VIRTUAL BIOLOGY EXERCISE FOR THE ACTIVE LEARNING OF MENDELIAN GENETICS AND DEVELOPMENT OF KEY COMPETENCES

Miro Puhek
Sinergise, laboratory for geographical information systems, Ltd., Teslova ulica 30, Ljubljana, Slovenia

Andrej Šorgo
Faculty of Natural Sciences and Mathematics, University of Maribor, Koroška cesta 160, Maribor, Slovenia

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Abstract: Over years of growing peas Gregor Mendel set the basis of modern genetics. When he was comparing different peas he used problem based activities and practical work. All these methods can be described as key activities for developing competences. With these activities students tend to gain more knowledge and the teachers do not have to worry that students would be under challenged. While it is hard to expect that teachers will turn classes into gardens to grow peas, the virtual experiments are far more reachable. The cooperation between Sinergise and Faculty of Natural Sciences and Mathematics results in developing interactive virtual environment that will stimulate students to actively learn about science. With the exercise Mendelian Genetics students have to solve problems that they are introduced to and consequently at the same time learn new terms connected with Mendelian genetics. The virtual exercise was created to stimulate the development of various competences, important in natural sciences. In the paper we presented the virtual exercise, which was initially tested on 31 students in second grade of lower secondary school. Results show that students did not come across extraordinary difficulties while working on it. When working on the explanation of the problem, the exercise helped the students with less knowledge.

1 INTRODUCTION

The salvation of different challenges and active student's participation in the educational process represent the foundation of encouragement of critical thinking and problem based learning (Prince, 2004; Savery, 2006). With active work learning changes from collecting facts and memorization to increase of inquiry and development of competences. Competences cannot be learned, but students have to develop them through active engagement (Špernjak and Šorgo, 2009). Practical work, such as usually found in laboratory and field work, is recognized as the method where students can achieve subject through active participation.

The Slovenian curriculum for genetics in the primary school defines genetics as the link of theory and practice, based on the student's experiential learning and their personal activity (Verčkovnik, 2000). Under the key methods are defined: laboratory and experimental work, individual and guided observation, work on projects and cultivation of organisms.

An example of that kind of work is Mendel's crossing thousands of peas in order to observe the transmission of characteristics on the offspring (Blumberg, 1997). With inquiry on growing peas, Mendel set the basis of modern genetics. Because of limited budget the school is unable to guarantee the sources and time that are needed for development of numerous generations of plants and animals. The teachers can now substitute this lack by introducing the information communication technology (ICT) in the classrooms. In the concept of classical experimental work as well as in the virtual work there can be differentiated between completely guided type of work (like cookbook) and work that encourages students to inquire the world around them (hands-on activities). Good examples of

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didactical tools are attractive and encourage the curiosity of students (Fancovicová, 2010). They do not only demand dull clicking (Špernjak et al., 2010), but are supposed to illustrate theoretical concepts in practice (Huang, 2004).

The purpose of the paper is to present the virtual exercise Mendelian Genetics and initial results of testing in the classroom. The exercise could be used, not only in the classrooms, but also as addition to the field work. The main aim during the development was the need to increase the students to get to the knowledge with active work and solving little problems to overcome an obstacle – to learn Mendels' laws. The exercise would be used in the virtual environment that we are developing at Sinergise.

2 METHODOLOGY

When developing the virtual exercises the main aim represented the active inclusion of students and achievement of higher cognitive skills. According to Boerwinkel et al. (2008) we choose Labrador retrievers as the object of experiment, because they show importance for the students, society and science. Through the case of Labradors the students can become aware that science is not only learned in school, but is present all the time in everyday life. Exercise could be later expended with other objects, especially when it will be used with outdoor activities.

Pilot testing of the virtual exercise was made on a small sample of students (N=31) in the second grade of the lower secondary school. The teacher used the exercise in the end of the class hour as a tool to renew the gained knowledge. To increase the debate between the students, the exercise was purposely tested in the "classical" biology classroom with one computer that was projecting material on the wall. Additionally, the students were asked to fill out the work sheets and the evaluation form to validate the exercise.

3 VIRTUAL EXERCISE MENDELIAN GENETICS

The basic view of the virtual exercise Mendelian Genetics is presented in the Figure 1. The exercise can be divided into five different parts (A, B, C, D and E), where students learn about the basic Mendelian principles of the first and second Mendel's law – Law of Segregation and Law of Independent Assortment. When students finish one chapter, they can continue with the next one. This principle forces them to be active if they want to gain feedback, which is presented through picture of the parent or the offspring.

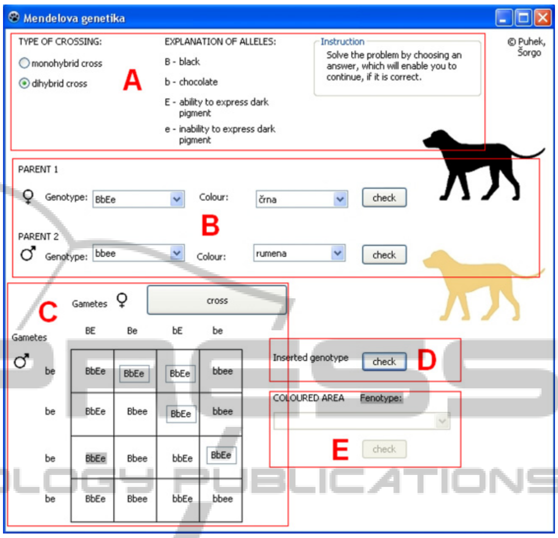

Figure 1: The basic view of the virtual exercise Mendelian Genetics with the markings of different tasks: A) menu with the explanations; B) selecting the genotypes and the matching colour of parents; C) crossing; D) defining the missing genotypes in the Punnett square; and E) matching randomly selected genotype with appropriate phenotype.

Part A serves as an introduction to the problem and as the basic menu to choose the type of crossing. The students are introduced to the terms alleles, monohybrid and dihybrid crossing. An explanation of different alleles used in the exercise is described in the legend. In the part B, students deal with the terms genotype and phenotype. The problem that has to be solved is to decode the genotype of each parent and link it with the matched colour. Students can observe the difference between the dominant alleles that are usually seen on the outside and the recessive alleles that are hidden behind them. If the answer that the student selects is correct, the picture of parent shows up. The progress to part C and the possibility to cross the selected dogs is enabled, when pictures of both parents are showed. During the salvation of the problem students meet the terms gametes and the Punnett square. Between the stage C and D the teacher can ask the students to predict the breeding results, where the right gametes in the Punnett square have to be included. A similar problem is presented in the part D, where some genotypes in the Punnett square are hidden and students have to guess them. At this point it has to be said that the answer is case sensitive and the order of different gametes is also important. In the final stage of the virtual exercise (part E), the marked genotype should be connected with the right phenotype from the drop-down list. The marked area is selected randomly. If teacher wants to choose another one, the problem can be launched again and again with clicking on the button. Again, if the answer is correct, the picture of the chosen Labrador offspring is shown. With the help of pictures that present the carriers of different pigments, the dogs can be defined as homozygous and heterozygous organisms. With this knowledge they can later calculate the frequencies of different phenotypes to support the Mendel's hypothesis.

4 RESULTS AND DISCUSSION

In the virtual exercise Mendelian Genetics we put the students into the shoes of modern Gregor Johann Mendel, the Austrian priest and the "father" of modern genetics. Instead of peas, students are breeding virtual Labradors. The exercise is developed interactively to support critical thinking and active learning approach. Anderson and Krathmohl's taxonomy of the cognition (Anderson et al., 2001) represented the core of the development of the exercise. Through working on the exercise the students are practicing different levels of cognitive domains (Table 2). With the help of well known breed of the dog, the science can be brought into the classroom and the exploration of different Mendelian principles can begin.

After the biology hour the students were asked to support us with the answers when the work with exercise was difficult and when attractive, to give us the disadvantages and advantages of the exercise. 59 % students declared that working with exercise was fun and enjoyable. 22% did not like working with it and 19% were unable to decide. The students were asked to give comments about the exercise and it was interesting that they did not only acknowledged the different learning approach but also defined this kind of learning as easier to understand a difficult learning material. Frequent answer was also that they like "new" type of learning, which has shown them the genetics from different perspective. In next par they declared that 81 % did not face any difficulties with usage and 19 % were unable to decide.

Table 2: Anderson and Krathmohl's taxonomy of the cognition in context of the exercise Mendelian Genetics.

Anderson and Krathwohl's Taxonomy	Task in exercise Mendelian Genetics	Part of the exercise (A, B, C, D and E)
1. remembering	to define an allele	A
2. understanding	to differentiate between mono- and dihybrid crossing	A
3. applying	to connect the genotype with true colour	B, E
4. analyzing	to analyze the Punnet square and fill the missing gaps	D
5. evaluating	to predict the result in Punnett Square	C
6. creating	to use the exercise and create desired colour of the breed	work sheet

Majority of students as advantage agreed that virtual tools helped them to understand the problem and provide answers. Based on the gained results we can conclude that students with less knowledge tend to express more interest than students with better knowledge. Additional important answers were that virtual tools are fun and as that more attractive to use when learning. As disadvantages students described the exercise as not understandable, which includes the technical part of the exercise. With the knowledge that students generally like working and learning with the computers (Špernjak et al., 2010), we were surprised that an answer suggested a lack of interest towards computer work. Students with better understanding of Mendelian genetics showed less interest in the exercise as students to whom the problem was harder to understand. An additional problem occurred that some students were unable to distinguish between learning and playing with computers, which indicates that some students found the exercise not interesting.

5 CONCLUSIONS AND FUTURE WORK

The presented virtual exercise was primary developed as a helping tool for understanding Mendelian genetics. The field of genetics introduces numerous new terms (alleles, phenotype, monohybridous organisms, Punnett square etc.), which are abstract to the students and therefore present difficulties understanding this complex structures.

The virtual exercise Mendelian Genetics can be used as an independent laboratory exercise, which is performed in virtual environment, or as addition to classical laboratory or even field work. With the exercise it is also possible to verify the hypothesis as the preparation for a new class or to refresh knowledge that was already gained. The exercise Mendelian Genetics is designed like a self-running program, which does not need internet access to work. This makes it a good practicing tool for students to refresh knowledge before the exam.

The initial testing, performed on students of lower secondary school (subject Biology), showed that majority of students did not have problems with the work on the virtual exercise and like the new way of learning. We also have to evaluate the pretest and posttest results to measure the effect of simulation on knowledge. The gained feedback will enable improvements of the virtual environment that we are developing at Sinergise.

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