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What do upper secondary students learn about evolution from an animation of antibiotic resistance?

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Titel
Vad lär gymnasieelever om evolution från en animering om antibiotikaresistens?

Title
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Författare

Andreas Göransson

Sammanfattning

Biological evolution can be described as a unifying concept in biology. A thorough understanding of evolution is thus important to fully understand different areas of biology. However, learning the concepts of evolution has proven difficult, both to students and teachers. During the last decade, the notion of threshold concepts in learning has emerged. Passing the threshold or grasping the threshold concept is a transformative process, thought to be irreversible and has been described as passing a portal to new areas of understanding. Threshold concepts of importance to understanding evolution has been suggested to be time, spatial scale, complexity, randomness and probability. A hypothesis is therefore that facilitating understanding of those threshold concepts also will lead to a greater understanding of evolutionary mechanisms.
Visualisations in science communication and learning has gained increased interest and animations as a form of visualisations has proven to facilitate learning in some situations. Since many (threshoid) concepts in evolution are untangible, such as deep time, small scale (micro and sub micro scale) animations could be a way to make those concepts more tangible for learners. In order to explore the potential for animations in learning evolution by making threshold concepts more tangible an interactive animation was designed and tested with upper secondary students in the course Biology 1. The subject of the animation was development of antibiotic resistance in bacteria.
Learning effect was measured as differences in pre and post test scores on a selection of previously used concept questions from the literature, the concept inventory of natural selection (CINS). Open ended questions were also used as well as interview sessions, to gain more insight to the eventual effects of the animation.
No statiscally significant improvement in the CINS scores could be observed in total, however improvement on a specific question category (biotic potential) could be observed. The number of misconceptions on evolution seemed unaffected after animation. Indications of conceptual conflicts could also be observed after the animation, indicating a potential for conceptual change with future revisions of the animation.

Nyckelord
Threshold concepts, evolution, learning, visualisation, animation, antibiotic resistance, biology

Contents

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Introduction

Evolution has been described as the grand unifying theory of biological science (Dobzhansky 1973). First proposed as a theory by Charles Darwin in the 19-th century and later refined into neo-darwinism with the synthesis of Mendelian genetics, molecular research and evolution by Ernst Mayr during the mid 20th century, it forms the foundation of modern biology. It is invaluable as an explanatory framework for things like animal behavior, plant physiology, physical appearance of different flowers, drug resistance among bacteria, to name a few (Mayr 2001, p xii, 267).

Due to this explanatory value it is of great importance to find effective ways of teaching and learning evolution. Also, from a society standpoint, knowledge of evolution is of great importance among the public given contemporary examples as antibiotic resistance, pest control and genetically modified organisms (Futuyma 1995). Unfortunately, the learning of evolution and associated concepts has proven difficult for students regardless of study level (Brumby 1979, Bishop & Anderson 1990, Gregory 2009, Nehm & Reilly 2007, Ross et al. 2010). Even teachers themselves has been found to possess incomplete conceptions of evolutionary mechanisms such as adaptation and natural selection(Zetterqvist 2003). Thus, an important research area is to find ways in facilitating understanding of the mechanisms of evolution. During the last decades, visulisation in the area of natural sciences has gained increased interest in research and learning, and this work tries to explore animations as a means of learning natural selection.

It might be argued that the swedish public has a relatively high level of belief in the theory of evolution (over 80 %) (Dawkins 2010) but this is not equivalent to a correct understanding of the evolution per se. A belief in evolution does not help us understand why precautions with antibiotic usage is of outmost importance, for example. In conclusion there is a need for improved learning and communication of evolution.

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Aim of the study

Evolution is difficult to learn but of great importance in biology education as well as in everyday life. The aim of the study was to assess the learning outcome on evolution after an intervention with an animation. The animation was intended to make certain stipulated threshold concepts more concrete for the learners (time, origin of variaiton, randomness and natural selection) in order to test the hypothesis that this will facilitate grasping the concept of evolution.

2.1 Research question

Can an interactive animation focusing the threshold concepts biotic potential, time, origin of variation, randomness, probability and natural selection facilitate learning of evolution by natural selection?

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Background

3.1 Biological evolution

Though evolution is not the main focus of this thesis, a short introductory summary to the theory is given here in order to acquitance the reader with the topic. The evolution builds on a number of observerable facts about living organisms:

1. There is an existing variation among organisms, not all individuals in a population are alike.
2. An excess in offspring is produced in each generation
3. Limited resources is avalaible from the environment (e g food, shelter etc)
4. Differences (variation) in traits affects the probability of an invidual surviving and proliferating
5. This leads to an altered frequency of different traits in next generation

The variation in traits ultimately originates on the molecular level or sub-microscale. This is due to random changes in the DNA-molecules of an organism (the DNA bears all the hereditary information). These random changes can occur through mutation or cross-over. An important distinction to make is that mutations are random with respect to function but not in localisation on the chromosomes. The variation in genetic information can produce different physical characteristics as well as differences in function of an organism. These characteristics and functions affects the survival probability of an organism in combination with a given environment This is termed *fitness* by biologists. The environment is limited in resources for organisms to utilize, hence all organisms can not survive and multiply, this was termed the *struggle for existence* by Darwin. (Though metaphorical and elegant, this term tends to lead to confusion and misconceptions and has given Darwinism a bad reputation sometimes. In this thesis the term struggle for existence or Darwinism is accordingly avoided in favour of evolution and limited resources / differential survival.) Thus, a change in environment can lead to an altered probability of survival for a individual with a specific trait. Since genetic information in the DNA is passed on to the offspring (heretability) this difference in survival inevitably leads to a higher probability of some traits occuring in the next generation. This was termed *natural selection* by Darwin. It might be in order to stress that natural selection is far from the only mechanism in evolution, though perhaps the most important one. Others are for example genetic drift and bottleneck effects. The differential survival rate in combination with the existing variation thus leads to that the surviving individuals are more adapted to the environment than their non surviving competitors. The term *adaption* is used for this process sometimes and this term might induce misconceptions, as discussed later in this report.

3.1.1 Evolution in the swedish secondary school curricula

In the curricula of the upper secondary swedish school, evolution is mentioned explicitly in the subject description of biology (aims of the subject)

> *Teaching should give students the opportunity to develop a scientific perspective of the surrounding world based on the theory of evolution.*

The outcomes of the biology subject also mention:

> *Knowledge of the concepts, models, theories and working methods of biology, and also an understanding of their development.*

(Skolverket 2011)

The subject of biology is comprised of several courses. In the course Biology 1 which the experiment group in this study was taking, the following core content regarding evolution is mandated for inclusion:

- Scientific theories about the origins and development of life.
- Evolutionary mechanisms, such as natural selection and sexual selection and their importance in speciation.
- Behaviour of organisms and the importance of behaviour for survival and reproductive success.
- Taxonomic systems and principles for classifying organisms. Main groups of organisms and evolutionary history.
- Development of biology with emphasis on evolution.

In addition, specific instructional methods are called for:

> *Field studies and research in ecology, including the use of modern equipment.* ***Simulation of evolutionary mechanisms e.g. natural selection.*** *How organisms are identified. Microscopy in studying cells or cell division.*

Conclusively, there is an emphasis of evolution in the curricula and also on the usage of tools such as simulation in the conjunction with the topic of evolution. Thus, there is a need for research in the field in order to find effective tools to learn evolution from.

3.2 Why is evolution difficult to learn?

Biology as a science differs a great deal from the physical sciences such as chemistry or physics. The difference is mainly the biology concerns the study of living, complex systems that behave in a non-deterministic way (Mayr 2001). These differences seem to give rise to a number of misconceptions regarding biological processes such as evolution. Gregory (2009) suggests a number of reason for difficulties in learning evolution: acceptance of evolution as a historical fact, lack of formal education in biology and robust misconceptions of evolution in part due to everyday view of the nature and in part to the ideas about scientific nature. These misconceptions can arise from the fact that we tend to rely on rules of thumb in our everyday lives, rules which can both help and hinder thinking. For example, we tend to think that things are designed or there is a purpose with everything that happens in nature, when there in fact is not. This way of thinking causes different types of cognitive constraint associated with learning evolution:

- essentialist constraint
- teleological constraint - tend to think there is a purpose behind mutations, change in characteristics - i e bacteria mutates so they can survive
- intentionality constraint

(Sinatra et al. 2008, Gregory 2009)

Essentialism

Essentialism can be described as the idea that there is an essence or hidden force in a species, hindering a deviation too far apart from the characteristics for the species. For example rabbits has som hidden property that make them rabbits and nothing else. By this kind of reasoning one fails to recognize the importance of individual variation among rabbits in a population and tend to think that rabbits can not evolve into a new species (Sinatra et al. 2008, Gregory 2009).

Teleological reasoning

Teleological reasoning has found to be common among children. Teleological reasoning ascribe purpose of features found in nature, for example rocks are pointy because animals need to scratch themselves. In evolutionary context this can be found in reasoning such as change in individual properties due to a need to survive. (Sinatra et al. 2008, Gregory 2009).

Intentionality and antropomorphism

This misconception is connected to teleological reasoning and extends it further by the idea that changes in traits occur not only with a purpose but also at will from the organism (Sinatra et al. 2008). A more elaborate version of intentionality is the idea of directed mutations, i e that a mutation occurs in response to a need for change in order for an organism to survive. Though seeming a bit alien for biologist today, this was actually an area of active research during the 1940:s. The idea was abadoned by the scientist in favour of random, non-directed mutations after Luria and Delbruck's elegant experiment in the (Luria & Delbrück 1943). Luria and Delbruck was able to design and perform an experiment to test whether bacteria mutations leading to resistance to viruses (phages) was induced from the presence of phages themselves or was present before exposure to the phages. Still, the idea of mutations being induced from the environment might arise as a consequence of intuitive reasoning by students. Of course, in an everyday sense, it might seem more plausible that mutations that are needed for specific changes in traits leading to greater survival are caused by a change in environment. Indications of this kind of reasoning was seen in this study and in the discussion section we suggest ways of dealing with this specific misconception in the context of animations.

The process of understanding evolution is, as mentioned earlier, an especially difficult one. It is not only dependent on several concepts that are counterintuitive, an understanding of evolution also has ontological consequences. Human thinking is often flawed with the notion of intentionality or design, not seldom extending to include naturalistic phenomena. Abandoning this view of nature or reality is therefore of deep emotional and ontological consequences.

Use and disuse

Though not a part in this study, this misconception is worth mentioning for sake of completeness. The idea is that evolutionary change is a reflection of use or disuse of a organ. This idea was put forward by zoologist Jean Baptiste Larmarck as his *First law* (Gregory 2009). An example of this way of thinking is ascribing the loss of eyes and pigmentation in troglobites (such as cave salamanders) due to disuse of these features. In fact these changes posed challenges in explanation by evolutionary biologist, nevertheless they are simply not due to disuse but to other factors such as genetic drift and complex gene regulation. (I wonder if this misconception is just another facette of the need-based thinking, since use of an organ could be coupled to coping in a specific environment. Probably the problem could be reduced to a common single line of thought: environment poses challenges in survival thus forcing the appearance of new traits).

Soft inheritance

Sometimes incorrectly termed *Lamarckism* in the literature this idea explains evolution by acquisition of traits by individual, traits that are supposed to be carried on to the offspring by inheritance. However, this idea is erronous simply because a change in a somatic cell can not be transferred to a gene in a germ cell. (This certainly doesn't get more easy to teach as research find new nuances such as epigenetics and complex gene regulation patterns are discovered by scientist).

3.2.1 Language and learning evolution

Misconceptions not only arise from reasonin but also from our use of language. Even professional biologists and teachers tend to use everyday language, metaphors and analogies (with the best of intentions of course), to facilitate understanding. However, many concepts has a radically different meaning in science than in everyday life, making misconceptions a likely consequence. Take for example the notion of adaption. Adaption is used in the sense of intentional modification in our everyday language. In the context of evolution, it simply means a consequence of the laws of nature, not by any means something intentional. Thus, we must be aware of both difficulties in terms of language, concepts etc and emotional and affective challenges when aiming for effective methods of teaching evolution. The issue of misinterpretation due to the difference in scientific versus everyday meaning of specific concepts was at debate already in Darwins lifetime. For example, Wallace pointed out in a letter to Darwin that he was troubled with Darwins choice of the term *natural selection*:

> *I have been so repeatedly struck by the utter inability of numbers of intelligent persons to see clearly or at all, the self acting & necessary effects of Nat Selection, that I am led to conclude that the term itself & your mode of illustrating it, however clear & beautiful to many of us are yet not the best adapted to impress it on the general naturalist public. (Wallace 1866)*

What Wallace was worried about was that Darwins antropomorphic way of story telling would lead to misunderstading of evolution. Given these accounts of early historic evidence of possible misinterpretations of evolution and specifically natural selection it might seem a little surprising that we still 150 years later face the same issues. Of course this calls for new ways in communicating the important concepts of evolution by natural selection.

3.3 Learning theories and conceptual change

The fact that evolution is difficult to learn and teach leads to the question what effective learning strategies can be employed in the context of difficult concepts. One often cited approach to teach evolution is the theory of conceptual change (**?**). Learning can be described and studied in many different perspectives. For example there is the cognitive, constructive and sociocultural perspectives on learning. Depending on the perspective employed, different areas of research are in the focus. There is no widely accepted definition of learning by researchers. However, since this study emphasizes cognitive perspectives on learning, and to limit a potentially endless review of different learning theories and perspectives of teaching, a demarcation is made in this report to include only the cognitive approach to learning.

The present research in the field of threshold concepts and constructivist learning can be said to rely on the ideas of Jean Piaget (Duit 2003). Conceptual change can be described in the Piagetan terms assimilation and accomodation:

- Assimilation - knowledge is added to existing structures, small modifications are made in cognitive structures in order to assimilate the new phenomenon.
- Accomodation - existing knowledge structures are insufficient. The new ideas conflict with existing cognitive structures (cognitive conflict). In order to accomodate the new information a restructuring of the cognitive structures takes place - sometimes termed conceptual change.

The research inspired by Piagets work led to the study of scientific misconceptions among learners. Posner et al set out to answer what happens when students encounter new ideas that are incompatable with existing conceptions. The result was a theory of conceptual change (Posner et al. 1982). The conditions found to foster a conceptual change or accomodation were:

- Intelligibility of a new conception
- Initial plausibility of a new conception
- Dissatisfaction with existing conceptions
- Fruitfulness of a new conception

However there a fallacies with oversimplification of the complex cognitive processes. Posner et al points out that conceptual change though a radical change need not to be an abrupt one. Rather it is likely a gradual process there students at a given time grasps certain but not all aspects of a new conception. Also, a fallacy that applies not least to teaching is that what might seem initially as a conceptual change is not complete. Posner et al gives the example of students accepting Einstein's two postulates but understands them in a non-scientific way (Posner et al. 1982). Mimicry is another effect of incomplete conceptual change, there students tend to reproduce rather than accommodate new concepts. There is, as we shall see, parallells to this in conceptual change towards the scientific conception of evolution. Careful testing and listening for real understanding can be utilized by the teacher to identify mimicry behaviour of students and thus promoting real conceptual change.

If we accept the premise that conceptual change is of importance in learning science, and might be a frutiful way in learning evolution, we must then turn to the conditions favouring conceptual change. What are the favourable conditions and how do we create these in a learning situation?

More specifically in this study, we are interested in whether interactive animations can facilitate conceptual change promoting understanding of biological evolution.

Posner et al suggest a number of educational implications of their research. Different aspects such as content selection and teaching strategies are described. The ones most interesting in the context of this diploma thesis are content and teaching strategies related. Regarding content selection Posner et al calls for *Retrospective anomalies* to be included as well as *Any available metaphors, models and analogies.* In the aspect of teaching strategies Posner et al suggest we develop *...demonstrations, problems and labs...* which can be used to creative cognitive conflicts in students. They also emphasize the importance of using multiple modes of representation and by helping students translate between those. (Posner et al. 1982). The modes of represention available to us are now even broader than in 1982, by the advances in recent decades in multimedia technology. Thus, now more than ever we should be in the position to invent new teaching tools fostering conceptual change. Sinatra et al. (2008) suggest we aim at understanding the sources of conflict and resistance to evolution in order to construct instruction that promotes deep thinking. Also, they suggest a number of strategies such as focus on the difference between everyday and scientific language, connect evolution to student's everyday experience and direct experience of phenomena.

3.3.1 Threshold concepts

Threshold concepts is a relatively recent addition to conceptual change theory. A threshold concept can be described as a concept central to mastery of a subject, like a portal, and these concepts have certain features in common (Cousin 2006). As described by Meyer and Land (Meyer & Land 2005) a threshold concept can be characterized as:

Transformative - leads to a new way to perceive the world, (conceptual and ontological shifts).

Irreversible - once grasped it is not likely to be forgotten.

Integrative - previously hidden connections between concepts are revealed to the learner.

Bounded in a conceptual space.

Troublesome - difficult and troublesome knowledge to acquire.

Threshold concepts are suggested to have both explanatory as well as practical potential in learning situations (Cousin 2006). For example teaching could focus on identifying and facilitating understanding of threshold concepts in a discipline and thus promoting conceptual change. The troublesome character of threshold concepts might pose obstacles in learning in that the new concept is counter-intuitive or requires an uncomfortable shift in ones view of the world. Examples of such intuitive understandings and ontological discomfort have been exemplified in the earlier section on learning of evolution (see Section 3.2).

3.3.2 Threshold concepts in biology and evolution

Given that the research area of threshold concepts is relatively new, there is not an accumulated body of literature on threshold concepts in biology. Nevertheless, some work has been done in the area of biology and also evolution. Some suggest that evolution is a threshold concept in itself, while others suggest it is composed of other threshold concepts((Ross et al. 2010)). (Ross et al. 2010) claim it consists of a *complex of interconnected threshold concepts* such as *physical and genetic variation, inheritance, time scale of millions of years*. The notion of preexisting variation seems to be an important concept to grasp in order to avoid Larmarckian misconceptions of directed mutations or wilfull change. This was noted by Brumby (Brumby 1979). In her description of the nature of misunderstandings among university students she found that the first step in misunderstading was the absence of the concept of individual variation in a population, arisen from spontaneous mutations. This type of thinking is called populational thinking and is not seldom absent in students view of evolution. (Se further in 3.2).

In this study a number of stipulated threshold concepts are in focus:

- origin of variation (connected to different spatial scales)
- randomness (connected to probability)
- biotic potential (reproductive potential)
- inheritance
- temporal scale (a time scale of millions of years)
- spatial scale (phenomena occur on the submicro scale affect phenomena on the macro scale)

3.4 Learning with animations

Visualisation concerns with different representations, those can be both external representations as well as internal (mental) ones. As such, animations is a specific form of visualisations with a temporary aspect. Animations can be defined as simulated motion picture representing depicitions of objects or simulated content. Animations can have advantages over still picture representations, especially when dynamic or complex processes are to be depicted (*Visualization* 2012). Animations can be utilized to show learners things not easily observed(Ainsworth 2008), such as slow or fast processes or small structures invisible to the naked eye. According to Mayer, meaningful learning from animations occur then learners construct new knowledge by selecting, organizing and integrating new material with older (Mayer & Moreno 2002). The learning potential of animations has been explored in several studies and has led to the conclusion that learning may or may not result from them (Mayer & Moreno 2002, Ainsworth 2008). This in turn seem to be due to the many different factors influencing learning with animations (Ainsworth 2008) and their complex interplay. Thus, the current research on learning with animations aims for clarifying under what conditions and how animations affect learning. There is evidence that there is a delicate balance between overloading the learner with information and underwhelming effect. The latter is a state where the learner simply observe the animation and no further cognitive processing takes places. That is, the learner tend to rely on the external support provided by the animation rather than engaging in necessary cognitive processes (Ainsworth 2008). Ainsworth stresses that *"surprisingly little has been written about the perceptual aspects of animations"* and concludes that there is a need to understand how to design animations with patterns that are readily perceived by our visual system. Rundgren and Tibell found that there are difficulties in interpreting animations that relates to scale, size and other dynamic aspects (Rundgren & Tibell 2010). Thus, an increased understanding of certain aspects of animations relating to their effects in learning settings are needed. In the area of evolution and animation, work is currently ongoing within the EvoVis project at Linköping University, there this study is an early pilot study.

3.4.1 Learning evolution with animations

In a relatively recent study by Abrahams et al, the learning effect from an computer based simulated laboratory on evolutionary concepts was evaluated. The authors conclude that while the lab appeared to reduce some common misconceptions, no evidence was found that it succesfully increased student understanding of natural selection (Abraham et al. 2009). Abrahams also suggest that continued development of teaching tools to confront misconceptions should aid students in understanding evolutonary theory. Other studies have found positive effects on some learning outcomes in evolution when instruction was combined with simulations. However, the effect of instruction alone was not measured, thus the effects of the simulations remain unclear. Yet, other models of evolution tailored for learning appliances depict virtual organisms and failing to recognize the importance of basic concepts such as origin of variation, which may lead to appearance or reinforcement of misconceptions such as teological or intentional thinking.

4

Methods

The study was done using a mixed method approach, with both quantitative and qualitative data collection methods. The aim was to collect responses to multiple choice question combined with essay questions pre and post animation, as well as performing follow up interviews with voluntary students in order to paint a broad picture of how the animation was perceived by the learners. Not only were we interested in any effects on understanding evolutionary concepts but also questions about the effective design of the animation and the multiple choice questionnaire. Thus we wanted to collect data about the phenomenon of evolution but also data to do eventual iterations of the animation design.

4.1 Experiment group

Upper secondary students enrolled in the national Nature resource use program and the Technology program participated in the study. The students from the natural resource use program were all enrolled in the orientation toward animals. The students were all part of an introductory course in biology (national course Biology 1, 100 credits, (Skolverket 2011)), which builds on knowledge from compulsory school. The experiment group was divided into two subgroups by randomization. One group (A) was to experience the entire animation and the other group (Control group) was to experience the animation without the part explaining the mechanism behind origin of variation.

4.2 Design of the animation

The main rationales for choosing animation as visualisation are the possible advantages in representing dynamic sequences of specific activities. could be advantageous when there is a need to represent dynamic activities in a specific sequence and to make dynamic information explicit in order to reduce cognitive effort or load. Therefore, our idea was to make threshold concepts such as time, origin of variation, natural selection and biotic potential more explicit by means of animation.

The animation was designed from a storyboard containing the main scenes. The main subject of the animation was to depict the emergence of antibiotic resistance in the bacterium *Escherichia Coli.* The reasons for this were the short generation time in bacteria and thus their ability to multiply into very large number over night. This would allow us to avoid the problem of deep time in evolution and thus make the time scale more tangible for learners. Also, we thought that a familiar problem could facilitate learning as well as create a motivational setting for the learners by making connections to prior knowledge and familiar topics.

The animation was composed of several different scenes. The scenes were either animated sequences made with the molecular visualisation package UCSF Chimera or interactive content made with Adobe Flash. Chimera is developed by the University of California, San Fransisco (supported by NIGMS P41-GM103311) (Pettersen et al. 2004) . In particular, Chimera was used to animate zoom in sequences of a DNA molecule in the bacterial nucleoid. In order to create a longer DNA model than the shorter fragments found in the Protein Data Bank, we used a web service called 3D DART available online from the Univeristy of Utrecht (van Dijk & Bonvin 2009). This allowed us to generate sufficiently large DNA models in PDB-format for visualisation and animation in UCSF Chimera. The animated sequences were exported as PNG-files that were imported in Adobe Flash. Background images were either modeled and rendered in Blender 3D or drawed in Adobe Illustrator.

Supplemental information was given in each scene by means of on screen text. Narrations are found to be positive for the effect of animations, the so called dual-coding hypothesis (Mayer & Anderson 1991). Unfortunately, due to the time limit of the study, we were not able to add narrations in this version of the animation.

4.3 Knowledge assessment

There are several documented attempts to develop methods for measuring knowledge of evolution. Among those the Conceptual Inventory of Natural Selection(CINS) is perhaps the most widely used. CINS was developed by Anderson et al. (2002) with the aim of testing conceptual understanding of evolution through multiple choice question. It has been verified by (Nehm & Schonfeld 2008) against other methods such as interviews and found to be valid. CINS consists of twenty multiple choice questions. Each question has four alternative answers. Common misconceptions are used as distractors among the answer alternatives. Another reason for the choice of CINS was that it provides easy scoring and eliminates inter-rater reliability issues associated with essay questions. Since it has been used in a number of previuos studies we should be able to compare our results to others also. One difficulty in this study was related to language. Since CINS was developed in english originally, a translation into swedish was made. The translation was made by graduate student Daniel Orraryd and was revised several times by the author and professor Lena Tibell. The CINS questions were implented as online quizzes within a learning manegement system that was familiar to the students in the experiment group. The answers were collected electronically and exported for further analysis (se analysis of data).

4.4 Student interviews

Student interviews were made according to a semistructured clinical interview method (Kvale 2008). The interview protocol was a modified version from (Rundgren & Tibell 2010) and can be found in Appendix C. Student participation in the interviews were voluntary. The interviews were intend to be performed directly after the experiment. For reasons beyond our control the interviews had to be postponed for two weeks. Three interview sessions were conducted. In two of the sessions, one student was interviewed alone and in the third session two students were interviewed simultaneuosly. Before the interviews were conducted, the students got the opportunity to watch the animation once again. This decision was made since two weeks had passed since the main experiment, thus leading to the interviews being a stimulated recall variant. The interviews were recorded and transcribed verbatim (see appendix D).

4.5 Analysis of data

4.5.1 Multiple choice questions

Each correct response was scored 1 point. Average correct responses were calculated pre and post animation for the CINS. A comparison of the number of correct responses pre and post animation with Wilcoxon sign rank nonparametric test was conducted in order to test for significant effects. Also, one tailed Wilcoxon signed rank tests wer performed for each of the responses categories of the CINS.

4.5.2 Open ended questions

The answers from the essay question on antibiotic resistance analyzed by a coding procedure. There are always difficulties in categorizing and coding qualitative information for quantitative analysis. We choose to settle with 4 categories of the most commonly found misconceptions in the essay questions. These four categories were found to cover all the misconceptions found. It must be noted however that finer categorizing would be possible yet this would not be meaningful in this study since the number of responses were low. The number of correct principles used or mentioned were also coded. Five key principles of evolution were used: Mutation, Differential survival, Population change, Inheritance and Natural selection. The present misconceptions were coded as Willful change or need (MC1), directed variation or mutations (MC2), adaptation (MC3), Population change (MC4). The number of misconceptions present pre and post animation were compared. If a student utilized several different misconceptions, all were noted as present in

Figure 4.1: Examples of misconception coding

Misconception	Example
MC1 Willful change or need (Change becaues of need or will to do so)	**Student(16)**:"[...]So the bacteria change during a few generations in order to survive."
MC2 Directed variation (Varations or mutations are caused by a need or a change in environment)	**Student(7):** The bacteria must get new properties in order to survive and adapt to the environment. Their cells develops something via the genes that makes them tolerate antibiotics.
	Student(16):[...] If there is something hurting or killing them mutations and changes take place that enable them to cope with the threat. So the bacteria change during a few generations in order to survive.
MC3 Adaption (Environmental change induces changes in function or appearance)	**Student(9):** "If you take antibiotics for a long time, ultimately the bacteria get used to it and become resistant..."
MC4 Population change (Population change as a unit, no significance given to individual variation)	**Student(16):** If there is something hurting or killing them mutations and changes take place that **enable them** to cope with the threat. So **the bacteria change during a few generations** in order to survive.

the table. Due to the low sample numbers, testing for statistically significant differences was not meaningful.

5

Results

5.1 Animation

The finished animation was packaged as an interactive flash movie(swf), that was embedded in a HTML document and published on a web server. The animation can be found at
http://learninglabs.se/exjobb/start.html. For ease of reference, screenshots from the animation is also available in Appendix A.

5.2 Multiple choice questions(CINS)

We could not observe any significant change in the overall CINS score (n=11 students) post animation compared to pre animation scores (One tailed Wilcoxon signed rank test). The number of students with low scores (1 pt) decreased post animation. The students with higher scores both decreased and increased their scores (Figure 5.1). There was also a slight change in mean score, but not statistically significant neither with Wilcoxon signed rank test nor with sign test. In terms of effect size the improvement was positive but quite small (Cohen's $d = 0,18$). The average pretest score was 31 % and the post score average was 32 %.

We also analyzed the scores with respect to different concept categories of CINS(*biotic potential, fitness, inheritance and natural selection*. Student performance on the biotic potential concept showed a significant increase from 32 % to 59 % (Wilcoxon signed rank test), (Figure 5.2). Three concept categories seemed unaffected (fitness, inheritance and natural selection) and one concept category seems to slightly decrease post animation (origin of variation).

5.3 Open ended question

In connection with the pre and post tests (CINS), an essay question was also given to the students. The essay question asked the student to explain how resistance to antibiotics could evolve among bacteria. Unfortunately, few students provided

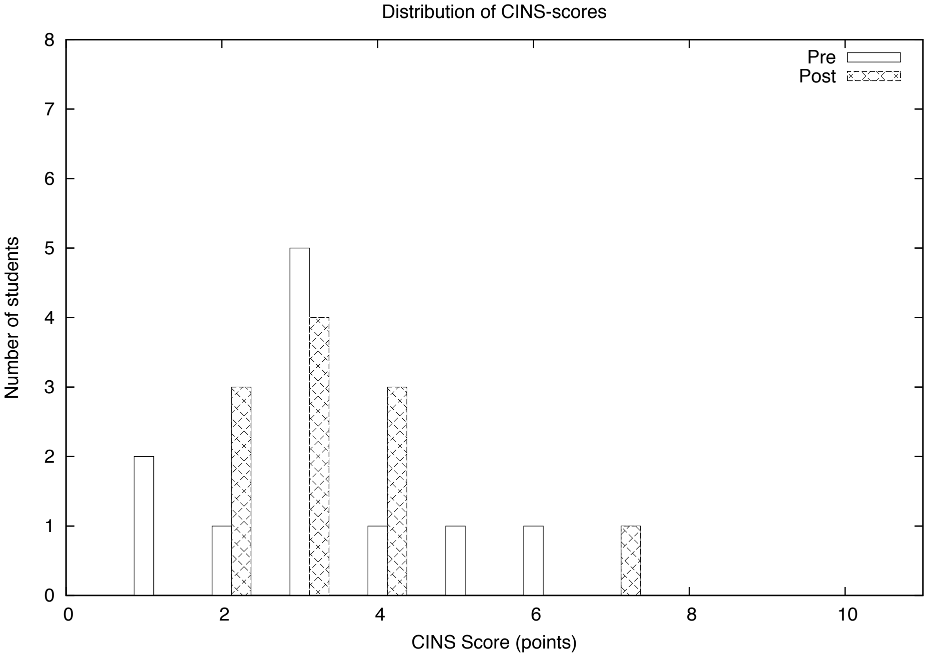


Figure 5.1: Distribution of CINS Scores pre and post animation ($n = 11$). One point equals one correctly answered test item.

complete answers to this test item. Instead, a rather typical catalogue of common misconceptions were found. In addition there was no significant change in number of misconceptions post versus pre animation. The categorization of the different misconception can be found in the Methods section. The prevalence of the different misconceptions can be seen in Figure 5.3.

We observed only one elaborated explanation of antibiotic resistance pre animation:

> ***Student(11):*** *"The bacteria which are not resistant to antibiotics die. The few that manage to survive are also those who can multiply. At the mitosis several other become resistant (those who did not [become resistant] died) and then it is yet the resistant who survives. Thus more and more become resistant."*

This explanation describes the concept of natural selection by differential survival, also including the basic concept of inheritance. Very few students provided lengthier reasonings as answers to this test item. Some mentioned a few correct terms or

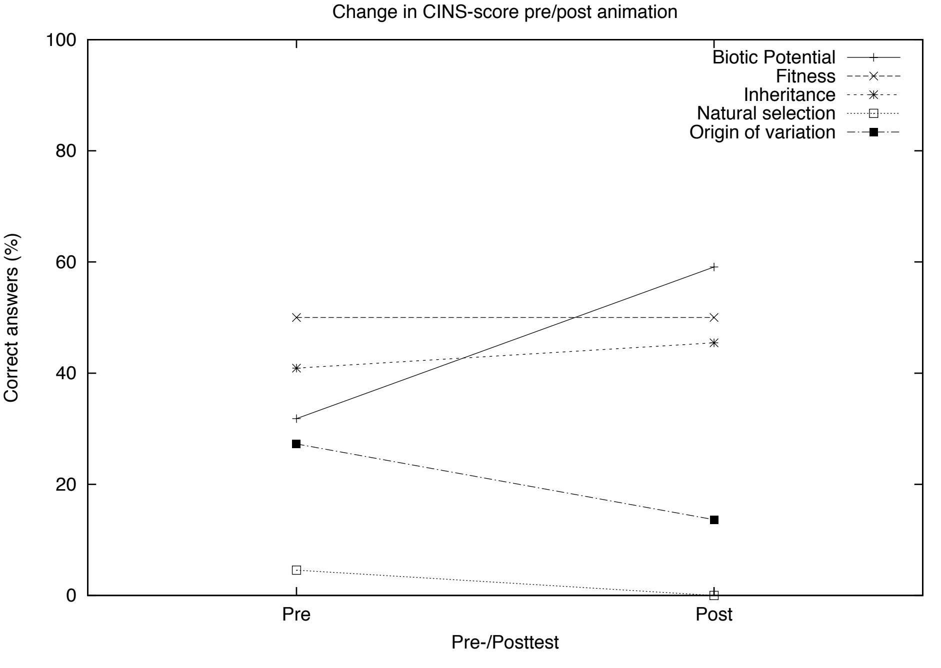


Figure 5.2: Change in CINS scores per concept category. ($n = 11$ students)

concepts such as *natural selection* or *mutations* but not in conjunction with other reasoning. Often correct concepts were mixed with typical misconceptions.

> ***Student(9):*** *"If you take antibiotics for a long time, ultimately the bacteria get used to it and become resistant..."*

> ***Student(3):*** *"Antibiotics has been used frequently and probably to much occasionally, , then you felt a little ill and doctors have prescribed antibiotics. On these occasions the bacteria have learned to cope with the antibiotic and begin to become immune to the effect of the antibiotic."*

As an example of teleological and intentional reasoning this response is illustrative:

> ***Student(16)***:*[...] If there is something hurting or killing them mutations and changes take place that enable them to cope with the threat. So the bacteria change during a few generations in order to survive.*

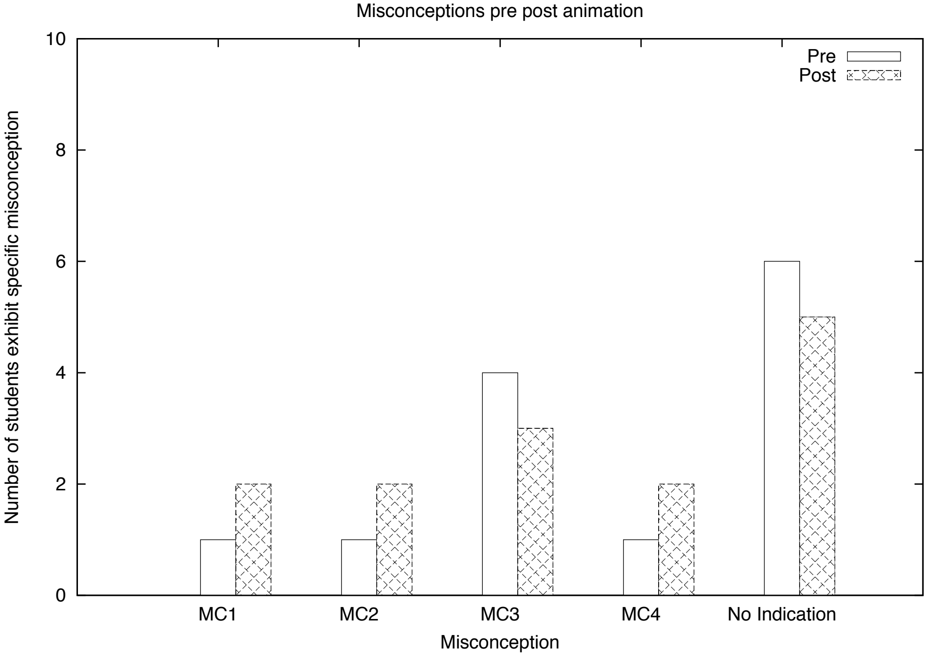


Figure 5.3: Misconceptions pre and post animation ($n = 11$).

The reasoning clearly indicates a belief in a casual relationship of the environment and the mutations that leads to resistance. Possible reasons underlying the insignificant changes in misconceptions pre and post animation are further explored in the discussion section.

5.4 Predict-observe-explain

As described in the method section, a predict-observe-explain form was added to the interactive animation. After the sequence depicting streak plating, the animation was paused and an essay form was displayed asking the students to predict the outcome of the resistance assay. After submitting the form, the animation was resumed and the incubation over night was shown with gradual appereance of colonies on the different plates. The form was displayed again after the experiment, asking the students to revise their explanations.

5.4.1 Predictions

Three out of eleven students did not provide any explanation at all, neither pre nor post animation. Two of the students made the prediction that they had *"no idea"* what was going to happen. Another three made the prediction that growth would be slower in plates with antibiotics and/or that the control plate without antibiotics would contain higher number of colonies/bacteria. One student made the incorrect assumption that the plates containing antibiotics would harbour a larger number of colonies, *"especially the one with nitrofurantoin"*. Also, one student predicted that no difference would be seen between the different plates, due to *"the number of generations that would pass"*. One of the students also predicted that mutations would take place:

> *Student: "There **will** be mutations in the bacteria."*

Since this answer was given after the animation part depicting the plate streaking, a possible conclusion must be that the student thinks that mutations are directed, i e takes place in presence of antibiotics.

5.4.2 Explanations

Four out of eleven students gave no explanations at all (blank answers). Of the remaining seven, three concluded that antibiotics had an inhibitory effect on the number of bacteria and they expressed that this was as expected by them. Two mentioned that they had expected more bacteria to grow on the plates with antibiotics. One of these students explained that the number of generations passing over night would lead to no difference between the plates. The same individual also noticed a slight difference in colony numbers between plate no 2 and 3 (in fact due to a technical mistake during the production of the animation). One student provided a fairly lengthy reasoning. He or she realized that the predicition provieded by her or him was erronously formulated:

> *"Student: ... of course the one [the plate] without antibiotics will have more bacteria because antibiotics are used to stop the growth of bacteria in the body."*

The same student also noted the difference in colony numbers between plate no 2 and 3 and that he or she thought that the number of bacteria would be lowest in the nitrofurantoin sample. The student motivated this conclusion by *"because it has no green thing"*, but he or she also concluded that *"I don't know why it was lower in nitrofurantoin"*. Thus a range of different explanations were employed but none of the explanations were very elaborate.

5.4.3 Possible indications of cognitive conflicts

An interesting question was whether indications of beginning cognitive conflicts, or dissatisfaction with existing concepts, could be observed post animation. Indications of this would be reasoning concluding that the students had observed something contrary to their prior conceptions. Four of the eleven participants did not provide any explanations at all post animation. Of the seven remaining answers, two provided clear indications of observations contradicting their predictions:

> *Student: "What happened was that the antibiotics slowed the growth [of bacteria]* ***which I didn't expect****"*

> *Student: "****No, I thought*** *that so many generations would pass over one night that all [plates] would look alike. You could see that the ones with antibiotics became much more than the other two. Number 1 [referring two antitiobic 1 in the animation] became a few more than number 2 [referring two antibiotic 2]."*

This could be an indication of that our animation can elicit a dissatisfaction with existing conceptions, the first step in Posner and Strike's model of conceptual change (Posner et al. 1982).

5.5 Interviews

Follow-up interviews were performed with four students after watching the animation. This gave more valuable insights into what could be comprehend from the animation. For practical reasons two of the students were interviewed as a pair, the other two individually. The students were asked to describe their observations from the animation. The obvious parts such as bacteria, the building blocks of the bacteria and bacteria culturing were mentioned. Also, the resistance occuring was mentioned by all. However the cause of the resistance seemed more unclear to the students. One student acknowledged that the bacteria reacted to the antibiotics but that they somehow became resistant by sensing the antibiotics (directed mutations or change). Yet others mentioned mutations in the context of change, e g

> *"[The bacteria] adapted to the antibiotics after a while"*

which implies a teleological thinking. However this student also noted that there must exist differences in antibiotic tolerance of the bactiera, thus giving some emphasis on variation.

Also noteworthy in this interview (2) was that change and mutation were used somewhat interchangeably:

> *Student:* ***Somewhere*** *they* ***change****, there are* ***mutations*** *happening so that they* ***can manage*** *the antibiotics* ***somehow***

Thus the mechanism of origin of variation and its effect on phenotype seem unclear to the students. Interestingly some indications of noting the embedded fundamental or threshold concepts were given in the interviews. In interview 1 the student noted that

> *"...it was interesting that it takes so many [bacteria] to reach a millimieter, that they are so small but yet living creatures". (spatial scale)*

In interview 2 one of the participants mentioned that she had noted that there was an enormous difference in time scale between humans and bacteria with respect to the larges difference in generation time.

> *"... you can see a change, it depends on the conditions also, how bacteria and humans evolve. It took 1500 years for 48 generations [for humans] and for bacteria it took 24 hours so there is an incredible difference..." (temporal scale)*

We also asked the participants in the interviews whether they looked at the pictures or read the on screen texts first. All 4 participants anwered that they read the text first and then looked at the graphical content. Reasons given for this were that they supposed that it would ease interpretation of the graphical content:

> *"...because then you get the facts you will be able to* ***understand*** *what's going on in the animation.*
>
> *...otherwise you wouldn't* ***understand*** *the pictures... there you have this thing spinning and there that it is happening...*
>
> *I read the text first ...to* ***get the whole picture****, I think it is easier to grasp what you are seeing if you've read what to look for, it's easier to focus on what you're supposed to look at.*

In other words, the students seem to acknowledge the importance of preknowledge in interpretation of the visual elements in the animation. Also, from a variation theoretical perspective focusing different aspects seems to be of importance according to students perspective and they seem to think that the text will supply them with this information.

6

Discussion

6.1 Contextual factors

Our study contain only eleven students out the originally intend twenty due to practical reasons beyond our control. The experiment was performed in the end of the semester just before summer vacation, thus low motivation to engage in the study might be an explanation. In the experiment group, many of the students were low achievers, with a significant number of students facing learning difficulties in several subjects. Therefore other factors such as reading comprehension issues might contribute to the low scores on CINS and the relatively large number of blank answers on the essay questions. These issues could be overcome by enlarging the sample group in the future. Nevertheless, there are some interesting indications from both the CINS scores and essay questions as well as the interviews, that can be useful in future development of the animation. Also, the indication of no significant improvement in total CINS scores raises interesting questions of which features of the animation could be altered in order to increase learning gain.

6.2 Understanding of evolution

The small and non significant change in total CINS score observed is in line with the findings of other similar experiments (e g (Abraham et al. 2009)). (Abraham et al. 2009) measured the learning impact of an interactive simulation and could observe a small increase in post test scores (72 % to 75 %). However, in this study CINS was not used as the test instrument thus making it not directly comparable to our data. Yet another study employing the CINS by Sinatra and Nadelson, preservice teachers (undergraduate students) reached a pretest score of 46 % , thus our results of 31 % on the pre test seems reasonable given that our experiment group consisted of upper secondary students.

In our study, only one of eleven students provided a fairly complete description on the essay question. This is also in line with the findings of Abraham et al. (2009) where a significant number of participants did not provide answers to essay questions. This might be due to several reasons, for instance motivational and affective factors.

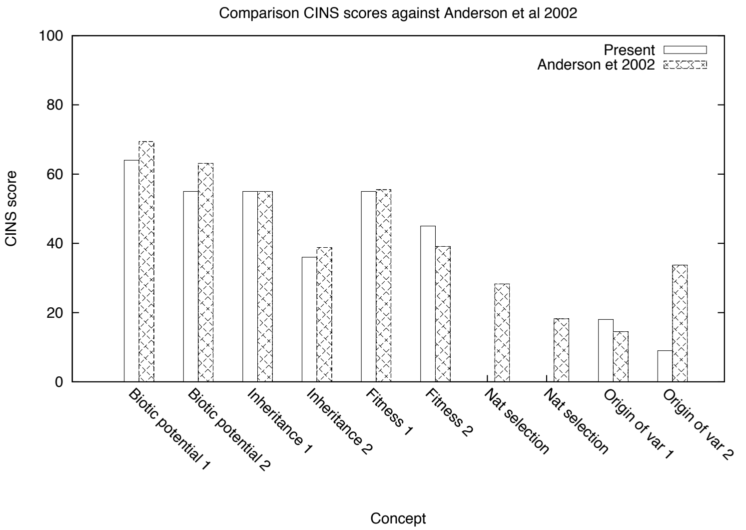


Figure 6.1: Comparison of CINS scores (post experiment) on individual questions between presents study ($n = 11$), and (Anderson et al. 2002) ($n = 206$).

We find the apparent effectiveness of the animation on the concept of biotic potential is interesting(see 5.1). The change in mean score on the two CINS items on biotic potential was from 32 % to 59 %, thus nearly an 100 % relative increase. Ainsworth & VanLabeke (2004) examined the dynamic representations in instructional simulations in the context of population dynamics. An important property is the transient versus persistent nature of dynamic representations. The graph in our scene (story node?) on biotic potential (bacteria growth) (see fig 6.2) concerns with multiple external representations, one in the form of a running counter on population numbers and one in the form of a dynamic graph plotting the population number versus time. According to the terminology of Ainsworth & VanLabeke (2004) the counter is a *time-singular* (TS) representation and the dynamic is *time persistent* (TP).

TP representations like the previously mentioned graph are thought to lessen the cognitive load on the learner by making all the previous information states available, thus alleviating the cognitive load on the learner. In the example of our graph, the learner can easily trace and compare the history of the growth - or as Ainsworth & VanLabeke (2004) conclude: "Time-persistent representations are ideal for showing relationship between current and past values of a variable.". This could be a reason for the apparent effectiveness of the present animation on the concept of biotic potential. In addition, line graphs are part of the curricula in mathematics and sciences in earlier school years, thus presenting a familiar representation. Of course, this has to be further elucidated by more research.

The concept of inheritance was not explicitly shown in the animation. Hence it is not surprising that we see not improvement in this concept. The intention was that the student would infer this since all bacteria in the depicted experiment came from a common ancestor. Unfortunately this fact was not very explicit either. A solution to this could be to depict cell division on the microscopic scale simultaneously with an animation of chromosome replication. In essence, this would be to employ the concept of dynalinked multiple external representations (MER), where the linkage would functions as a constraint in interpretation (Ainsworth & VanLabeke 2004) and thus could be a beneficial strategy for learning. MER:s are visualisations composed of several simultaneously presented parts that could act in concert to enable learning. An example of a MER could be a visualisation accompanied by textual descriptions. Dynalinking refers to a functional link between two different representations so constructed that a change in one representation is mirrored onto the other representation. This is thought to have the potential of faciliting understanding.

Likewise, the concept of origin of variation was not affected significantly by the animation. Although the concept of mutation was shown in a zoom in sequence, this was shown out of context in the animation, thus making it a transient part of the animation. Transient information places increased demand on learners (ref) and this could be one reasons for difficulties for the learners to relate this part of the animation to the overall sequence of events. Given this it is not surprising that no differences in CINS scores could be observed between the two experiment groups.

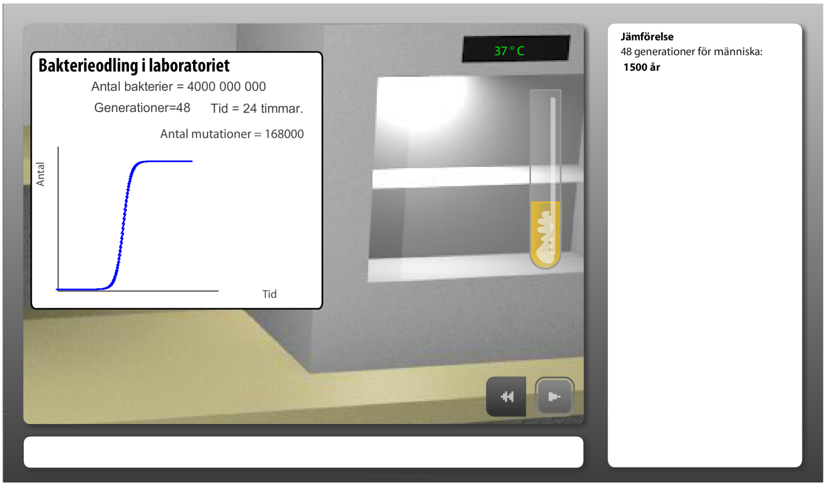
The reasons for the low CINS scores (close to 0 %) on the concept of natural selection could be manifold. In all the interviews students mentioned specifically that they found the wording of these questions difficult. Also, natural selection is a concept requring understand of other concepts such as biotic potential, differential survival, inheritance and pre existing variation (Ross et al. 2010). Since we could only observe an increase in CINS scores on one of those concepts (biotic potential) it is not suprising to find a lack of increase in the natural selection questions of CINS. Future research should therefore consider reworking the questions or find new test instruments as well as reworking the animation itself.

6.3 Nature of the misconceptions revealed

The examples of misconceptions found in our study coincides very well with those found by others. For example, Nehm & Schonfeld (2008) shows an example of misconception of how antibiotic resistance evolves that is almost identical to those found in our study. The idea quoted by Nehm & Schonfeld (2008) is that given sufficient time is allowed to pass, the environment will induce some change allowing the bacteria to adapt. Thus, the importance of pre adaptive variation to be explicitly shown must be further considered to address this common misconception. It will most certainly deal with the tendency to identify a nonexistent causal relationship between a change in environment and the emergence of a certain function or trait. Here, we must critize our own animation that does not make this explicit. thus allowing for this misconception to prevail or even worse, to arise from our animation. The next iteration of our animation should therefore specifically address this issue.

In the essay questions, several students showed the misconception of directed variation. A speculation is that this could be due to lack of explicitiness of pre-adaptive mutation or variation in the animation. The only indications of mutations taking place pre-adaption was a counter showing the number of mutations occuring during bacteria culturing in the test tube (see Figure 6.2. To make the prevalence of mutations pre adation clearer "a zoom in zoom out" feature could be added to show the microscopic phenomenon of mutation in different indivuals. Another difficulty is to visualise the range of different mutations occuring and their coupled phenotypic changes without introducing new misconceptions or simplifying too much. A possible solution might also be to divide the animation in two representations, one depicting the breadth of variation arising from mutation and one depicting the occurence of a mutation of specific interest such as a change in an efflux pump protein that affect the survival rate of the bacteria in an antibiotic environment. By a dynamic linkage between those two representations a constraint could be imposed in order to direct the learners attention to the casual relation between these events.

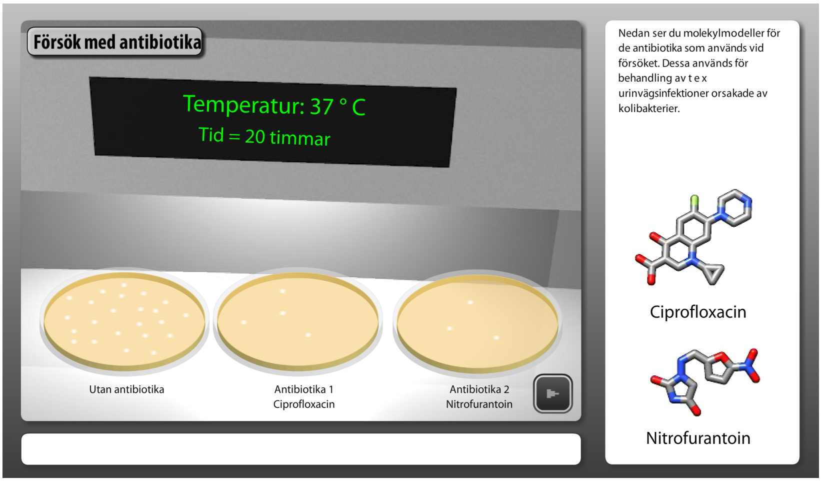
Figure 6.2: Animation of exponential bacteria growth with mutation counter.



The unintentional difference in number of colonies between the two antibiotic containing plates was perceived as something important by a few students. Contrasts in dimensions such as colours or numbers appeal to our mind and we might tend do draw conclusions based on these differences. For example one of the students coupled this difference in colony number to the green coloured nitrogen atom in one of the molecular models in the animation (see Figure 6.3).

Thus, the student tried to make meaning out of the information at hand, a

Figure 6.3: Result of the experiment



logically possible explanation was of course that the green colouring was choosen to highlight an important feature of the molecule and that this so contrasted feature should be coupled to the contrast in number that could be discerned from the experiment. The conclusion drawn from this unintentional clues is that design of the animations should be done very carefully and that variation in a dimension appeals to our perpetion of a phenomenon. In order to avoid wrong conclusion variables not important to the intended inference should be kept constant.

6.3.1 Appropriateness of CINS as a test instrument

An other reason for lack of improvement in CINS scores might simply due to that CINS is not sensitive enough to possbile changes in student conceptions. CINS has been developed and evaluated as a pre/post test in conjunction with courses in biology having a duration for weeks or months. Nehm & Schonfeld (2008) compared CINS to open response questions and interviews. They conclude that their data

> suggest that this test is very difficult for undergraduate non majors

. This is well inline with our data of an average 33 % score on the chosen CINS questions, which is just slightly above chance. Thus, we see conflicting evidence from earlier studies on CINS as well as from our data, and hence further research on appropriate knowledge testing instrument might be necessary.

6.4 Mode issues

According to the interviewed subjects, all stated that they read text before studying the graphic elements. Presenting text and graphic elements simultaneously can lead to split visual attention and increased cognitive load, hampering learning from dynamic visualisations. Therefore, the dual-coding hypothesis is prevalent in the design recommendations for animations in that narration or spoken text is better than written. However, according to Schmidt-Weigand (2006), written text can be equally succesful as spoken if the pace of the visulisation is under learner control. Since our animation is mostly under learner control the choice of text instead of narration this could be true for our experiment as well. However, we consider to restructure the annotations in a future version, reducing the amount of onscreen text and making more explanations available through hyperliniking instead.

6.5 Other effects (non-conceptual)

A hope we nurtured for before our experiment was that antibiotic resistance would be a familiar and relevant subject to the students. As Sinatra et al. (2008) points out, motivations and emotions are of importance in conceptual change and that a strategy can be to connect to topics relevant to student's everyday experience, such as GMO or antibiotic resistance. Though not asked for specifically in the interviews, we found indications of what seems to motivate students in one of the three interviews:

> ***Interview with student 4:*** *[...] I thought it was very realistic. You could see immediatly what it was... [...]. And it was like a laboratory, you could see that clearly, I thought that made it a little more interesting than just a white background and some stuff, I thought it was good.*

Though not mentioning antibiotic resistance per se, the choice of context thus seem motivating and promising for future animations. In the event of future versions of the animations, data could be collected on the motivational effect of the animation topic to further research this.

As mentioned in the results section, we could observe indications of observations contrary to belief in the students explanations post animation. This could be a first step towards dissatisfaction with existing conceptions and thus a first step towards conceptual change. The next step is that the learner must come to see the new explanation as more appropriate. However, our animation ended after this step. This could leave the learner in a state of dissatisfaction but with no new plausible explanation at hand. This was in fact indicated by one of the students in the interviews:

> ***Interview with student 15:*** *You would probably like an answer in the end [of the animation], but since you are supposed to answer the questions again...*

A new iteration of the animation could therefore gain from interpretative support and focus more on the result of the experiment. A speculation is that this would lead to greater learning gain on the concept of natural selection and differential survival.

7

Conclusions

The first version of the animation lacks a number of important features and needs further refinement. No significant change in knowledge about evolution was found when the learners were subjected to the animation. However, an increase in understanding of the biotic potential of organisms could be observed. A number of common misconceptions on evolution could be observed both pre and post the animation. The collected data together with the interviews suggest that the animation must depict pre-adaption variation in order avoid misconceptions such as teleological reasoning and directed mutations. The timing of different events, such as mutations pre-existing a change in environment should be made very explicit in order to avoid common misconceptions about cause and effect. This supports the hypothesis that time is a threshold concept, or rather timing/ordering of events. Some evidence of learners grasping the concept of different scales were also found, suggesting that zoom-in and scale bars could be a successful way to convey scale phenomena.

The open ended questions generated important information about the interpretation of the animations and should be employed in future iterations of the animation. Design issues such as colour coding and variation in number of colonies are important since uncareful selection can lead to inaccurate conclusions from the observer (as noted in this study).

The random, non-directed nature of mutations was discovered by Luria and Delbruck and later by Lederberg and Lederberg. These important historic experiments could be suitable for parts of the animation, as suggested by (Robson & Burns 2011).

Supplying the learners with more metacognitive tools pre and post animation could activate more cognitive processes possibly in turn leading to conceptual change. Examples could be generating hypothesis through scaffolding with computer aids and feedback.

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Appendix A

Animation

Figure A.1: Scene 1, before zoom in on bacteria.

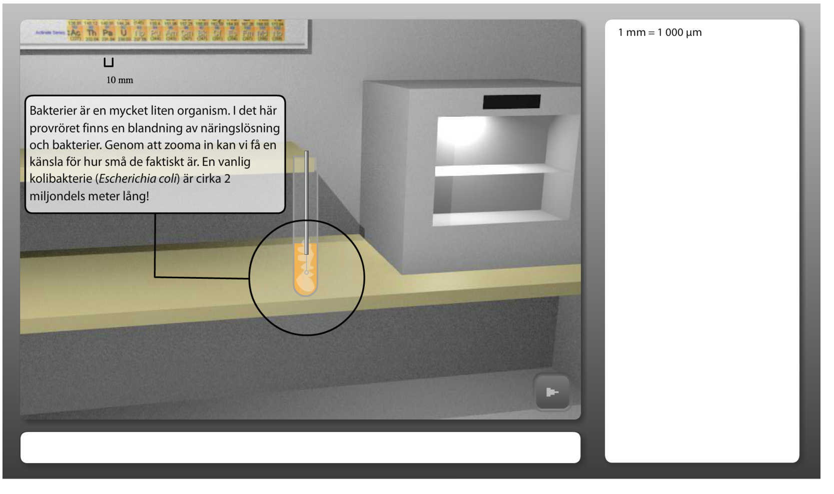


Figure A.2: Zoom in 1. Inoculation loop.

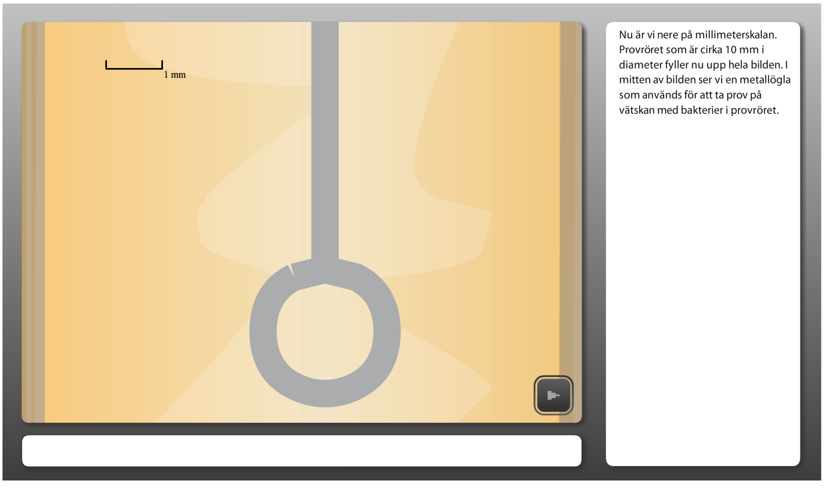


Figure A.3: Zoom in 2. Bacteria barely visible.

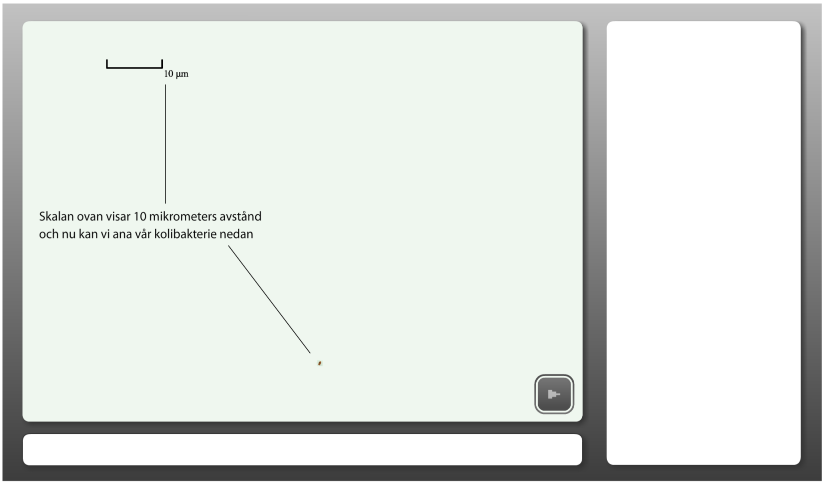


Figure A.4: Zoom in 3. Bacteria and intracellular structures visible.

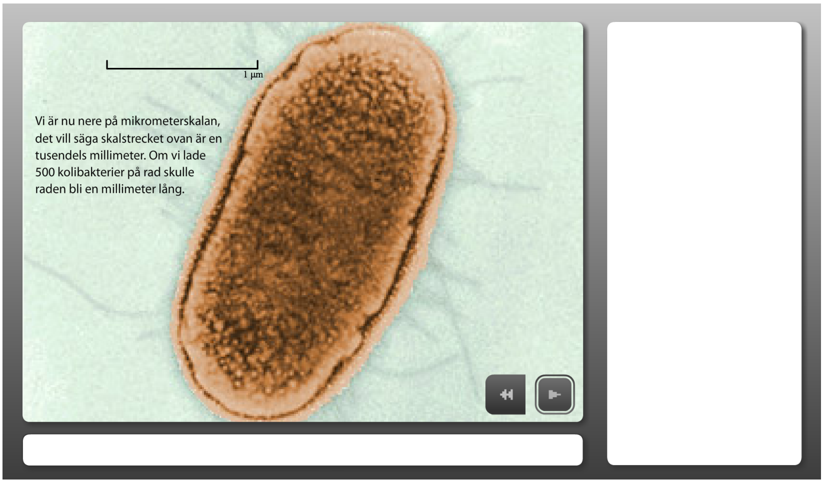


Figure A.5: Bacteria

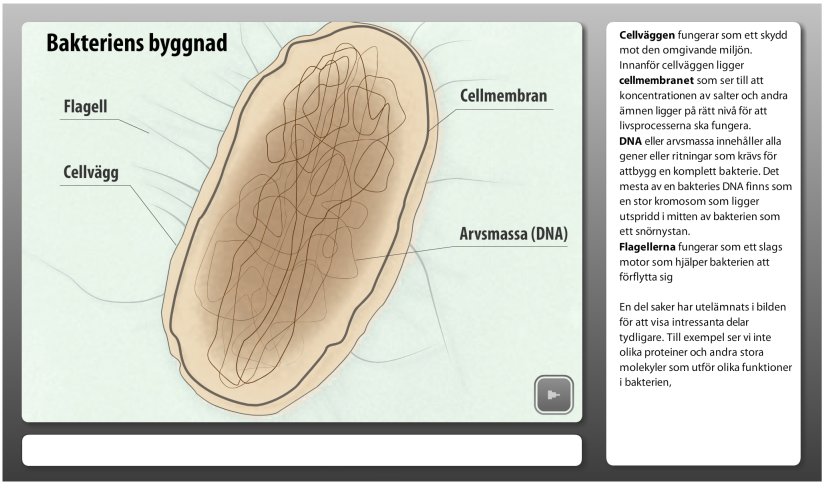


Figure A.6: DNA 1

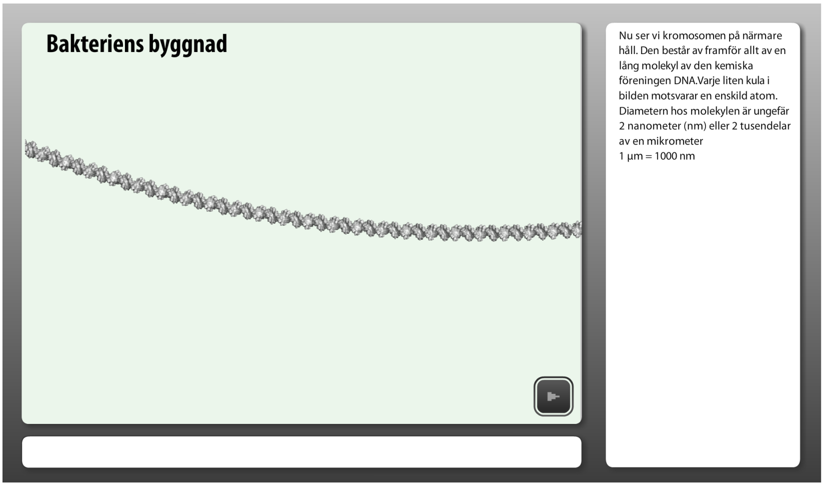


Figure A.7: DNA 2

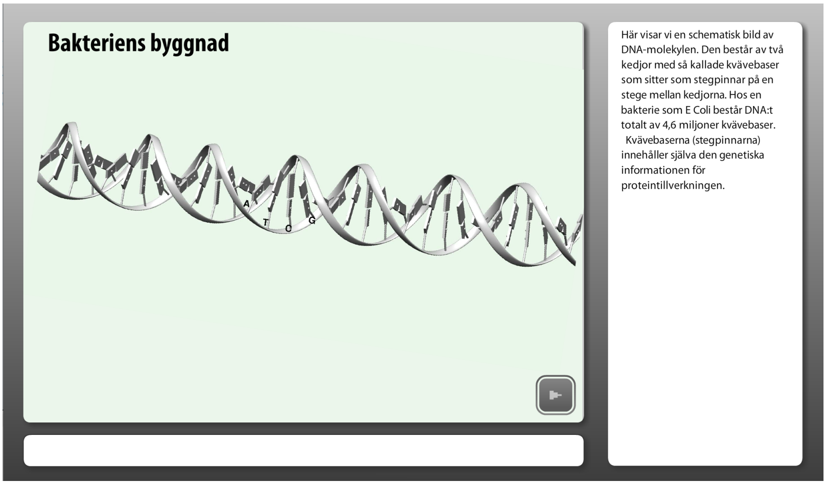


Figure A.8: DNA 3

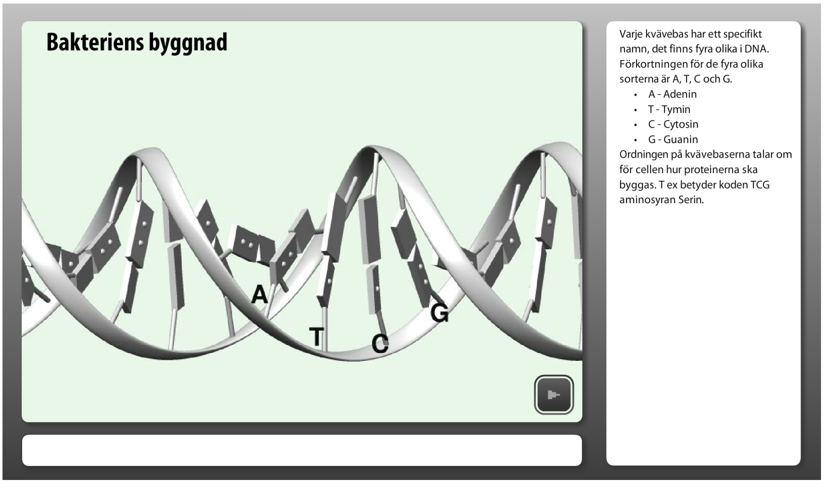


Figure A.9: DNA 4

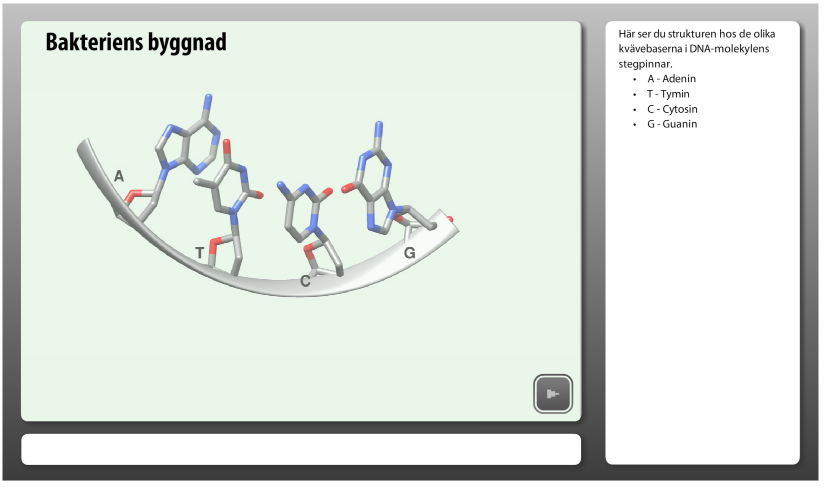


Figure A.10: Growth of bacteria.

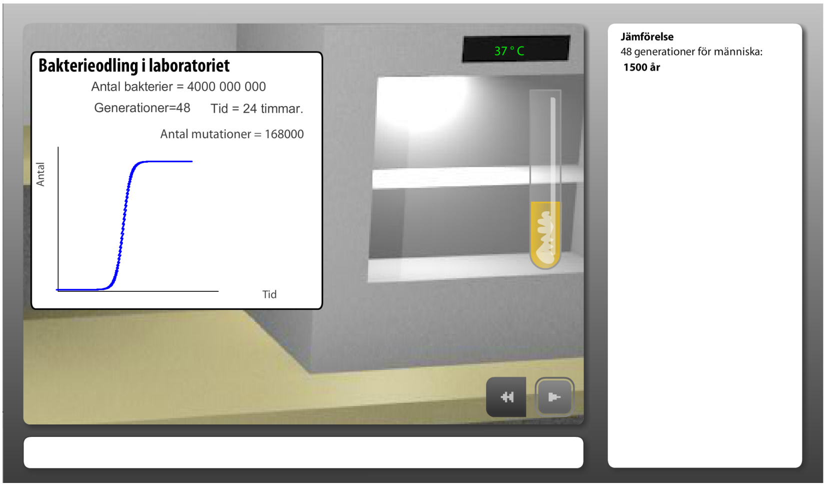


Figure A.11: Mutation

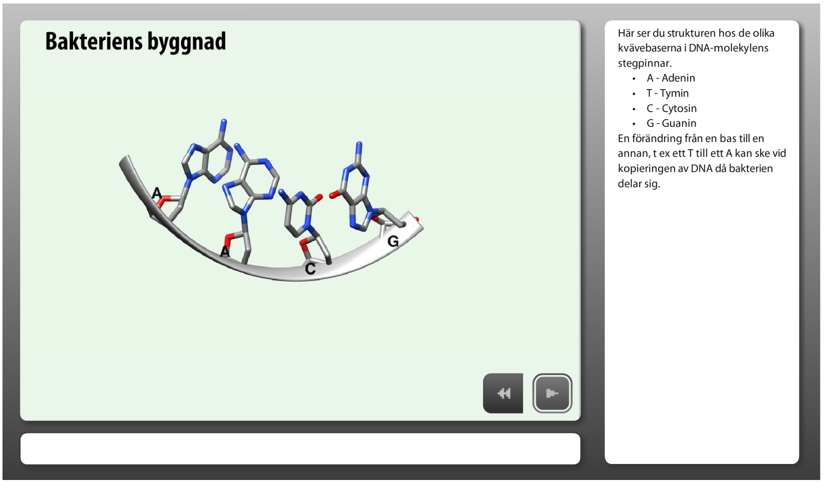


Figure A.12: Plates

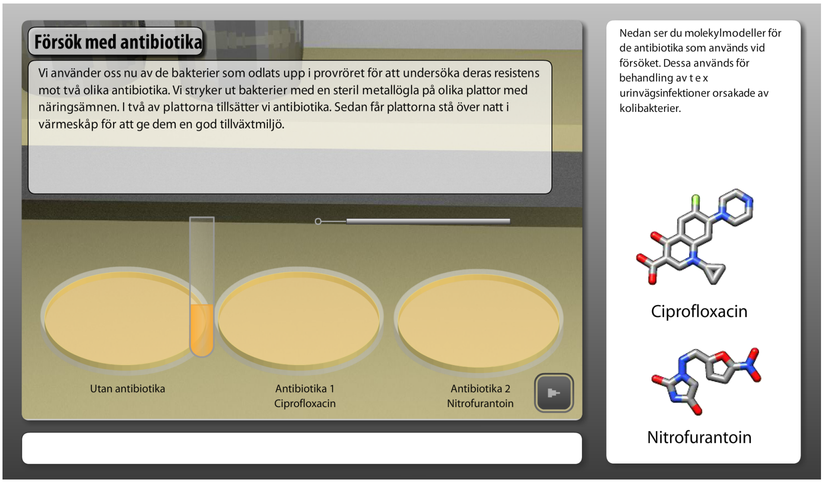


Figure A.13: Streak plating

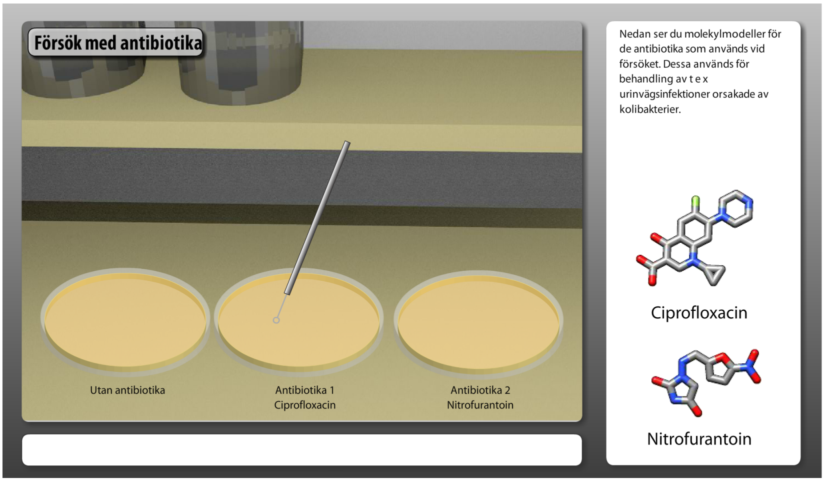


Figure A.14: Predict form

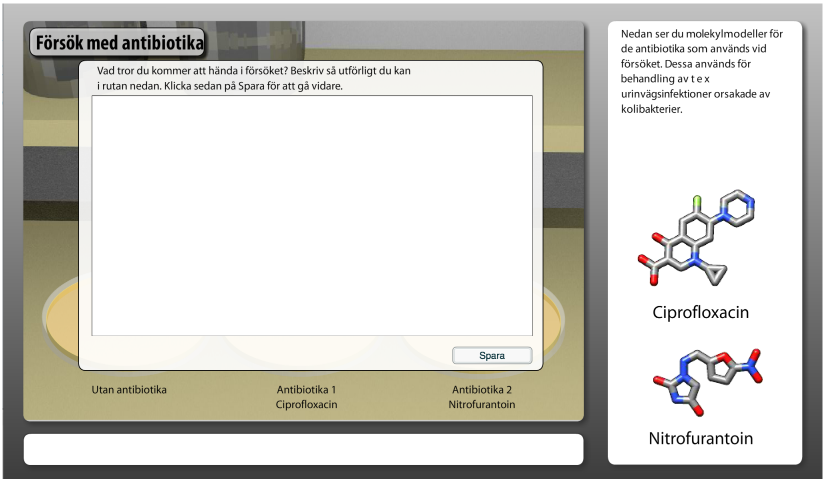
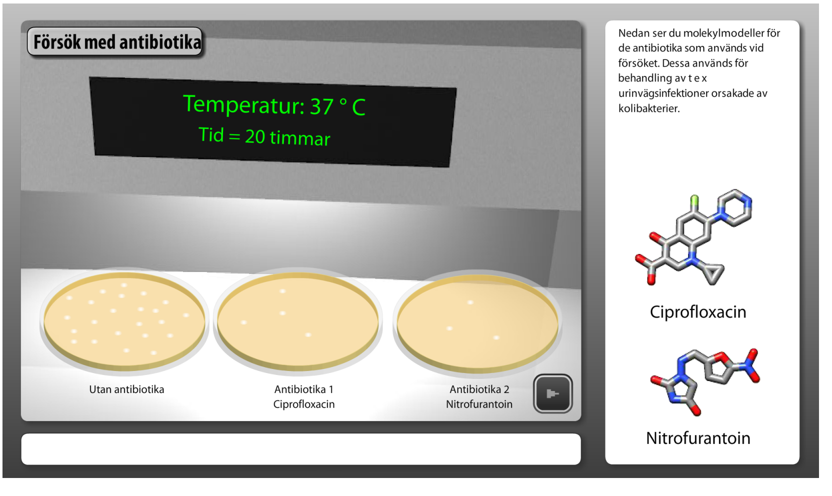


Figure A.15: After incubation



Appendix B

CINS Questions

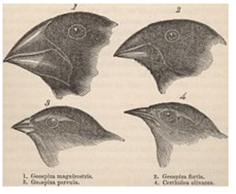
Swedish translation used in the study.

Konceptuell inventering av Naturlig Urval

Dina svar på dessa frågor kommer att användas för att bedöma din förståelse av evolutionen . Välj det alternativ på varje fråga som du tror motsvarar hur en biolog skulle svara **(tror inte denna ingress och överskrift ska användas i frågeformuläret till eleverna).**

Galapagos finkar

Biologer har länge trott att de 14 arterna av finkar som finns på Galapagosöarna har utvecklats från en enda finkart, Drillfinken (*Certhidea olivacea*), som flög till öarna för mellan en och fem miljoner år sedan. Nyligen utförda DNAanalyser stöder den hypotesen. I dag lever olika arter lever på olika öar. Till exempel Darwinfinken (*Geospiza fortis*) och Kaktusfinken (*Geospiza scandens*) lever på en ö, medan den Större kaktusfinken (*Geospiza conirostris*)håller till på en annan ö. En av de saker som skiljer de olika finkarterna är deras näbbars storlek och form, - se bilden.



Nedan kommer några frågor som handlar om hur dessa olika arter kan uppkomma och vilka faktorer som påverkar utvecklingen.

Välj det svar på varje fråga som du tror bäst motsvarar hur en (evolutions)biolog skulle svara.

1. Vad skulle hända om en hane och en hona av samma art placerades på en ö med perfekta förhållanden, inga rovdjur och oändligt med mat, så att alla individer överlever? Efter tillräcklig lång tid har passerat skulle..:
   a. ..antalet finkar vara litet eftersom fåglar bara får så många ungar att de ersätter föräldrarna.
   b. .. antalet finkar skulle fördubblas och därefter stanna på ungefär samma nivå.
   c. .. antalet finkar skulle öka drastiskt.
   d. ..antalet finkar skulle öka långsamt och sedan plana ut.

2. Finkar behöver mat att äta och vatten att dricka.
   a. När det är ont om mat och vatten under en period kommer en del av finkarna få svårt att skaffa vad de behöver för att överleva.
   b. När det är ont om mat och vatten kommer finkarna hitta andra födokällor, så det kommer alltid räcka till alla.
   c. När det är ont om mat och vatten kommer finkarna äta och dricka mindre så att alla överlever.
   d. Det finns alltid gott om mat och vatten på Galapagosöarna så det räcker till alla finkar.

3. När en grupp finkar har bott på en viss ö i många år..
   a. .. fortsätter antalet finkar att öka snabbt.
   b. .. är antalet finkar ganska stabilt över flera år, med vissa tillfälliga förändringar.
   c. .. ökar antalet finkar kraftigt och minskar kraftigt flera gånger varje år.
   d. .. minskar antalet finkar stadigt.

4. Vilka är de primära förändringar som sker gradvis över tid i en finkpopulation.
   a. De individuella egenskaperna hos varje fink förändras långsamt inom en grupp.
   b. Förhållandet mellan antalet finkar med olika egenskaper i en population förändras ..
   c. Framgångsrikt beteende som vissa finkar har lärt sig överförs till ungarna.
   d. Mutationer sker för att möta finkarnas behov när miljön ändras.

5. Vad finkarna äter beror på näbbens storlek och form. En del finkar äter nektar från blommor, andra larver under trädens bark, små frön eller stora nötter. Vilket påstående beskriver bäst förhållandet mellan finkarna och deras mat?
a. De flesta finkarna på en ö samarbetar för att hitta mat och delar sedan på det de hittat.
b. Många av finkarna på en ö kämpar mot varandra och de som är fysiskt starka vinner.
c. Det finns mer än tillräckligt med mat till alla finkar så de behöver inte kämpa för att hitta mat.
d. Finkarna tävlar framför allt med finkar som är nära släkt och äter samma slags mat. Det leder till att några kan dö av svält.

6. Hur uppkom de olika näbbtyperna bland Galapagosfinkarna från början?
a. De olika storlekarna och formerna på finkarnas näbbar uppstod på grund av de behövde kunna äta olika sorters mat för att överleva.
b. Förändringarna av finkarnas näbbar uppstod av en slump och när en näbbform passade den sorts mat det fanns gott om fick de fåglarna fler ungar.
c. Förändringarna av finkarnas näbbar uppstod på grund av att miljön orsakade de nödvändiga genetiska förändringarna.
d. Storleken och formen på finkarnas näbbar förändrades lite grann i varje generation, några blev lite större och några lite mindre.

7. Vilken sorts variation bland finkarna förs vidare till ungarna i nästa generation?
a. Alla beteenden som en fink lärde sig under sitt liv.
b. Bara egenskaper som var till nytta för finken under dess liv.
c. Alla egenskaper som bestäms av finkens gener.
d. Alla egenskaper som gynnades av miljön under finkens liv.Vad var orsaken till att finkar med olika näbb (former och storlekar) utvecklades till olika arter på de olika öarna
a. Finkarna hade ganska olika näbbar från början och de som hade egenskaper som passade bäst för att skaffa mat på en viss ö förökade sig snabbare.
b. Alla finkar är ganska lika så det är egentligen inte fjorton olika arter.
c. På de olika öarna finns olika sorters mat och därför förändras gradvis varje finks näbb efter vad den behöver för att skaffa mat på den ö där den lever.
d. Olika grupper av finkar utvecklade olika näbbar för att de behövde det för att kunna skaffa den mat som fanns.

Guppys från Venezuela

Guppys är små fiskar som lever i bäckar i Venezuela. Guppyhanar har klara färger med svart, rött, blått och med silvriga fläckar. Hanarna kan inte vara hur färggranna som helst för då blir de uppätna av rovfiskar som då lättare får syn på dem i vattnet, men om de har för neutrala färger kommer honorna att välja andra hanar att para sig med. Naturligt urval och sexuellt urval drar åt olika håll. När en grupp guppys lever i en bäck där det inte finns några rovfiskar ökar andelen hanar med häftiga färger inom gruppen. Om aggressiva rovfiskar kommer till bäcken kommer andelen färgstarka hanar att minska inom fem månader (3-4 generationer). Effekten av rovfiskar på guppyns färgsättning har studerats i konstgjorda dammar med aggressiva, inte lika aggresiva, repsktive inga rovfiskar och på liknande sätt i naturliga bäckar (Endler, 1980)

Nedan kommer några frågor fler frågor som handlar om hur dessa olika arter kan uppkomma och vilka faktorer som påverkar utvecklingen. Välj det svar på varje fråga som du tror bäst motsvarar hur en (evolutions)biolog skulle svara.

8. En typisk naturlig grupp med guppier består av hundratals fiskar. Vilket uttalande beskriver bäst guppys av en enda art i en isolerad grupp?
a. Guppierna har likadana egenskaper och är identiska.
b. Guppierna har alla viktiga egenskaper gemensamt, mindre skillnader finns men påverkar inte överlevnaden.
c. Guppierna är helt lika på insidan men har många skillnader i utseendet.
d. Guppierna delar många viktiga egenskaper men de varierar i andra egenskaper.

9. Fitness är ett begrepp som används av biologer för att evolutionära förklara framgången för vissa organismer. Vilken egenskap skulle en biolog säga är den viktigaste för att avgöra vilka Guppisar som

har högst fitness?
a. Stor kropp och förmågan att snabbt kunna simma från rovfiskar.
b. Utmärkt förmåga att tävla om mat.
c. Många ungar som överlever till reproduktiv ålder.
d. Många chanser att para sig med många olika honor.

10. Om vi antar att det är perfekta förhållanden, med massor av mat och utrymme, och inga rovdjur -Vad skulle hända om ett par guppier placeras i en stor damm?
a. Antalet guppy kommer att öka långsamt eftersom guppierna bara får så många ungar som behövs för att upprätthålla gruppens storlek.
b. Antalet guppy kommer att öka långsamt till en början sedan kommer de snabbt öka i antal och tusentals Guppy kommer fylla dammen.
c. Antalet guppy kommer inte att öka och bli väldigt stort eftersom det bara är insekter och bakterier som förökar sig på det sättet.
d. Antalet guppy kommer fortsätta öka långsamt medan tiden går.

11. När en grupp guppy har levt i en naturlig damm (med andra arter och rovdjur) i flera år, vad skulle då hända med antalet fiskar i gruppen?
a. Antalet guppy i populationen kommer förbli ungefär lika stort.
b. Antalet guppy kommer att fortsätta att öka i snabb takt.
c. Antalet guppy kommer minska gradvis tills detatt det inte finns några guppy kvar.
d. Det är omöjligt att svara på eftersom gruppstorlekar inte förändras enligt några mönster.

12. Vilka är de primära förändringar som sker gradvis över tid i en guppypopulation?
a. De individuella egenskaperna hos varje guppy inom en grupp förändras långsamt.
b. Förhållandet mellan antalet guppyer med olika egenskaper kommer förändras inom gruppen.
c. Framgångsrikt beteende som vissa guppyer har lärt sig överförs till ungarna.
d. Genförändringar sker för att guppiernas behov förändras när miljön ändras.

Ödlor på Kanarieöarna

Kanarieöarna är sju öar utanför Afrikas västkust. Öarna koloniserades stegvis av olika livsformer; växter, fåglar osv. Tre olika arter av ödlor som lever på öarna liknar en art som finns på Afrikas fastland. På grund av detta antar forskare att ödlorna färdades från Afrika till Kanarieöarna flytandes på trästammar som spolats ut i havet.

Nedan kommer ytterligare några frågor som handlar om hur dessa olika arter kan uppkomma och vilka faktorer som påverkar utvecklingen. Välj det svar på varje fråga som du tror bäst motsvarar hur en (evolutions)biolog skulle svara.

13. Ödlor äter olika sorters insekter och växter. Vilket påstående beskriver bäst tillgången på mat för ödlorna på Kanarieöarna?
a. Det är aldrig svårt att hitta mat, det finns alltid så mycket som behövs.
b. Eftersom ödlorna kan äta olika sorters mat kommer det alltid finnas tillräckligt med mat till alla ödlor.
c. Ödlor kan klara sig på väldigt lite mat så det spelar inte så stor roll hur mycket mat det finns.
d. Det är troligt att det ibland finns tillräckligt med mat men ibland kommer det inte finnas mat så det räcker till alla ödlor.

14. Vad tror du händer inom en viss art av ödlor om det inte finns tillräckligt med mat.
a. Ödlorna samarbetar för att hitta mat och delar på det som de hittar.
b. Ödlorna slåss om den mat som finns och de starkare dödar de svagare.
c. Genetiska förändringar som gör att ödlorna kan äta nya sorters mat uppstår.
d. De ödlor som är minst framgångsrika i kampen om mat kommer troligen att dö av undernäring och svält.Ödlepopulationer består av hundratals individuella ödlor. Vilket påstående beskriver bäst hur lika individerna i en grupp sannolikt är varandra?

a. Alla ödlor i gruppen är nästan identiska.
b. Alla ödlor i en grupp är helt lika på utsidan men det finns skillnader mellan hur deras inre organ ser ut och fungerar, till exempel hur de bryter ner maten.
c. Alla ödlor i gruppen delar många likheter men skiljs åt av saker som storlek och klolängd.
d. Alla ödlor i en grupp är helt unik och delar inga egenskaper med andra ödlor.

15. Vilket påstående skulle kunna beskriva hur egenskaper förs vidare från en generation ödlor till nästa generation?
a. Ödlor som lär sig fånga en viss sorts insekt överför denna nya förmåga till sina ungar.
b. Ödlor med förmågan att höra men som inte får någon överlevnadsfördel av denna hörselförmåga kommer så småningom att sluta föra vidare förmågan till sina ungar.
c. Ödlor med starkare klor, som gör att de kan fånga vissa insekter, får ungar som under sin livstid kommer att få ännu starkare klor.
d. Ödlor med en viss färg eller ett speciellt mönster kommer att föra vidare denna egenskap till sina ungar.

16. Fitness är ett begrepp som används av biologer för att förklara hur evolutionärt framgångsrik en varelse är. Nedan ses en beskrivning av fyra olika ödlehonor. Vilken av dessa ödlor skulle en biologi anse ha högst fitness?

	Ödla A	Ödla B	Ödla C	Ödla D
Kroppslängd	20 cm	12 cm	10 cm	15 cm
Ungar som överlever till vuxen ålder.	19	28	22	26
Ålder vid dödstillfället	4 år	5 år	4 år	6 år
Kommentarer	Ödla A är väldigt frisk, stark och smart.	Ödla B har parat sig med många ödlor.	Ödla C har mörk färgteckning och är väldig snabb.	Ödla D har det största reviret av alla ödlorna.

a. Ödla A
b. Ödla B
c. Ödla C
d. Ödla D

17. Hur uppkom troligen variationen i kroppsstorlek hos de tre ödlearterna, enligt teorin om naturligt urval?
a. Ödlorna behövde förändras för att kunna överleva så nya fördelaktiga egenskaper utvecklades.
b. Ödlorna ville bli olika stora så fördelaktiga egenskaper utvecklades gradvis i gruppen.
c. Slumpmässiga genetiska förändringar och sexuell rekombination bidrog båda till att skapa nya varianter.
d. Miljön på öarna orsakade genetiska förändringar hos ödlorna.

18. Vad kan orsaka att en art förändras till tre arter med tiden?
a. Grupper av ödlor mötte olika miljöer på de olika öarna och för att överleva behövde de bli olika arter med olika egenskaper.
b. Grupper av ödlor måste ha blivit geografiskt isolerade från varandra och över tiden har slumpmässiga genetiska förändringar samlats i dessa skilda grupper.
c. Det är kanske små skillnader men huvudsakligen är alla ödlor lika och alla tillhör samma art.
d. För att överleva behövde olika grupper av ödlor anpassa sig till de olika öarna, och därför utvecklades gradvis alla organismer i en grupp till att bli en ny ödlearter.

Appendix C

Interview protocol

Intervjuguide

(Modified after Rundgren & Tibell 2009)

1. Introduktionsfrågor
   a) Är du intresserad av naturvetenskap? Biologi? Varifrån kommer ditt intresse?
2. Huvudfas, efter att ha sett animeringen.
   a) Beskriv vad du såg i animeringen?
   b) Hur tolkar du det?
3. Avslutande frågor
   a) Läser du texten först eller tittar du på bilderna / animeringen först?
   b) Kan du rita DNA på tre olika sätt?
   c) Vad avgör om en viss bakterie kommer att överleva antibiotika?
   d) Vad tycker du om frågorna som fanns i frågeformuläret? Förstod du dem?

Appendix D

Interview transcripts

Intervju 1

I = Intervjuare
E4 = Elev

I: - Då tänkte jag först fråga om du är intresserad av naturvetenskap?
E4: - Ja.
I: - Du har ett intresse för det?
E4: .Ja, jag tycker det är intressant.
I: - Är det något särskilt du är intresserad av där, till exemepel biologi eller nåt annat?
E4: - Ja, jag tycker det är intressant hur kroppen reagerar, på, ja olika saker och ting, och sen tycker jag även att det är intressant hur kroppen fungerar och så där.
I: - Mm
E4: Och även andra organismer, hur de är, stora som små
I: Några särskilda organismer med tanke på att du går naturbruksprogrammet?
E4: Eh, Djur menar du?
I: Ja?
E4: Ja, jag tycker väl att, alltså, sällskapsdjur är väl det som är mitt toppintresse dårå. Men jag tycker även det är väldigt intressant att veta hur svenska djur, som fåglar och andra, hur dom är och det är ju också intressant att veta när det kommer in sjukdomar sånt där och hur dom sprider sig och så.
I: Varifrån kommer ditt intresse, vet du det?
E4: Ja, jag hade ju en biolog.. eh... komps till våran familn och han hållde ju på med fladermöss, jag hållde ju på mycket med att studera fåglar gjorde jag som femåring.

I: Nu när efter att ha sett animeringen, kan du kort beskriva vad du såg, utifrån ditt eget minne så att säga, vad såg du=?
E4: Ja, jag såg ju en bakterie, och vilka delar den hade, och även dess uppbyggnad och så där, Och så sen så jag även hur en bakterie reagerade på antibiotika.
I: Ja
E4: Som då visades tydligt att, ja, de blev kraftigt påverkade av antibiotika och bryts ned.
I: Hur tolkar du det du har sett då ? Du säger här att bakterierna t ex blev påverkade och att de bröts ned av antibiotika och så, hur tolkar du alla de sakerna du sett?
E4: Ja...
I: Vad tror du man vill visa i animeringen?
E4: Jaa, vad jag kan se i den här sista bilden så verkar det ju vara så att bakterierna verkar mindre påverkade av …
I: Hur tänker du då.
E4: Jag antagligen så har bakterierna evolutionärt kanske blivit mer resistenta mot antibiotika 1 än vad tvåan är då.
I: Vad är det i animeringen som får dig att tro att det är så?
E4: Ja för utan antibiotikan var det ju massa bakterier (i plattan med antibiotikainnehåll men inte i de andra?)
Tekniskt fel på inspelingen...
I: Några men inte alla?
E4: Ja... dom har väl starkare så här arvsmassa eller nåt så det inte tränger i deras uppbyggnad och förstör deras DNA som bygger upp dom.
I: Okej, dom här vita prickar du ser på plattorna, här vad tror du dom är för nånting?
E4: Jag tror det är bakterier som har odlats upp?
I: Hur många tror du det är i varje sådan här? (Pekar på en koloni)
E4: Ja, det är väl kanske, ett hundratusental kanske.

I: okej, eh något annat du såg i animeringen som du funderade på eller som du fäste uppmärksamhet vid?
E4: Jaa.. jag tyckte det var intressant att det var.. att det krävdes så många för att det skulle bli en millimeter, att dom är så himla små men ändå en levande varelse.
I: Hur tyckte du att den här inzoomningen var, gick den, i hastighet, gick det att följa med, förstod du vad, vad som hände?
E4: Ja , jag förstod vad som hände, men jag tyckte lite att den, att det var många tryck för att den skulle komma in, alltså på play-knappen, för att det skulle zoomas in, annars att det hade varit lite bättre ifall det hade zoomat in långsamt bara genom ett tryck.
I: Ja, ja,
I: Något annat sånt du tänkte på i animeringen, med knapptryck, förstod man hur man skulle göra på olika ställen eller var det nånting man skulle kunna ändra på för att det är lättare att förstå hur man ska ta sig fram i den?
E4: Nej, jag tyckte det var bra.
I: Eh, när du tittar på animeringen läser du texten först eller tittar du bilderna eller det som rör sig först?
E4: Texten.
I: Du läser texten först, varför gör du det då, tror du?
E4: Ja för då eh får man läsa mer fakta så man förstår sig på vad som händer i animeringen.

[Rita DNA – eleven ritar olika DNA-modeller]
Fortsättning:

I: Eh, vad tror du avgör om en specifik bakterieindivid kommer att överleva antibiotikan eller inte, tror du?
E4: Ja, jag tror att dom där flagellerna antar jag att dom känner av att det kommer nånting i närheten och att dom då kan undvika att bli träffade av dom.
I: Tror du att det är olika hos alla bakterier i den här soppan, eller är alla likadan?
E4: Ja, det finns väl olika, beroende på var dom uppstår, kanske i magen lite större för att kunna bryta ned mat och så....

I: Nånting annat du skulle vilja skicka med om vi ska göra den här bättre framöver?
E4: Nä, jag tyckte det var väldigt verklighetstroget och att man såg vad det var på direkten och så där så det, det tycker jag inte. Och det var liksom laboratorium såg man ju tydligt också, det tyckte jag var, det gjorde att det blev lite intressantare, än att det hade bara varit en vit bakgrund och några grejor så där, jag tyckte det var bra.

I: Läste du den här sidan när du kom hit också?
E4: Nä, det gjorde jag inte, jag fokuserade mest på animeringen.

Intervju 2

E10 och E13

I = intervjuare

I: Nu tänkte jag att efter ni har sett animeringen att ni skulle få berätta litegann vad ni tycker att ni har sett i animering och vad, vad , hur ni tolkar det ni ser, vad är det som visas , vi kan börja med dig E10, vad såg du i animeringen.
E10: Förändring.
I: Vad sa du?
E10: Förändring.
I: Vad då för förändring?
E10: Mutationer (frågande tonfall, något osäkert)
I: Mutationer, ja, kan du utveckla det litegrann?
E10: Hur menar du...
I: Vad är det för mutationer du ser eller vad är det för förändring du ser?
E10: Det beror väl på vilket förhållanden...
I: Var såg du mutationen någonstans?
E10: Där jag missade den. (refererar till samtal innan inspelning om att hon missat visning av denna.)
I: Det du såg då, förändring säger du...
E10: Nej man ser ju en förändring, det beror ju på vilka förhållanden det är med, hur bakterier utvecklas och hur människan utvecklas, det tog 1500 år för 48 generationer och för bakterier tog det 24 timmar så att det är ju otrolig skillnad på det...
I: I tid?
E10: Mmm, i tid.
I: Du då E13, vad tyckte du att du såg i animeringen?
E13: Ja, först var det lite information om vad som fanns i själva bakterien och så. Och sen var det ju det som E10 sa, det med mutationer och förändringen, så då anpassade den väl sig efter ett tag till antibiotikan, antar jag.
I: Mm. Hur tror ni den anpassningen kan dyka upp?
E10: Anpassningen dyka upp?
I: Var kommer den ifrån, finns den där från början hos bakterierna? En del klarar sig ju här och en del inte, var tror ni den uppkommer?
E10: De kanske har olika förutsättningar, det var ju olika antibiotika.
I: Mm,
E10: Dom slår väl på olika saker.
I: Mm. Men alla tål inte antibiotika utav bakterierna tror ni eller?
E10: Nej,
E13: Nej.
I: Var lite ledande fråga i och för sig men.
E10: Vissa är känsligare än andra.
I: Vad visar det här ni ser på skärmen då tror ni? (Pekar på de tre olika plattorna) Om ni jämför dom där två t ex
E10: Den ena har ju antibiotika och den andra inte, och där ser vi att den slår ut nästan allting.
I: Mmm, hur kommer det sig att alla inte slås ut då?
E13: För nånstans blir det ju att dom förändrar sig att dom blir lite mutationer så dom kan klara av antibiotikan på nåt sätt.
Var det något annat ni såg i animeringen som ni tänkte, nåt nytt, nåt som ni lärde er eller upplevde?
E13,E10: Nen

I: När ni tittar på animeringarna, läste ni texterna först eller bilderna, eller det som rör sig först?
E10: Texten först.
E13: Jag läser också först. Sen kollar man på bilderna.
I: Och det gjorde ni första gången ni såg den också?
Båda: Mmm.
I: Varför gör ni så ni tror ni?
E10: Man vill hinna med och läsa texten.
E13: Få en liten uppfattning och sen kanske bestämma att ah men ah...
E10: Annars förstår man ju inte bilderna, där snurrar det där och där händer det där utan, jag läser alltid texten först. Sen så är det, Likadant när det kommer en powerpoint, åh jag måste hinna med att läsa nu, så så det är ju alltid lite så.
I: Upplevde ni att det var svårt att hinna med att läsa och att titta på bilderna eller det som rörde sig?
E10: Ja, ja det skulle ju, ja jag tycker det är enklare om texten kommer först och sen bilden, för att då har man läst texten.
E13: Nu kunde man, visst, den hära målningen aå gick ju lite väl fort, men man kan ju trycka själv om man vill gå vidare så man hinner ju läsa ändå lite och så.
I: Dom här texterna som låg till här vänster (avser textruta till höger, fel av intervjuaren), läset ni dom också?
E13: Ja
I: Ni gjorde det?
E13: Allt som går att läsa.(skratt)
I: Upplevde ni att det var svårt eller lätta att veta vad man förväntades göra när man kom in i animeringen, hur man skulle ta sig fram i den?
E10: Nej, det är väldigt tydligt, det blinkar ju.
E13: Ja.
E10: Och sen är det ju oftat att det är där nere nånstans man tar sig vidare eller så hoppar den vidare av sig själv.

//Ritar DNA

Utvärdering av CINS-frågorna (ej ordagrant transkriberat, endast för utvärdering)

- Lätta spontant
- Förstod inte sammanhanget mellan frågorna och animationen
- Nämner dock Galapagosfinkarna och ödlorna, man visste det sen innan att det hade att göra med ”evolutionen och mutationer och så”
- Identifierar en fråga som svår att förstå ”vi minns att det var en – vad var det här för något”
    - Den här med ”primära” (syftar på primära förändringar)
    - Primitivt, något slags förändring säger en, en annan vilken förändring som skedde över tid.
    - Det var två stycken, som jag gissade på!
    -

Annat i animeringen som de tycker kan förbättras:
E10: Text först, bild sen! (Frågan om kognitiv belastning), Man fokuserar på bara på texten, man fokuserar på flera saker Kommer bilden sen tittar jag bara på den då.

Intervju 3

Elev 15 = E15

I = Intervjuare

I: Bra, den första frågan jag tänkte ställa handlar om naturvetenskap, om du har nåt intresse för det?
E15: Jaa, Alltså jag tycker det är kul med miljön o så, och det är ju miljöproblemet och sånt, jag gick ju en sån linje innan. Så, nämen det tycker jag är kul.
I: Hur är det med biologi då, har du nåt speciellt intresse för det... utöver miljön?
E15: Njaej, jag tycker det är kul med amen, djur och alltså visst, hur vi är uppbyggda och så, men det är väl inget jätteintresse...
I: Nej, utan det är miljön som är det stora intresset inom det?
E15: Jaaa, eller det var iallafall, jag är väl lite genuint intresserad av det mesta.
I: Men du går naturbruk nu, är det djur?
E15: Ja..
I: Varför blev det just djur då, vad är det som är intressant med det då?
E15: Nej, Jag vet inte jag var skoltrött så jag ville gå nåt jag kunde. Men, det är kul tycker jag.
I: Men du har ett djurintresse menar du då?
E15: Jaa.
I: Är det sällskapsdjur då?
E15: Nej det är alla möjliga.
I: Varifrån kommer ditt intresse då tror du för naturvetenskap eller djur, hemifrån?
E15: Det är nog lite blandat, hemifrån och från skola.

I: Om man nu tänker att du har sett animeringen nu här kan du kort beskriva vad du såg för nåt i animeringen?
E15: Ja, dom visar ju, eller dom odlar ju bakterier, eh, och sen visar dom ju hur det typ muteras och ja, det är väl mest det.

I: Hur tolkar du animeringen, vad tror du den vill säga?

E15:Att, ja beroende på, alltså som jag tolkar det, att beoende på mutationerna så, alltså, händer olika saker för att jag tolkar det som att det är antibiotika, de blir ju resistenta mot antibiotika bara för att, antibi... , de muteras ju och blir bättre, bakterierna kan ju inte, bakterierna kan angripa antibiotikan iallafall, för att de typ har utvecklats så.

I När tror du mutationen skedde som gör att de tål antibiotikan, sker den i det här steget eller när de var i provröret?
E15: Jag tänker nog i... men det lär ju nästan ha skett i provröret.
I: Tänkte du det när du såg den första gången?
E15: Ja...
I: Funderade du över det?
E15: Ah, inte jättemycket kanske men...

I: Okej, när du tittar på animeringen läser du texten först eller tittar du på bilderna och animeringen först och läser texten sen?
E15: Texten först.
I: Varför gör du det då tror du?
E15: För att få en mer helhet, tycker det är lättare att uppfatta liksom vad man ser ifall om man läst

lite vad man ska se, blir lättare att kolla på det man ska kolla på.
I: Såg du texterna här till höger också?
E15: Mm
I: Läste du dom?
E15: Ja.
I: Gjorde du det första gången du såg animeringen ocks?
E15: Nja... var lite trött då. (skratt)
I: Så då läste du inte den alla gånger då...?
E15: Nja, det var lite slarv då.

Frågor om animeringen / förslag på förbättringar (ej ordagrant transkriberat)

Inzoomningen av mutationen – förkara mer varför man får se samma sak igen (”man undrar lite varför”)

”Helt okej, den förklarar bra” ”Det är bra att få både en bild och en text till”.

Frågor om CINS-frågorna (ej ordagrant transkriberat)

Bra, men det var vissa svarsalternativ som var lite lika ibland, ”läste dom lite extra”. ”Måste vara svårt om man inte läst ämnet innan”

”Det här handlar ju om mutationer och det gjode animeringen också” (om kopplingen mellan frågorna och animeringen)

”Man skulle nog vilja ha ett bättre svar i slutet men eftersom man ska svara på frågorna igen så … hehehe”

Man vill ha en förklaring på resultatet.(Tyder detta på att animeringen är för svårtolkad då svaret inte var uppenbart?!)