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| Kingswood School |
| Survival of the fittest teaching aid |
| Comp4 project |

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| --- |
| 01robinson |

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**Further work required to Analysis section**

xxx – further work needed

How to choose ant simulation part (as this has no technical reasons and is purely biology related)? Should this be mentioned in the problem background?

Explain ant simulation? (e.g. how can change the ant’s properties to change how long it survives for) Where should this be done? Should I explain why this is being done?

Describe the concept of logging in as no password will be needed only the class ID and the pupil’s ID, these should be secret but do not need to be secure as gaining access to a pupils account is not dangerous. Also the teacher’s login dose require a password but just the class ID as the user name, as the teachers account if accessed dose leverage privileges.

More comparisons with current systems?

Need to show that the simulation is the main project and that the teacher’s admin interface and the pupils score board are features of the simulation (not the main project)

# Section 1: Analysis

## The problem: identification and background

### Problem identification

The problem which is addressed in this project is that of developing a computer-based tool which will enable secondary school teachers of Biology at a school in Bath to illustrate how evolution occurs in a population. This problem was identified from interviews with Biology teachers which found that the subject of evolution is difficult to teach to younger pupils (aged around 12-13).

These interviews have shown that pupils in this age range find it difficult to grasp the abstract ideas of evolution as this involves following an argument with several stages to it and a number of novel concepts such as ‘genes’, ‘mutation’, ‘selection’ and ‘inheritance’. The interviews also found that presentations and handouts failed to capture the dynamic nature of evolutionary change and failed to ‘bring it to life’. Further, due to a shortage of suitable tools and materials it is difficult for teachers to set meaningful classroom exercises on evolution and to encourage pupils to do independent learning outside of the classroom.

As a result of these problems in teaching the subject teachers have found that some pupils can have misconceptions about natural selection. For example, some pupils persist in believing in Lamarckism - the idea that an organism can pass on characteristics that it acquired during its lifetime to its offspring. It was felt, in the interviews, that a computer-based tools could enable pupils to have more of a ‘hands-on experience’ and could be an excellent way for pupils to understand for themselves why ideas such as Lamarckism are wrong - rather than being taught simply that they are wrong.

Online research and face-to-face interviews with teachers (see Appendix A for details) has shown that there are many types of videos, handouts, presentations and other written materials currently available for school teachers on the subject of evolution. In addition, there are some computer-based tools which simulate how evolution occurs and which can, for example, allow different timescales and types of populations to be selected and different simulations to be run. These computer-based tools are evaluated and a new solution is developed in this project.

### Teaching context

The teachers in question are two Biology teachers who each have two classes a year of 15 – 20 mixed ability twelve to thirteen year olds. Evolution is taught as part of a Combined Sciences course in an introduction to the natural world and two 40 minute lessons are devoted to it. In these lessons the teachers cover the following:

* Definition of evolution.
* An overview of how it occurs – differences within a population, natural selection, timescales.
* Examples – could include a reference to Darwin, the Galapagos Islands and well-known examples such as Darwin’s finches or the evolution of butterflies in contemporary Britain.
* What evolution is not – Lamarckism.
* Lessons are a mixture of explanation, taking questions and using video or written materials to illustrate the subject.

Computers with internet access are available during lessons with one computer for every pupil.

## Description of available tools

Description of current system? Should this be put in feasibility studies?

The two Biology teachers who have been interviewed are not currently using any computer-based simulation tools as part of their lessons on evolution. However, some tools do exist and this section assesses the leading examples.

The examples discussed cover tools focused on evolution as well as those focused more broadly – for example, on the impact of disasters on animal populations. The table below summarises the tools which have been assessed.

|  |  |  |
| --- | --- | --- |
| **Name** | **Description** | **Assessment** |
| **“Who Wants to Live a Million Years?”** | * Focused on evolution * Learning and simulation sections * Shows impact of a change on a population and the effects of natural selection | * Learning and simulation sections * Poor treatment of mutations * Poor representation of gradual evolution processes * Not very engaging/fun * Minimal user interaction |
| **“Stop Disasters!”** | * Focused on disaster prevention * Shows the impact of disasters | * Engaging * Good level of user interaction * Good information and links * Encourages further learning |
| More to be added |  |  |

The tool “Who Wants to Live a Million Years?” (<http://science.discovery.com/games-and-interactives/charles-darwin-game.htm>) is an example of an independent learning tool to help teach the concept of evolution. It is a flash based web application aimed at teaching the basic concepts of evolution by demonstration. The tool contains a learning section and a simulation section. The learning section shows the user both text and pictures in a fun, animated way to help engage users. The simulation section allows the user to choose a starting population and then demonstrates a change in environment (new predator, natural disaster) to show how only those best suited to the new environment will survive and reproduce while the others will not. The simulation takes x minutes to complete and involves …..

The simulation gives a misleading representation of natural selection as it presents mutations as a non-random event (as user driven while in reality they are totally random and cannot be chosen). The simulation is also not very engaging, there is minimal user interaction (which does not make it fun) and it does not encourage users to look further into the concept of evolution.

Another example of a web application based in flash is “Stop Disasters!” ([http://www.stopdisastersgame.org](http://www.stopdisastersgame.org/)). The focus of “Stop Disasters!” is not evolution but a broader simulation tool which can be used to teach students about disaster prevention in geography. The simulation takes xx minutes to run and involves … It is much more engaging then “Who Wants to Live a Million Years?” as it allows the user to interact with it – for example, by xxxx. The simulation demonstrates why things happen not just how and also encourages users to read more about the subject area using facts and links to additional information and simulation. Overall, “Stop Disasters!” provides a good model to study when creating a similar tool for simulating natural selection.

More examples to be added

In summary, the current tools which have been analysed have a number of advantages and disadvantages and none have been judged to meet all the relevant criteria. While “Who Wants to Live a Million Years?” is focused on evolution it has a number of drawbacks in the user experience. “Stop Disasters!” has a better user experience, being fun and informative and with significant user interaction, but is not focused on evolution.

## Identification of prospective users

Two types of users of the system have been identified – teachers in the classroom and pupils.

Teacher users are teachers of Biology who conduct classes for 12-13 year olds at Kingswood School in which an introduction to evolution is required. Class sizes are from 10-15 pupils. The teacher users have good knowledge of computing and applications but are not IT specialists. Teachers will use the tool to demonstrate the basic concepts of evolution to the pupils, and will act as an administrator for the tool.

Pupil users are aged 12-13, are of mixed ability and have already had some background in science. They lack any detailed knowledge of evolution, although they have heard of it, and are likely to find the idea challenging. The pupil users know how to follow simple instructions on a computer and use simple applications. Pupils will use the tool to see how concepts of evolution taught to them in the classroom relate to the real world.

## Identification of user needs and acceptable limitations

Analysis of user needs and acceptable limitations has been undertaken for both sets of users – teachers and pupils.

### User needs – teachers

Teachers require a tool that quickly and easily illustrates the concept of evolution in a manner that is understandable and interesting to children and which is easy to administer. Teachers’ more detailed requirements are:

1. A tool which **illustrates the concept of evolution**. This concept is summarised in Appendix B. The main ideas of the concept of evolution should all be covered:
   1. Organisms have genes which determine their makeup.
   2. As a result of the mutation of genes, variations capable of being inherited exist within populations of organisms.
   3. Organisms produce more offspring than can survive.
   4. These offspring, with their different inheritances, vary in their ability to survive and reproduce.
   5. In conditions with competition between organisms for survival and reproduction those organisms with traits that give them an advantage over their competitors pass these advantageous traits on, while traits that do not confer an advantage are not passed on to the next generation. AS a result we have the ‘survival of the fittest’.
   6. As a result species change over time – they change or may even die out.
2. As a teaching tool there **should not be a steep learning curve** as this defeats the point of simplifying the teaching of the concept.
3. As the tool is for teaching it **must be an accurate illustration** of the concept of evolution.
4. The tool should provide a **simulation involving movement** since evolution involves dynamic change and a static tool would not be appropriate.
5. As the tool is used as both a teaching tool and a tool to prompt independent learning/further study into the subject area by pupils the tool must be able to be **used within the classroom** (or computer room) as well as **by the pupils in their own time or for homework at home**.
6. The tool needs to be **able to be used by 12-13 year old pupils**, either individually or in small groups, and must be **extremely simple to use** with minimum tutoring required
7. **Setting up and running a simulation should take no more than minutes** by pupils.
8. The tool must be **portrayed in a way to best engage this age group** with any linking content suitable for this age group. The tool must be fun and engaging.
9. All pupils in the classroom and outside the classroom should have **equal access to the tool** and there should be **no minimum system requirements** (e.g. owning a smart phone), so that everyone can use it.
10. When first introduced, **the tool must be demonstrated by a teacher through a projector** so that the pupils can get the most out of the tool and so that it is used correctly and all features used to their maximum effectively.
11. The simulation should **not be expected to be completely accurate** and approximations may be made so not to increase the complexity of the simulation beyond the scope of the teaching.
12. Teachers require a **simple administrator’s user interface**.

### User needs – pupils

The specific needs of pupils are as follows:

1. The tool must be **suitable for 12-13 year olds** in terms of the complexity of content and the ease of use.
2. It must be **fun and engaging**.
3. It must be capable of **communicating clear learnings**.
4. It must be capable of being **accessed by all pupils**.

More limitations (on ant simulation?)

More specific limitations (e.g. 800x600 projector) to show specific to end user

## Data sources and destinations

There will be two main data sources & destinations within the tool:

1. The teacher will input names in the system to be used as logins for the pupils. There will be 10–15 names, and these will be stored and also outputted on the admin interface so that the teacher can check each name. There will be minimal processing on this input just checking that they are unique.
2. The pupils will input values through buttons and sliders into the simulation via the user interface. The values selected will be used to change how the simulation runs and will therefore require heavy processing (running through the simulation). The simulation will output the result in an animation onto the screen.

## Data volumes

There will be two teachers who will each use the tool for half a lesson (22 minutes) and prep once a year. While using the program the 10-15 pupils will update the simulations values once every 20-30 seconds on average. The teacher will update the pupil’s names once every year. The 10-15 pupil names stored through the system will be no more than ⅓ kilobyte on the disk.

Users score, admins login

## Analysis Data Dictionary

The table below shows …..

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Type** | **Description** | **Relationships** |
| **Score** | 32bit integer | Contains the highest score a pupil has reached, defaults to 0 |  |
| **Last login date** | Datetime date 8 bytes | Contains the last login date of the user, defaults to? |  |
| **User ID** | <20 character string | Contains a unique identifying string for each pupil in a class i.e. first name + last name initial. Chosen by teacher |  |
| **Class ID** | 16bit integer | A globally unique integer to identify the class |  |

## Data Flow Diagrams

### Entry relation diagrams

This is not applicable to my project.

### Object analysis diagrams

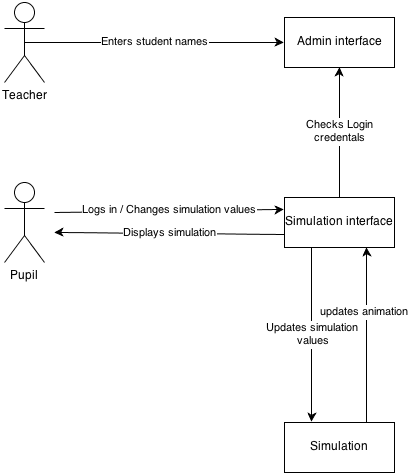


Figure - Object relationship diagram

Is this the correct diagram, is there more that can be added, how to model processes like login?

Should the ant simulation be included in the diagram?

## Objectives for the proposed system

Should this include objectives for the ant simulation? (e.g. chemical trials, terrain simulation, certain attributes, random mutations….) Or should this just be for the interface (e.g. allow login, admin panel, high score board…) or both?

### Ant simulation objectives

1. The simulation should be able to generate realistic (e.g. has a gradient) random food placement.
2. The simulation should be able to create random maps (food and obstacles)
3. The ants should have variable basic characteristics Including:

3.1. Speed the ants move

3.2. The lifespan of the ants

3.3. The reproduction rate

3.4. The amount of food ants are able to carry

3.5.

1. The simulation should be able to introduce random mutations and events such as natural disasters into the system to change the environment (so pupils can see how the ants must suited to the environment will survive).
2. The simulation should model energy intake from food needed for ant to survive depending on the size and speed of the ants so not to make it unfair.
3. The simulation must model a nest.
4. The simulation must model basic types of ants (e.g. worker, queen, solider).
5. The simulation must be able to model fighting of ants.
6. The simulation must run smoothly on [system requirements] systems as well as the average speed home computer.
7. The simulation must model fermion trails including:

10.1. Their creation when an ant is moving

10.2. Their evaporation due to conditions

10.3. How ants respond to the trials

10.3.1. Following to find food.

10.3.2. Avoiding exploring.

10.3.3. Following back to nest.

10.3.4. Detecting invaders.

### Simulation interface objectives

1. xxx
2. xxx

### Admin Interface objectives

1. xxx
2. xxx

## Appraisal of potential solutions

### Smart phone app

A smart phone app written in Java (android) or Objective-C (IOS) which would run the simulation on the phone and then connect to a remote server for login and keeping the highest score of each user. The teacher could have a password protected access to an admin panel within the app to add and remove users and to check that all of the pupils had logged into the system.

This would fulfil the majority of the requirements due to a smart phones portability it can be used both inside and outside the classroom. Phones are also internet enabled so logging into a remote server would not be a problem (unless they had no signal). The age group would already be familiar with the concept of apps and so would be familiar with the interface. And smart phones are powerful enough to run a complex biological simulation and so keeping the simulation accurate would not pose any difficulty.

Although, not everyone has a smart phone and so not everyone in the class would be able to use it. Furthermore due to the fragmentation of smart phone apps you would need to write the same app for multiple different architectures (IOS, android …) thus making the project even more complex. Lastly if the exercise is done in class there would be no way to know if the pupils where using the tool or using their phones for another use.

### Web application

A web application written in HTML5 and JavaScript again with a server side database is another solution. Using the web is a great solution as you know they will have internet and so logging in would not be a problem. People are very familiar with web application interfaces and so there would be a shallow learning curve. A more usual form factor for an admin interface could be used (a webpage). There would be little issue with cross compatibility as both html and JavaScript are web standards and implemented in all Morden browsers. What’s more the speed of JavaScript has increased dramatically and so it is fair to assume that an accurate simulation would be able to run smoothly. Access to the tool would not be a problem as almost everyone has access to a computer (i.e. school computer lab) thus for filling the users requirements.

However the complexity of the project may increase due to the use of multiple languages [language for server backend? Ruby on rails, php, nodejs], a server backend would be needed to control the user logins and also the admin panel and a separate language for the simulation inside of the browser.

### Desktop application

A desktop application written in C++ with a server backend could be used. Again this would be great as the simulation could easily run due to C++’s speed and also access to a desktop. A special login protected admin panel within the application could be used by the teacher for adding and removing pupils. A connection to a server could be used to update the scores in real time. Like the web application in (HTML5, JavaScript) it could be used by everyone at home or in the classroom for filling the end users specification.

Although the application would have to be cross compatible between the major Operating Systems (Windows, Mac and Linux) in order to make sure everyone could use it on their machine. Furthermore the increased setup time of tool would make it less user friendly (i.e. user must download and install the program).

### Pen and paper simulation

A non-technical solution to the problem would be to create a set of rules and then uses counters on a gridded board to simulate how the ant’s behaviour would change depending on depending on their input values. Random mutations could be introduced by using a die. This would fore fill many of the limitations although may require much more work to setup and may also not be as engaging as other potential solutions.

## Justification of chosen solution

The chosen solution would be an ant simulation written in JavaScript on a website hosted by a server which is running a database which would collect the high scores of each of the pupils and also would record their last login data, the information would be accessible by teacher (admin) and a high score board would be available to the pupils.

The solution was chosen due to cross compatibility between devices (i.e. it can work on any internet enabled platform). What’s more there would be a very shallow learning curve as everyone knows how to use the web.

relate justification to objectives and user requirements

Survey/interviews

Analysis of current systems/observation

# Section 2: Design

## Overall system design

## Description of modular structure of system

## Definition of data requirements (Design Data Dictionary)

## Description of record structure

## Validation required

## File organisation and processing or database design

## Sample of planned SQL queries

## Identification of storage media

## Identification of suitable algorithms for data transformation, pseudo code of these algorithms

## Class definitions (diagrams) and details of object behaviours and methods

## User interface design (HCI) rationale

## UI sample of planned data capture and entry designs

## UI sample of planned valid output designs

## Description of measures planned for security and integrity of data

## Description of measures planned for system security

## Overall test strategy

# Section 3: Technical Solution

# Section 4: System Testing

# Section 5: System Maintenance

# Section 6: User Manual

# Section 7: Evaluation

# Appendix A: Availability of Teaching Materials on Evolution

### Online research

The following sources illustrate the types of materials which are available for school teachers on the subject of evolution and related subjects (such as conservation).

|  |  |  |
| --- | --- | --- |
| **Website** | **Materials available** | **Assessment** |
| http://www.arkive.org/education/  (searched 2/10/13) | * Presentations, teacher notes and spreadsheets on numbers of Finch variations in the Galapagos Islands and on peppered moths * Aimed at 14-16 and 16-18 age groups | * Focus on conservation * Attractive materials * No online or computer simulation tools on evolution but some data which can be used in classrooms |
| More to be added |  |  |

### Interviews

Two interviews with Biology teachers have been conducted at Kingswood School, Bath. The findings were as follows:

* xx
* xx

Additional interviews will be undertaken with teachers at other schools.

# Appendix B: Evolution – the main concepts

From Wikipedia – entry on ‘Evolution’

“Evolution by means of [natural selection](http://en.wikipedia.org/wiki/Natural_selection) is the process by which genetic mutations that enhance reproduction become and remain more common in successive generations of a population. It has often been called a "self-evident" mechanism because it necessarily follows from three simple facts:

* Heritable variation exists within populations of organisms.
* Organisms produce more progeny than can survive.
* These offspring vary in their ability to survive and reproduce.

These conditions produce competition between organisms for survival and reproduction. Consequently, organisms with traits that give them an advantage over their competitors pass these advantageous traits on, while traits that do not confer an advantage are not passed on to the next generation.

The central concept of natural selection is the [evolutionary fitness](http://en.wikipedia.org/wiki/Fitness_%28biology%29) of an organism.[[96]](http://en.wikipedia.org/wiki/Evolution#cite_note-Orr-96) Fitness is measured by an organism's ability to survive and reproduce, which determines the size of its genetic contribution to the next generation. However, fitness is not the same as the total number of offspring: instead fitness is indicated by the proportion of subsequent generations that carry an organism's genes.[[97]](http://en.wikipedia.org/wiki/Evolution#cite_note-Haldane-97) For example, if an organism could survive well and reproduce rapidly, but its offspring were all too small and weak to survive, this organism would make little genetic contribution to future generations and would thus have low fitness.

If an allele increases fitness more than the other alleles of that gene, then with each generation this allele will become more common within the population. These traits are said to be "selected *for*". Examples of traits that can increase fitness are enhanced survival and increased [fecundity](http://en.wikipedia.org/wiki/Fecundity). Conversely, the lower fitness caused by having a less beneficial or deleterious allele results in this allele becoming rarer — they are "selected *against*". Importantly, the fitness of an allele is not a fixed characteristic; if the environment changes, previously neutral or harmful traits may become beneficial and previously beneficial traits become harmful. However, even if the direction of selection does reverse in this way, traits that were lost in the past may not re-evolve in an identical form.”