided him in gaining understand through discussing and helping each other.

Additions to the game Subject 2 thought that a future addition to the game could be to allow the player to affect the wolf population as well in order to introduce more complexity to the game.

C.2 Group 2

C.2.1 Interview: Subject 1

Overall Impression Subject 1 from group 2 enjoyed the game for several reasons. She enjoyed the idea of working together with someone and in general enjoys working in a team. In addition she liked the environment because it was simple and clean, and she could easily see what was happening which was aided by the size of the screen. One specific thing that she enjoyed was the control over the environment, along with the freedom of exploration the game gives you. However, the one issue she had with the game was that at times she thought she had completed the challenge when it actually was not. She felt that the criteria

for completing the challenge were unclear. She also noted that at first she did not realise you could close both panels and suggested that more emphasis the panels are used.

Interactive Table In regards to using the interactive table, Subject 1 had a positive response, repeatedly using the word '*cool*' to describe her feelings in regards to the table. She found that it was easy to see the information presented by the large screen. In addition, it was also the novelty of using a new technology she hadn't used before.

Tutorial Subject 1 said that the tutorial was easy to understand. When asked why, she admitted that at times, she actually did not pay attention to the tutorial and was therefore glad her partner did so he could point out things she missed. In addition she also suggested that there was no need for a tutorial for someone of her age, since it is fun to figure out how to use the buttons during the challenge phase. However, she did admit that being told how to use buttons was good information, since it can provide a feeling of certainty to the player on how to play the game. She did also note that this tutorial might be a lot more useful for someone of a younger age.

Interface When discussing the interface Subject 1 expressed her preference for the 3D environment over the panel with the textual information, because she found it more visually pleasing and colourful. She said that the 3D environment showed more useful information than the panel, such as the changes in the rabbits population. Out of the three attribute changes that could occur, subject 1 found the color changes to be the most visually obvious due to contrast, while speed was the hardest to see differences in. Aspects such as the hunt markers aided her to see what types of rabbits were being hunted, which gave her more information about how the hunting methods worked.

Collaboration Both participants decided to stay on either side of the table, unlike the first group. When asked if subject 1 had any issues with only having one panel available at a time, she declined. In fact, she said that it encouraged her to converse with her partner more and it was easy to share information between them. She also said that standing across from one another also induced communication between them, and that to her it felt normal and easier to stand on either side of the table, rather than next to each other.

Additions to the game Features that subject 1 would like to have added to the game are more levels similar to the impossible challenge, since she felt

like it gave you more freedom to discover and explore. Another suggestion was more preys and predators in one environment to interact with each other.

Last thoughts Lastly, when the subject was asked if she would have enjoyed playing a game like this in a classroom when learning she agreed. This is because she felt a level of excitement while playing the game, and stated that it is a fun way to learn.

C.2.2 Interview: Subject 2

Overall Impression Subject 2 thought that the game was a fun way to explore evolution and how those systems work in general. The reason subject 2 thought it was fun is because it was interactive, unlike when reading a book which you do not have influence over other than what information you read. Along with that, he commented that the model used to simulate the game was sufficiently complex and could surprise, you which he thought was good for this game. In addition, he thought that the collaborative aspect added to the game since it encourages you to think together. On the other hand, he disliked that he was not certain when the game checked whether or not they had completed the challenge and when mating season occurs. At times he thought they had completed the challenge when in reality they did not, which he found frustrating.

Interactive Table In regards to the table, subject 2 also had a positive opinion about it, mostly due to the novelty of using such a technology which he found fun and exciting.

Tutorial Subject 2 found the tutorial easy to navigate and understand since the concepts were clearly explained one by one, while at the same time the players were allowed to test out all the concepts alongside it. However, subject 2 found that he could have done with a shorter tutorial or that it could have been more 'playful', or in other words, make it more gamified than it already was.

Interface When it came to the interface presented to them, subject 2 said that for information he mostly focused on the 3D environment rather than the panel. If he thought that he was missing some information from the environment, he would look at the panel. Subject 2 found the information presented by the environment easier to grasp than it would have been if it were presented in pure text. When it came to the visual feedback of how the rabbit population changes, this participant found color the easiest change to notice while small

changes in the speed of the rabbits was harder to see. In addition, the visual feedback of the hunting cycle markers was useful to the subject, since it helped him to know how the population was affected immediately, which further aided him in anticipating failure or success with other strategies he had in mind.

Collaboration When it came to only having one panel available at a time, subject 2 said that that it could have caused problems since he was afraid of 'stealing control' away from his partner, and he would have liked the option of not asking for permission to press the button. However, when asked if he felt like having only one panel available incentivised discussion, subject 2 admitted that it did play a part in encouraging him to talk with his partner. It also encouraged him to offer control over the panel to his partner. However, he found that the main source of collaboration was discussing strategies on how to complete the challenges and which possible actions they should take and why. He also claimed that some things still would have been pointed out and discussed even if both of them had had a panel available at the same time. When it came to moving around the table, subject 2 found it inefficient and that it was nice to have one side of a table to himself. In addition, standing face to face to someone was a much more pleasant way to converse as opposed to standing side by side.

Additions to the game A feature that subject 2 thought might benefit the game in a positive way, is adding more interaction that doesn't just revolve around button pressing. This would make the game more interactive with the environment itself as well. He said that the statistics in the information panels should stay, since it did give more information if necessary but to focus more on making the game less about button pressing.

Last Thoughts Lastly, subject 2 said that he indeed would have enjoyed using this while learning about evolution, since it is, as he said earlier more fun than just reading information.

C.3 Group 3

C.3.1 Interview: Subject 1

Overall Impression Subject 1 from this group found the game fun, since she found it interesting to see what kind of rabbits you can make. In addition, connecting what each method does was also a fun part of the game. She liked the discovery aspect of the game. It was the notion of discovering how you can affect the population of rabbits and figuring out how to solve the challenges satisfied her sense of curiosity. The game was also easy to get into and it is not

easy to fail. She pointed out that if a game is easy to fail it can get frustrating. One thing she did not like in regards to the game, was that the menu covered up part of the screen when opened and that sometimes you could not see what is happening behind it unless you closed it, which she did not realise you could do at the start of the game.

Interactive Table Subject 1 found that using the interactive table was enjoyable, since it was nice to have a top down view of the environment. She said that it gave her a God-like feeling of control over a small world, which made her feel more immersed in the game.. The the screen of table was also was also visually helpful, since different elements were easy to see on the big screen and it allowed more room for different rabbits.

Tutorial Subject 1 found the tutorial easy to navigate due to its simple mechanic of clicking through the tutorial in a step by step guide. She said that the tutorial allows for an initial quick look at how the rabbits and wolves interact, which further aid you in figuring out how to approach the challenges.

Interface Like previously participants, she also preferred the 3D environment over the information panel. This was because she got most of information from the environment itself and did not feel the need to look at the panel for information. In addition, the notion of having a prey and predator interacting in a colourful environment was more fun to look at than numbers and text. Out of the three attributes of change in the rabbit population, subject 1 thought that the colors were the most noticeable right away, followed by size and then speed. Another important aspect of the game were the hunting markers that appeared during the hunting cycle. Subject 1 found them useful in identifying what type of rabbits were being hunting with which method, since it was easier to see which group of rabbits were being hunter rather than if they were not marked.

Collaboration Subject 1 admitted that she had a shy personality in general, which was visible during the experiment. When asked if she enjoyed working with her partner, she agreed and pointed out that having only one panel available at a time encouraged her to communicate more with her partner than she would have if 2 panels were available. This was because it gave her a feeling of needing to ask about the next step and a need to explain why she wanted to do something, rather than just doing it without permission. She confirmed that at the start she felt shy, but due to the necessity of needing to share information, she found herself feeling more comfortable as the game progressed. However, she did say that during the tutorial it would have been helpful to have the in-

formation available for both players, but other than that, using one panel was not a problem.

Additions to the game When asked about any additions of changes she would to the game subject 11 expressed a desire for more options for the bushes, so that they have more effect on the population and environment. She suggested this because she feels like it would add more to the discovery part of the game.

Final Thoughts Subject 1 already enjoys learning about evolution, however she said that she really enjoyed that the game allowed her to experiment and learn for herself. The moments where she figured something out and was correct were satisfying to her and made her happy.

C.3.2 Interview: Subject 2

Overall Impression Subject 2 also enjoyed the game, due to its colourful models and interactive environment. They also liked that it allows you to think about how each action affects the environment. The appearance of the game made it seem playful to subject 2. The freedom of trying out things on your own and come up with your own conclusions and connections, again was linked by subject 2 with the sense of discovery which her partner described. However, there were things that Subject 2 disliked about the game. Like subject 1, she thought that the panels could have been made smaller to cover less of the environment when opened. She also found the notion of 'big rabbits' ambiguous when it came to the first challenge:

"Is my idea of big the same as the game's idea of big?" She wanted to know what exactly the game defined as *big* rabbit.

Interactive Table Once again, the aspect of novelty was the reason why the participant found using the interactive table fun.

Tutorial Subject 2 found the tutorial easy to navigate and helped her understand each of the concepts of the game. She liked that the tutorial just told them to click and see what happens instead of telling them outright. She felt like this added to the experimentation part of the game. In addition, she liked that it was pretty short and that it gave you enough information to tackle the challenges. She did also make a comment that if there were no tutorial, it would take a longer to figure out how the buttons worked.

Interface As with previous participants, subject 2 also preferred the visual feedback of the environment over the textual one presented in the panels. She said that she looked at the environment most of the time, since it presented most of the information needed for the game. The change in the rabbits that was most obvious for her to see, was the change of color within the population. She found the hunting markers useful, since they helped her understand and connect how each of the methods worked. In addition, she also found it fun to watch a specific wolf chase a rabbit.

Collaboration Subject 2 was visibly less shy than her partner, but she still felt that having one panel encouraged her to communicate and interact with her partner more than she otherwise would have. She being face to face with her partner, since she felt that it is more natural to communicate and hence felt no need to move around the table. When asked if having one panel available was a problem, she disagreed. She said that as long as one of them read out the important information or discussed their actions with each other, having one panel was fine. She did comment that if one of the participants was less active there might be significantly less discussion because the other participant might decide to take full control of the game because their partner will not contribute to the discussion.

Additions to the game Subject 2 suggested the addition of other environment features to make the game more complex and interesting. One such suggestion was the idea of having the environment have different coloured sections, or even terrain such as grass that affect other attributes of the rabbits.

Final Thoughts Subject 2, when asked if she would have enjoyed having the game in her classroom when she was younger, she enthusiastically agreed, since it was a fun game that also teaches you about evolution.

C.4 Group 4

C.4.1 Interview: Subject 1

Overall Impression Subject 1 found the game fun and frustrating at the same time. They found the game fun because it presented interactive challenges that had concrete goals. Teamwork was also enjoyable for this participant, since they find communal work and figure things out together enjoyable in general. They felt that the game helped to encourage you in participating in the discussion, since both players have the same goal. The reason they found the game frustrating was due to the last challenge since it was impossible and they did

not enjoy trying to achieve a goal that gave no results. However, they did enjoy the feeling of freedom to test things out in the environment that the challenges encouraged.

Interactive Table Subject 1 found the interactive table fun due to the fact that they found it innovative in its use and enjoyed the futuristic design of the table.

Tutorial For subject 1 the tutorial was easy to navigate and understand due to its step by step set up. They thought that the information was presented linearly and all the tools were presented one by one in a concrete and concise way.

Interface Subject 1 found that the panel could be useful at certain moments (for example looking at the population size, when trying to kill off all the rabbits), but found that the 3D environment more useful and pleasing to look at. This was due to the fact that the environment gave you more information. They found that the mating season feedback given in the information panel was not obvious enough, even when paired with the visual information and would have liked more visual feedback that mating season was occurring in the game. Of the three attribute changes that occurred in the rabbits, Subject 2 thought that color was most obviously visible due to the contrasting difference in colors, whilst speed was most difficult to tell the difference between. Subject 2 also found the hunting markers useful when figuring out what group of rabbits was being affected by the hunting method, however they felt like there was no need to color code which rabbit was being hunted by which wolf and stated that this was unnecessary information. In their opinion, all the information that the markers should represent, is which group of rabbits as a whole is being hunted.

Collaboration Subject 1 told us that they were a person that liked teamwork in general, and commented that this game seems more fun to play with someone you don't know, allowing you to develop a team dynamic whilst attempting the challenges. They admitted that having only one set of information and limited controls for the two of them did encourage collaboration, since they needed to agree on the actions taken. In addition, they found that harder challenges induced more discussion, since it introduced more disagreements.

Subject 1 moved to stand on the corner where the panel was located. When asked why, they said it was due to wanting more control over the panel. They found that having one panel was no problem as long as they had some control over it. This is also noticeable when asked about the last challenges, where subject 1 admitted to getting frustrated at her partner and constantly discussing what to do next. They handled this by pressing the buttons to test out the

theories without waiting for her partners confirmation to do so. In the interview they confirmed that they did enjoy having most of the control of the game in her hands.

Additions to the game The participant claimed that the game was not balanced between the rabbits and the wolves and that there should be an aspect of a game that can also cause the wolves to die, such as a too small population of rabbits to feed the wolves. In addition, they also suggested more challenges with higher difficulty values.

Last Thoughts Subject 1 would have enjoyed having a game on an interactive table to learn as a preteen, however they expressed concern of young students 'going crazy' over the table and not understanding what was being taught.

C.4.2 Interview: Subject 2

Overall Impression Subject 2 found that the game was nicely designed and intuitive to play. He commented that he liked how the feedback of the different actions taken in the game were obvious and immediately shown to the players, and he was glad he did not have to wait a long time for it. He liked that it showed and visually explained the process of evolution. He did, on the other hand, dislike how the wolves would occasionally take a long time to catch a rabbit. In addition to that, he was not sure of the role of the bushes in the game and wished they had a more active role.

Interactive Table Subject 2 has had experience working on similar platforms like the interactive table and generally enjoyed using them.

Tutorial Subject 2 found that the controls were clearly explained and therefore the tutorial was easy to understand. However, during the tutorial, he was confused with what the role of changing the environment colour was. The role of this button made clear to him once he was playing the challenge phase. He did confirm that playing the tutorial aided him how to use the methods to eliminate the correct rabbits.

Interface Subject 2 claimed that he did not look at the information on the panels until they were trying to eliminate all the rabbits. He mostly watched what was happening in the environment, since it gave him more information than the panels did. For subject 2, the most visually obvious attribute change

in the rabbits was the color. Subject 2 confirmed that the hunting markers were indeed helpful with connecting how each hunting method affected the populations. Otherwise, he said he would have had to focus on one wolf and the single rabbit it hunts, while with the hunting markers he can see what group of rabbits were being hunted.

Collaboration Subject 2 had no problem with having one panel available due to the fact that his partner had simply walked over to his side to control and see the panel. He did find working with the partner fun, since they were enthusiastic and enjoyed discussing their actions. He felt that if he were to play this game on his own, he would not have gone as deep into thinking about what he was doing as he did with a partner.

Additions to the game Subject 2's suggestions for improving the game are to add a different selection of prey and predators for the player to choose from. He believes, that this would increase the variety of the game experience. He also thinks there is no need to add additional hunting methods, since in his opinion it is enough to get the message across.

Last Thoughts When Subject 2 was younger, he had a similar game to teach him about evolution, but it was done with pieces paper which he found interesting and fun. Therefore, he said that he would have also enjoyed having access to this game for learning about evolution.

C.5 Group 5

C.5.1 Interview: Subject 1

Overall Impression Subject 1 enjoyed that the game felt like a puzzle, since she had to connect the relationship between the hunting method and how the population of rabbits change. She also enjoyed that even after the tutorial you continue to learn how the game works. She said that discovering something for yourself is satisfying. However, at one point during challenge 3, both subjects thought that the colour of the background matches that of the rabbits, whilst in actuality they were a slightly different shade and thus did not complete the challenge. She commented that this caused frustration in both her and her partner.

Interactive Table Subject 1 found that using an interactive table was 'cool' because she had never used one before. She felt that it was a completely

different experience from using a computer and/or a tablet. In comparison, the table gave her a bigger and nicer overview of the game.

Tutorial Subject 1 found that the tutorial was not necessarily useful to her, since she had handed over the controls to her partner. She also commented that she thinks her partner might have gotten more of the useful information out of it. She also said that she did not understand the necessity or role of the in the game.

Interface Subject 1 found the information panel useful, however, she claimed that she mostly focused on the 3D environment, since it was easier to see more information than the panel. Out of the three attribute changes in the rabbits she found that size was the most visually obvious. She did not name color due to the fact that at one point they thought their population of rabbits was the same color as the environment but the game said it was not. When asked about the hunting markers, subject 1 said that they were useful in regards to giving them feedback on how their actions were affecting the environment. While also allowing them to watch which wolf hunted which prey and how they interacted, which she found amusing.

Collaboration When asked if only having one panel available at a time was a problem, subject 1 said that it was not, due to the fact that one person could always read out loud what it said. It also encouraged them to discuss their actions and reasoning more and helped them make plans what to do before one person presses a button. However, subject 1 commented that having one panel available during the tutorial was a bit of a problem, since she let her partner have it open. She mentioned that her partner has dyslexia and she did not want to pressure her partner into reading the information of the tutorial out-loud, but rather read it herself upside down. Another aspect that she felt had caused her to communicate more with her partner was the need to discuss a strategy or to clear up any uncertainties she had. Subject 1 enjoyed working with her partner since they were friends and tended to work together on projects in general. She liked working with a partner for this game, because sometimes one of them could see something the other could not and point it out. She thinks this game is best played with 2 people, since she feels that if she played it alone, it might not be as fun and it would be more difficult to solve. On the other hand, she advises not to have more than 2 people play the game at a time, since it might group together to many different personalities, which might be problematic.

Additions to the game Subject 2 suggested that the game should have a limited number of colours, since some colours were too similar to each other, making it difficult to differentiate them.

Last Thoughts Subject 1 says she would have enjoyed having this tool for her lower education, since it was a visual representation of a subject. She also thinks that learning in a gamified way is fun.

C.5.2 Interview: Subject 2

Overall Impression Subject 2 said that the game was nice and fun, due to its simple and easy to understand design. She enjoyed that the rabbits were cute and colourful, and was amused with how they moved in the environment. She said that she enjoyed watching the wolves trying to chase the rabbits, since it was amusing to watch them fail and run around. Like some other participants, she also mentions that the game allows an aspect of discovery, which makes playing the game and the topic it presents interesting. What she did not enjoy about the game was the length of time it could take to solve one challenge due to the mutations; if it takes too long it gets a little frustrating.

Interactive Table Subject 2 also enjoyed using the interactive table, since it is not something she can or has used on a daily basis before. She felt that it was more collaborative than when using a computer, since you can stand face to face with your partner rather than sitting next to them.

Tutorial Subject two found the tutorial useful due to its step by step explanation of how each button works. However, she did admit to not paying attention to how the hunting methods work in the tutorial. This made her take more time in challenge phase to figure out how the population of rabbits was affected.

Interface Subject 2 preferred the 3D environment over the panel, both to look at and as a source of information. She claimed that it was more pleasing to look at and it showed the more important information. However, she mentioned then if she wanted to check some information that she would glance at the panel. Subject 2, just like subject 1, thought that the size of the rabbits was the most visible attribute change within the rabbit population. She also found that the hunting markers were useful for making connection between the hunting methods and how it affects the rabbit population, which helped her 'connect the dots'.

Collaboration According to this subject, having one panel available was not a problem. In fact, she had earlier said that having one panel made her more aware of not wanting to be in full control. Therefore this encouraged her to share why she wanted to perform a certain action and make sure her partner agreed

with her. She also believes that if both of them had the panel available, that there would have been less discussion between the two of them. In addition, the fact that the game presents a common goal for both of them gave them reasons to discuss their action and try to achieve it together.

Additions to the game Subject 2 had one suggestion for an addition to the game and it was to add the option for the players to choose which species they wanted to play with, other than rabbits and wolves. She suggested this because she thought it would make the player feel more control of the environment and give the players a bigger sense of freedom.

Last Thoughts Subject 2, when asked if this is something she would have enjoyed using as a learning tool as a preteen, agreed because the game made the topic interesting due to its aspect of discovery.

C.6 Group 6

C.6.1 Interview: Subject 1

Overall Impression Subject 1, when asked what his impression of the game was, replied that it was okay. His answer was vague and his tone showed disinterest. He did say that he liked having to adapt their actions depending on the challenges, and that figuring out how solve them was fun. He said that if the game was straightforward, there would not be much to do otherwise. Despite saying that he enjoyed the aspect of figuring out what to do, at the same time he disliked the fact that he did not know how to accomplish the challenges given to him.

Interactive Table When asked if he enjoyed the interactive table, he said it has its flaws. This was due to an earlier described incident where he miss-clicked a button. He claims this happened merely because he waved his hand over the screen when in reality he had actually touched the screen.

Tutorial Subject 1 found the tutorial straight forward and gave him an accurate view about what sort of game he was going to play. When asked what made the tutorial helpful he said it gave him a basic understanding of the game and he was glad it didn't explain how to solve challenges before presenting them.

Interface Subject 1 said that he occasionally glanced at the panels, but preferred to try things out and look for the information presented in the environment over the panel. He preferred the visual environment, since the 3D models were easier to identify with, as opposed to if it were a purely text based game. This subject found that the color attribute of the rabbits was the most visually obvious change. Lastly, this subject found the hunting markers useful. Because, otherwise seeing which group of rabbits was specifically being hunted would have been harder to see and would not have been as helpful with solving the challenges.

Collaboration Subject 2 said that having one panel available may have had some influence on him talking more than usual. He admitted to preferring to figuring things out on his own and if he cannot, only then go to someone for help. He said that what also influenced him to communicate, was his partner starting up most discussions. He admits that he prefers competitive games and that it is how he 'works'. He also thought that having a partner was not necessary, despite saying that two people is better than one for problem solving and that having discussions can be motivating.

Additions to the game Subject 1's suggestion for additions or changes to the game was to make competitive instead. His idea was to have two information panels with two different goals for each of the player. He suggested this because he prefers competitive games. He also suggested to give the bushes more meaning in the game, rather than just controlling the population.

Last Thoughts When asked if he would have enjoyed playing this when he was younger, he said yes, though no further explanation was given.

Limitation This participant was very difficult to interview and it was difficult to get complete answers out of him. It was difficult to get him to explain his reasoning for some of the answers. This might have been influenced by the fact that subject 2, when recruiting them, had convinced him to do this experiment despite, not wanting to at first. It was noticeable in his attitude while playing the game and answering the questions that he just wanted to finish it as soon as possible and leave.

C.6.2 Interview: Subject 2

Overall Impression Subject 2 found the game difficult to figure out at times, but in spite of this still found the game fun due to the godlike feeling it gave

her. She felt in control of the environment and liked that she had a diverse way of impacting the game. She did not like the fact that one you figured out how the hunting methods affect the prey population, most of the challenges were easy to complete.

Interactive Table Subject 2 was fairly excited about using an interactive table, due to never having used one before.

Tutorial Subject 2 found the tutorial easy to navigate, and found it helpful that it showed you how to use the buttons in a step-by-step way. She did admit that the tutorial did not help her in making connections between the hunting methods and how they affects the prey population, since she did not pay attention to that during the tutorial. She did point out that, later on during the challenge phase of the game, her strategy for completing the challenges was to try everything and figure it out from there.

Interface Subject 2 admitted to not even looking at the information panels since, she was more focused on watching the animals move in the environment. She also found that the environment gave more information, along with, being more attention grabbing than the panel, due to its colors and 3D models. She also claimed that the color changing within the prey population was the most visually obvious while speed was the least obvious. The hunting markers, according to her, were also useful in pinpointing which rabbits were being hunting and figuring out when and how the rabbits were being affected. It also added an interactive element to the game by allowing the players to track the wolves hunting the rabbits, which sometimes added funny moments.

Collaboration Subject 2 found that having only one panel available for both of them, rather than having two increased communication, especially when it came to pushing the button and why a certain button should be pushed. She did not think that having one panel available was a problem. In fact, she claimed that if they both had a panel, they would have made actions without discussing with the other first. In addition to having one panel, the subject points out that seeing different and funny things occur in the environment also prompted her to start some discussion. At one point, the two participants reached a disagreement, which caused their discussion to go on for a longer time. The subject first claimed that this was why she feels like their cooperation was bad. However, when it was pointed out that it did cause them both to discuss the subject in length, subject 2 did agree that the sharing of ideas and reasoning helped her and she retracted her previous statement.

Additions to the game Subject 2 suggested that the game should have more populations of the prey and predator, which will make the game bigger and more challenging. This is because in her opinion, once all the connections are made, the game becomes too easy.

Last Thoughts Subject 2 was very enthusiastic about using the interactive table, and said that she would have enjoyed using it as a learning tool during secondary education.