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Effectiveness of the Use of Educational Software in Teaching Biology

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Abstract

The paper analyzes comparative effectiveness of the use of educational software and traditional teaching methods in biology instruction for high school students. A random sample consisted of 173 students of grade 12 of a high school in Zrenjanin, Serbia, who were randomly distributed into the control and experimental groups. The students in the experimental group learned biology content (Mechanisms of Heredity) using educational software, whereas the students in the control group learned the same content using the traditional teaching methods. The research was carried out using the pretest - posttest equivalent groups design. All instruments (the pretest, the posttest and the retest) contained the questions belonging to three different cognitive domains: knowing, understanding and reasoning. The analysis of the posttest and the retest results showed that students from the experimental group achieved significantly higher quantity and quality of knowledge in all three cognitive domains than the students from the control group. It can be concluded that educational software has a positive impact on improving students' achievement in biology teaching.

Key words: *achievement; genetics; teaching efficiency; traditional teaching.*

Introduction

Teaching biology and other sciences in schools in the Republic of Serbia is still dominantly organized and conducted in a classical way, so that students' activities during classes are only organized as passive listening, receptive learning and studying by heart. In such teaching students' opinions are neglected, especially creative thinking and looking for new ideas. Presently, the educational environment has changed from teacher-centered to student-centered. In student-centered teaching the teacher acts as a facilitator, creating the learning conditions in which students actively engage in experiments, interpret and explain data and negotiate understandings of the findings with their peers. "By applying interesting didactic scenarios he/she supports the students' development of cognitive, affective and psychomotor learning domains" (Borić & Škugor, 2014, p. 150). For students, learning science is active and constructive, involving inquiry and hands-on activities (Ronoh, Wachanga, & Keraro, 2014).

Teaching and learning biology supported by information and communication technologies offers an alternative to the solutions used in the traditional lecture based approach. Learner-centered approaches to technology-enabled learning can empower learners and leverage good learning experiences that would not otherwise have been possible (Dumont, Istance, & Benavides, 2010).

The use of educational software (ES), supported with appropriate teaching and learning strategies such as research-based learning (RBL) (Gelbart, Brill, & Yarden, 2009), problem-based learning (PBL) (Annetta, Minogue, Holmes, & Cheng, 2009) or inquiry-based learning (IBL) (Kyza, Constantinou, & Spanoudis, 2011), has a special importance in teaching and learning. All these strategies make the individualization of teaching possible, provide the individual knowledge, constant feedback and enable the monitoring of students' progress. By using some special techniques, the controlled function of teaching is realized, the teaching process is regulated and inner motivation for learning is encouraged (Mandić, 2010). Didactically well-designed programs enable gradual improvement in accordance with student's abilities, awakening the feeling of competence at each level. More competent students can leave out parts of lessons that are well-known and/or easy to them, while students lagging behind have to learn that material to be able to understand further information (Voskresenski, 2004). Educational software must be projected so that it satisfies the needs of all participants in the educational process. The simplicity in using the software must be provided for students, as well as a high degree of obviousness of the teaching material which is being presented in this way. Besides, software should be interesting and stimulating to motivate students for studying (Virvou, Katsionis, & Manos, 2005). Computer animation can be used to give an accurate and rich picture of the dynamic nature of cellular processes, which are often very difficult to understand from the text-based presentations of information (Rotbain, Marbach-Ad, & Stavy, 2008).

During the design of educational software certain learning theories should be taken into consideration, which provide a basis for the determination of the learning process and for this reason they can facilitate the design itself. The theories of constructivism can be used as an example, since constructivism emphasizes the construction of new knowledge by the learner, as well as a focus on active learner-centered experiences (Vernadakis et al., 2011). It assumes that learning can only take place when students are actively engaging with the topic, 'constructing' their own knowledge based on individual experience and applying this knowledge directly to their environment. Because of this need for engagement, many constructivism-based teaching methods, like inquiry, problem-based learning or learning through discovery use a lot of student-directed activities (Vilotijević, Mandić, & Nikolić, 2010). The structure of the learning environment, based on constructivism, is to promote opportunities that encourage and support the building of understanding (Hartle, Baviskar, & Smith, 2012). The software should provide students with many opportunities to express and evaluate their personal ideas and lead them to 'cognitive conflict' situations, in order to provoke conceptual change and facilitate construction of scientific knowledge.

Extensive body of research has confirmed the efficiency of the utilization of the computer and teaching software in the presentation of teaching material in biology. The effects of tutorial and edutainment software programs related to genetics concepts on student achievements, misconceptions and attitudes were investigated by Kara and Yesilyurt (2007). The results showed that only tutorial design software contributes to a better understanding of notions in genetics, while the use of software in the form of teaching games develops positive attitudes among pupils towards biology. Williams, Montgomery, and Manokore (2012), explored students' understanding of heredity and related concepts, such as cells and reproduction, using a Web-based Science Inquiry Environment (WISE) curriculum unit that was developed to help middle school students learn about genetic inheritance. Their findings suggest that students made significant progress from pretest to posttest. The computer simulations used in biology teaching enable repeated trials of an experiment, provide immediate feedback, offer a flexible environment that enables pupils to proceed with their own plans (Cakir, 2011) and support comprehension and knowledge transfer (O'Keefe, Letourneau, Homer, Schwartz, & Plass, 2014). Within the domain of genetics, Gelbart, Brill, and Yarden (2009) found a significantly positive influence of the computer simulation on learning outcomes, in comparison with regular teaching methods. The forms of assessment that use interactive simulations do a better job of distinguishing student proficiency across different types of knowledge and skills than static or active online assessment does (DeBoer, Quellmalz, Davenport, Timms, Herrmann-Abell, Buckley et al., 2014). In instructional contexts, simulations have been shown to support content understanding and problem-solving skills in the area such as genetics (Buckley, Gobert, Horwitz, & O'Dwyer, 2010).

Many researchers have claimed in their papers that the use of educational software (ES) has increased and that it has had a positive impact on the achievements of students; the speed of learning is greater, the understanding of abstract phenomena and processes is enabled and the motivation for learning is growing (Djurić & Stanisavljević, 2011; Efe & Efe, 2011; Hancer & Tüzman, 2008; Kara & Yesilyurt, 2008; Philip, Jackson, & Dave, 2011). Due to the presented advantages and positive effects of the ES on the teaching practice and its improvements worldwide, it is necessary to work in an organized way in order to introduce, as soon as possible, the use of computers and computer software in teaching biology and other natural sciences in the Republic of Serbia.

Genetics is considered as one of the most important topics in today's society, but very difficult to teach and learn (Lewis & Wood-Robinson, 2000; Marbach-Ad & Stavy, 2000). Research on students' understanding of genetics and heredity shows that these topics are difficult for students to learn because they are of complex and abstract nature (Lewis & Wood-Robinson, 2000; Tsui & Treagust, 2007). The general problem that students have is understanding complex genetic phenomena such as the relationship between genes, alleles, and chromosome segregation (Banet & Ayuso, 2000; Lewis & Kattmann, 2004). Students struggle to make connection between genetic material (DNA, RNA) and proteins (Duncan & Reiser, 2007) and to understand genetic inheritance concepts (Lewis & Kattmann; 2004; Venville, Gribble, & Donovan, 2005). According to Venville & Dawson (2010), students' understanding of genetics and gene technology is piecemeal and not well connected with that of living things and biology. For example, many students consider that plants are non-living things (Venville & Donovan, 2008) and others believe that objects such as computers, cars, and cartoon characters have deoxyribonucleic acid - DNA (Venville, Gribble, & Donovan, 2005). Without connections between genetics concepts, students often stay at the lowest cognitive domain, the remembering of knowledge (Griffiths, 2008). Another problem is that genetics remains conceptually and linguistically difficult to teach and learn (Annetta, Minogue, Holmes, & Cheng, 2009; Tsui & Treagust, 2007).

Many studies have shown the efficiency of the use of computer software with simulations, animations, tutorials and games for the clear visual representation and conceptualization of genetics concepts (Corn, Pittendrigh, & Orvis, 2004; Law & Lee, 2004; Tsui & Treagust, 2003) and for the correct understanding of contents in genetics (Gelbart, Brill, & Yarden, 2009; McClean, Johnson, Rogers, Daniels, Reber, Slator et al., 2005; Rotbain, Marbach-Ad, & Stavy, 2008). Some of them report that achievement, motivation and learning attitudes of students with different learning styles have changed positively by using ES (Tsui & Treagust, 2003).

The main purpose of the current study was to investigate, empirically, whether teaching and learning with educational software can enhance students' understanding of genetic concepts. Taking into account the importance of correct understanding of content in genetics, which is the very essence of life and biology as a science, the aim of this research was to determine the effects of ES and lecture-based teaching method on learners. Based on this, the following research questions were investigated:

1) Is there a significant difference between the students' posttest achievement scores (in general) in the experimental and control groups?
2) Is there a significant difference between the students' retest achievement scores (in general) in the experimental and control groups?

3) Is there a significant difference between the students' posttest achievement scores (in each individual cognitive domain) in the experimental and control groups?
4) Is there a significant difference between the students' retest achievement scores (in each individual cognitive domain) in the experimental and control groups?

Method
Research Design

The research was semi-experimental in nature because the equivalence of the control group and the experimental group was provided by random assignment of students either to the experimental or the control group. The research design followed by the researcher was the pretest-posttest equivalent groups design.

Sample

The population of the study consisted of all eleven classes, with 330 students of grade 12 of a high school in Zrenjanin, Serbia. For the purpose of the research a random sample consisted of six classes (173 students). The students' age ranged from 17 to 18 years. Three classes with 87 students were assigned to the experimental group and the other three classes with 86 pupils made up the control group. All six classes from the same school were taught by the same teacher during the experiment and all the classes had the same biology curriculum with two lessons a week. Thus, it was ensured that the differences in the quantity and quality of students' knowledge in the experimental and control groups at the end of the experiment could be explained by the influence of the experimental factor, while the effect of other factors in the study was reduced to a minimum.

Research Procedure

A pilot study was carried out in the school year 2011/2012 and was performed to access item difficulty and clarity of the posttest. The sample consisted of 160 students - 80 in the experimental (E) group and 80 in the control (C) group. The discrimination index and the index of difficulty were calculated for every question of the test. In determining the internal consistency of the knowledge test, the alpha reliability method was used. As a result of this process, 5 questions were considered unsuitable and were removed from the original final test.

The experiment was carried out in the school year 2012/2013, during regular biology classes in the second semester. Duration of the experiment was 9 weeks in total for both groups, simultaneously.

At the beginning of the research, before the introduction of the experimental factor in the experimental group, both groups were made similar on the basis of general success of the students, their success in biology at the end of grade 11 of high school and the pretest of knowledge in biology. After making the groups equal, the pedagogical experiment was done. In the E and C groups, different instructional procedures were used during the research process.

In the experimental model of teaching, while presenting the teaching topic Mechanisms of Heredity, the teaching process was performed in the computer science specialized classroom where students used ES individually. The classroom had a sufficient number of desks and computers for all students, enabling them to work individually on the computer. In the first week, the material was used twice in two lessons. Each lesson lasted for 45 minutes, during which the educational software as teaching material was used solely. These two lessons were organized as a double period. The educational software was used in two classes a week for the next seven weeks. In the 9th week, the posttests of the achievement were applied. During all biology classes, the teacher followed the course of work on the software of all students, at the same time providing assistance with the course assignments, if necessary.

At the same time, in the controlled model of teaching, the teaching was performed in the school biology laboratory using a traditional method of teaching, including three instructional strategies: frontal lectures, discussion and intermittent questions-asking by the teacher, and pupils' responses. Each week, the teacher first gave an oral presentation to students with the aim of drawing their attention and explaining the structure of the biology concepts. The teaching aids and devices used in the research were a textbook, the blackboard and chalk. The revision of the acquired knowledge was done through solving problems and oral answers to questions from the textbook. The students solved problems independently, and the results were discussed and written on the board and into students' notebooks.

Upon completion of the experimental research, the differences in the students' achievements in the experimental and control groups were analyzed, taking into account their achievements on the posttest. The analysis of knowledge and skill retention of students by performing the retest was carried out 60 days after the posttest in both groups.

Instruments

In this study the main measuring instruments were non-standardized knowledge tests made for the purpose of the research. The instruments which were designed and applied in the research were the pretest, the posttest and the retest. Each of these tests included questions grouped into three different cognitive levels (knowledge levels): the level of knowing the facts (Level I), the level of understanding notions (applying knowledge and understanding using full names - Level II), and the level of analysis and reasoning (Level III). The cognitive domains were established according to the model of the study TIMSS 2007 (Martin, Mullis, & Foy, 2008), which was used to categorize the questions for the tests. On each individual test within Level I the maximum number of points that could be gained was 20; within Level II the pupils could gain 55 points, and within Level III students could gain a maximum of 25 points. Thus, the total maximum number of points which students could gain on all of these tests was 100.

The pretest aimed to determine if the two groups of students had the equivalent basic knowledge and abilities for learning genetics. The second test, posttest, consisted of 23 tasks, with a full score of 100. The third one, retest, was identical to the final test and it was performed to determine the duration and quality of the acquired knowledge of the students in both groups. Tests of knowledge were created as sets of tasks of objective type.

The Cronbach's Alpha values for the pretest $\alpha=0.835$, for the posttest $\alpha=0.821$ and for the retest $\alpha=0.820$ showed a high reliability of the tests. According to Green and Salkind (2007), the reliability coefficient should be at least 0.70 for the test to be considered reliable.

During the research all participants were tested simultaneously in the school environment and each test lasted for 45 minutes.

Instructional Materials

Educational software "The Mechanisms of Heredity" designed for the purpose of the research was created in Adobe Captivate 5.5 program. The program supports export of projects into Flash CS5 where it can be additionally enhanced. This is possible due to the fact that Adobe Captivate is practically based on programming language Action Script 3 that uses Flash. By using these two programs alongside, impressive results for a really short period of time can be achieved. The project can be used in various formats: Flash (swf), Windows Executable (*.exe), MAC Executable (*.app), MP4 Video (*.mp4), Export to PDF. For the purpose of this study .exe option was used, which enables the program to start on every computer that operates under some kind of Windows operating system independently. An entire written material in the software is written in Serbian (native) language.

The educational software "The Mechanisms of Heredity" was prepared as a substitution for the textbook during the presentation of the contents in biology. When the program is started there are hyperlinks for the parts contained in the software: "The Introductory Lecture", "Teaching Materials", "Interesting Facts", "The Gallery", "Exercises" and "The Test". The section "Introductory Lecture" contains problem tasks which enable the previously acquired students' knowledge to be connected with the new material that has to be acquired during classes. The "Teaching Material" section has its own title slide and contents towards hyperlinks for all teaching units: Introduction to genetics (the importance of genetics research), Basic rules of heredity, Types of heredity, Chromosome basis of heredity, Recombination, Mutations, Chromosome aberrations, Population genetics, Artificial selection and improvement of plants and animals, Genetic control of development, Human genetics and Genetically conditioned human behavior. By clicking on a certain hyperlink, a chosen teaching unit is opened. The teaching content of all teaching units is illustrated with colorful pictures, and there are animations in some parts, too. After each teaching unit there is a formative test. The test consists of different types of questions and problem tasks. After giving the answer to a question, a student gets information about the correctness of his/her answer, and some additional pieces of information which can help him/her to get the right answer. A special conformity in tests is the possibility of automatic change of the order of the given answers, because the program offers a new variety of answers every time. In this way mechanical studying and copying is prevented, because each student has on his/her computer a different combination of answers. Every question, depending on its complexity, has a certain number of points. In the software there is a special section, "Interesting Facts", devoted to students whose interests are beyond the limits of the obligatory curriculum, through which the individualization of teaching is achieved. "The Gallery" contains 150 pictures and 95 schemes which are related to lectures/units. "Exercises" section is used in the form of dynamic interactive animations with tutorials and tasks which a student has to solve. In case of a student's error, he/she gets the response about the error as well as some additional instructions which help him/her to solve the problem. In the section "The Test" (summative test), there are 72 questions for checking knowledge of the material of the whole teaching topic at the end of its presentation. The most frequently used types of questions are: true/false questions, multiple choice questions, fill-in the blanks (type the answer) and matching (connecting correct answers). After the question is answered and the button *submit* is clicked, a user gets certain feedback which depends on the correctness of the chosen answer. If the student provides a correct answer, the application will confirm that. In case the answer is incorrect, the message can contain a short explanation so the error could be memorized and understood. This is a much more practical solution than having all correct answers offered at the end of a test, because the user is at a given moment focused only on one question. After answering the last question from summative test, the slide with results follows and it contains the following information: the number of achieved points, the maximum number of points, the number of correct answers, the overall number of questions, and success in percentage.

Data Analysis

To investigate potential differences between the experimental group and the control group in each of the tests, the students' number of correct answers was considered as his/her score in the respective test as a whole, and in the group of questions which measured different categories of knowledge levels: knowing the facts (Level I), understanding notions (Level II), and analysis and reasoning (Level III). For each test the descriptive statistics was calculated: the arithmetic mean and standard deviation. To examine the influence of the main factors – group (form of teaching) and time, as well as their interaction with the quantity and quality of pupils' knowledge, the 3X2 analyses of variance (ANOVA) with repeated measures was conducted. Univariate analysis of variance was used to examine the difference in the quantity and quality of knowledge between the groups at individual moments of time – the pretest, posttest and retest. Two independent samples t-tests were performed to follow up the significant interaction and assess differences between the teaching methods in the groups at each time period. In addition, the effect size d was computed to measure the strength of the t-test result.

The independent variable was the form of teaching and learning, which included ES application and traditional teaching method, while the students' achievement scores on tests were dependent variables. Each variable was tested using an alpha level of significance .05 and .001. Statistical data processing obtained from these tests was performed by using SPSS 19.0 software package.

Research Results

In this section, the findings of the study are shown in separate sub-sections. In the first sub-section the findings are related to the first and second research questions of the study, and in the second sub-section, the findings related to Questions 3 and 4 of the study are presented.

In order to determine the results of the first and second research questions, firstly the *t*-test analysis was conducted between the pretest, posttest and retest scores of the students in the experimental and control groups. The results of the *t*-test are shown in Table 1.

Table 1

The significance of differences in the experimental and control group in the pretest, posttest and retest of knowledge in general (t-test)

Variable	Group[a]	N	Mean	Standard deviation	t	df	p
Pretest	E	87	69.137	8.425	-1.117	171	.265
	C	86	70.128	8.233			
Posttest	E	87	79.847	6.323	8.518	171	.000
	C	86	70.338	8.299			
Retest	E	87	75.437	6.950	10.905	171	.000
	C	86	62.581	8.489			

Note: C=control group; E=experimental group

According to Table 1, it was determined that average pretest score of the students in the E group was 69.137, while in the C group it was 70.128 points. Differences in the mean ratings of knowledge performance between the two groups were not significantly different at the pretest; t(171)=-1.117, p=.265. On the basis of the pretest indicators, E and C groups were well synchronized at the beginning of the educational research concerning the pupils' previous biology knowledge and skills.

Immediately after the pedagogical research had been conducted, the posttest was performed in all classes of the experimental and control groups. The results of the final testing of students in the experimental and control groups (Table 1) show that students from E group achieved 79.847 points on average, while students from C group achieved 70.338 points on average. Analyzing the overall achievement on the retest in general, Table 1 shows that the students from the experimental group achieved 75.437 points on average, while the students from the control group achieved 62.581 points on average.

The repeated measures ANOVA indicated that the students' achievement scores changed significantly over time, F(2, 342)=96.475, p<.001, while the interaction effect between the level of time and the groups of the students was also significant, F(2, 342)=121.327, p<.001. Furthermore, the univariate test showed that there were statistically significant differences for the group achievement scores in general, regardless of the time moment F(1,171)=14.432, p<.001. Thus, there was a difference in achievement tests scores of students in the experimental group compared to the students in the control group.

The independent samples t-test was conducted to follow up the significant interaction and assess differences between the teaching methods used in the groups at each time period. According to the posttest results, there were statistically important differences in students' achievements in the experimental and control groups on the posttest, which are in favor of the experimental group, t(171)=8.518, p< .05. In addition, the effect size d was computed to measure the strength of the t-test result. In this case, the d value of 1.294 indicates a large effect size, implying benefit for the experimental group. Statistically significant difference in favor of the experimental group has been achieved on the retest: t(171)=10.905, p<.05; d=1.66.

With the aim of examining the quality of students' knowledge, the assignments on the tests were divided into three groups which measured different categories of knowledge: knowing the facts (Level I), understanding notions (Level II), and analysis and reasoning (Level III). Table 2 presents the relevant descriptive statistics.

Table 2

The significance of differences in E and C group from the pretest, posttest and retest according to the levels of knowledge (t-test)

Variable	Categories of knowledge	Group	N	M	SD	t	df	p
Pretest	Knowing the facts	E C	87 86	15.172 15.419	2.036 1.887	-.825	171	.411
	Understanding notions	E C	87 86	38.920 39.477	4.565 4.456	-.812	171	.418
	Analysis and reasoning	E C	87 86	15.046 15.233	3.110 3.024	-.400	171	.690
Posttest	Knowing the facts	E C	87 86	16.860 15.163	1.419 1.976	6.460	171	.000
	Understanding notions	E C	87 86	46.138 41.105	3.159 4.928	8.007	171	.000
	Analysis and reasoning	E C	87 86	16.851 14.070	2.335 2.375	7.764	171	.000
Retest	Knowing the facts	E C	87 86	15.781 13.884	1.820 1.925	6.665	171	.000
	Understanding notions	E C	87 86	44.310 37.605	3.764 5.356	9.536	171	.000
	Analysis and reasoning	E C	87 86	15.345 11.093	2.514 2.453	11.258	171	.000

The application of various forms of teaching resulted in significant differences in the quality of students' knowledge in the final state in all categories of knowledge (Table 2). Greater number of experimental group students were able to achieve the level of understanding notions (on average 46.138 points, which amounts to 82.39% of the maximum number of points), when compared to the pupils in the control group (on average 41.105, which amounts to 73.40% of the maximum number of points). The level of the analysis and reasoning of knowledge was achieved by 70.21% of experimental group students, while 58.62% of the control group students solved the tasks at this level (Table 2).

The analysis of the students' achievement in the experimental group on individual levels of knowledge on the retest shows the highest achievement on the second level of knowledge (44.310 points on average, which amounts to 79.13% of the maximum number of points) and on the first level (15.781 points on average, which is 78.91% of the maximum number of points), while a slightly lower achievement was detected on the third level of knowledge (15.345 points, which is 63.94% of the maximum number of points). Students from the control group had the highest achievement on the first level of knowledge (13.884 points on average, which amounts to 69.42% of the maximum number of points), lower achievement on the second level of knowledge (37.605 points on average, which amounts to 67.15% of the maximum number of points), while the lowest achievement was on the third level, i.e. on the most difficult tasks (11.093 points on average, which amounts to 46.22% of the maximum number of points).

A significant main effect of time on tests scores for Level I of knowledge was obtained, $F(2, 342)=27.806$, $p<.001$. This means that achievement scores after the treatment were significantly higher than before the treatment.

Moreover, for Level I, there was also significant interaction effect between the level of time and the groups of the students: $F(2, 342)=27.767$, $p<.001$. This indicates that students' scores at different testing times (pretest, posttest and retest) differed in the experimental and control groups. There was a higher mean difference in achievement test scores for the experimental group students from pretest to retest, than for the students in the control group.

The results of the univariate analysis of variance have shown statistically significant differences for the group mean scores $F(1,171)=26.961$, $p<.001$. The difference in the score (Table 2) demonstrates that more thorough knowledge was achieved by using the educational software while presenting the genetics content, compared with a traditional way of studying. According to the results of t-test for the experimental and control groups, there were statistically significant differences in students' achievements at Level I of the posttest [$t(171)=6.460$, $p<0.05$; $d=.988$] and retest [$t(171)=6.665$, $p<.05$; $d=1.019$], which are in favor of the experimental group. The results of the independent samples *t*-test indicated that the experimental group's retention test mean score was significantly higher than the one of the control group. Thus, the students in the experimental group, who used ES in learning, retained more of what they have learned on the level of knowing the facts. That is to say, the results revealed a significantly higher retention amount for the experimental group.

Descriptive statistics for Level II pretest, posttest and retest showed that the experimental group, which used ES, had a higher level of achievement compared to the control group (Table 2). A significant time main effect of tests scores on Level II of knowledge was obtained: $F(2, 342)=120.066$, $p<.001$. A significant interaction between group and time $F(2, 342)=87.562$, $p<.001$ and the results of the univariate analysis of variance have shown a significant main effect of group $F(1,171)=40.472$, $p<.001$. The level of understanding notions for experimental group was significantly different in comparison with the control group, on the posttest; $t(171)=8.007$, $p<.05$. This effect can be described as large, $d=1.225$. The results of the t-test of retest $t(171)=9.563$, $p<.05$, with large effect size $d=1.462$ showed that the use of ES was quite influential on students' higher cognitive levels of learning compared to the control group in which the majority of students reached only knowledge level.

The repeated measures ANOVA for Level III of knowledge indicated that the pupils' achievement scores changed significantly over time $F(2, 342)=80.037$, $p<.001$. This indicates that students' scores at different testing times differed according to their groups. The interaction effect between time and group was significant: $F(2, 342)=69.623$, $p<.001$. The univariate test associated with the group's main effect was significant: $F(1,171)=45.724$, $p<.001$. The t-test revealed a significant difference between the mean achievement in favor of the experimental group on Level III of posttest [$t(171)=7.764$, $p<.05$; $d=1.187$] and retest [$t(171)=11.258$, $p<.05$; $d=1.721$].

Discussion

In the preceding three grades, students were supposed to have gained knowledge about the structure of DNA and RNA, DNA replication, transcription, RNA and protein synthesis. This knowledge was tested in the pretest. Based on the results of the pretest of experimental and control groups (Table 1), there are no statistically significant differences in the obtained number of points between the experimental and control groups on the pretest, according to individual levels of knowledge (Table 2) and in general. On the basis of the pretest indicators, groups were well synchronized at the beginning of the educational research concerning the students' previous biology knowledge and skills.

The findings revealed that students who were taught by using the educational software made statistically significant achievements in their test scores, in terms of knowledge. Therefore, statistically significant difference in favor of experimental group was achieved on post-test and on retest in general as well.

According to the achievement of the experimental group students on the posttest and retest, individual form of work is predominant in studying and enables their self-reliance and creativity to be shown. Besides, the students studied by using quality computer software in which the teaching material was much better presented and illustrated than in the current biology textbook. Every student used the software in accordance with his/her own abilities and possibilities, at his/her own speed of work until they learned thoroughly all the prescribed materials. Students who felt that they were in control of their learning, actively participated and took advantage of learning opportunities and resources, and rated perceived course effectiveness higher than the students who did not have these learning experiences (Lowerison, Sclater, Schmid, & Abrami, 2006).

The achievement of the control group students on the posttest and retest did not show significant changes, compared with their achievements on the pretest of knowledge (Table 1). Much poorer results of the students were shown on the posttest in comparison with the success of students in the experimental group, which can be explained by the traditional teaching method used in presenting the teaching content of the topic Mechanisms of Heredity in the control group. Therefore, the drill and practice and other directed uses of the computer program have their advantages, allowing pupils to develop rapid recall of information which can help to create a solid foundation for future learning (Roblyer, 2003).

The material of the teaching units is rather complex and difficult to acquire and understand, and it demands the maximum participation and activity of students during classes. Among the students in the control group, due to the application of the traditional model of teaching, that activity did not emerge, which resulted in their weaker success on knowledge tests.

A great difference was found when observing certain levels of knowledge that students had achieved on the posttest. Much better results of the experimental group students were scored while solving more difficult tasks and questions (cognitive levels II and III) on the posttest, comparing it with the pretest; in other words, higher competence in solving complex tasks was noticed, which is exceptionally significant. They were encouraged to work with information to derive the meaning and understanding, form new mental representations of the material, and construct and reconstruct new knowledge based on their experiences. The results of the research show that the determined difference in students' achievements on the posttest was not only the difference in the quantity but also in the quality of their knowledge, skills and habits in biology as well. The results of previous research support this finding (Akwee et al., 2012; Efe & Efe, 2011; Županec et al., 2013). The data show that a large number of students in the experimental group were able to solve the tasks which included: analyses, parsing the content, classification, comparison, establishing differences between the genotypes, explaining the relationship between the genetic material and its products (protein, trait). On the contrary, students in the control group were not able to: formulate and build new structures from the existing knowledge and skills. Thus, computer technology and educational software should "stimulate active, autonomous learning, and the curriculum is adapted to the needs and capabilities of individual pupils" (Glušac, Makitan, Karuović, Radosav, & Milanov, 2015, p. 136).

Within the topic Mechanisms of Heredity, pupils need to adopt new concept of the gene, to understand the relationship between phenotype and genotype, between genes, alleles, and chromosomes (Lewis & Wood-Robinson, 2000), to understand the heritability of genetic traits (Banet & Ayuso, 2000; Lewis & Kattmann, 2004; Venville & Treagust, 1998), and adopt new principles and laws (e.g. Mendel‘s Law of Segregation, Hardy-Weinberg equilibrium). School practice shows that students often face problems in doing that. Educational software made it possible to make connections between the real life phenomena and abstract models and presented genetics phenomena dynamically by using videos and animations. These representations could help students realize the dynamic nature of the phenomena, activate students' prior knowledge (Wu, Lin, & Hsu, 2013), and may influence their performance in questioning, explaining and understanding genetics.

Multiple forms of knowledge representations such as diagrams, animations, maps and graphs could play a crucial role in the design of computer-based assessment and have been frequently incorporated in item presentation (Wu, Kuo, Jen, & Hsu, 2015). These multiple external representations (MERs) have been widely used in teaching and learning (Tsui & Treagust, 2004). In this study, the multiple representations and interactive environment for learning genetics are designed to provide students with a challenging and a real-world genetics problem to solve (Tsui & Treagust, 2004).

Studying genetics in this way develops the students' self-reliance in work, initiative, freedom of choice, skillful discussions and the presentation of work results. Also, they need to be active participants in the teaching and learning process, so the learning environment must support active, cooperative and autonomous learning. By the introduction of innovative didactic models in the process of teaching, modernization is achieved, the quality of teaching is improved and thus a lot of its social demands are fulfilled; for instance, its efficiency and rationalization. Keeping in mind the importance of biology for the education of a contemporary man, biology teaching must follow the modern trends.

The application of the ES in the biology teaching process has very positive effects in the domain of understanding, possibilities of knowledge application and retention. According to the results of numerous authors (Cvjetićanin, Pećanac, Sakač, & Djurendić-Brenesel, 2013; Ferguson & Chapman, 1993; Lee, 2001; Rotbain et al., 2008; Tsui & Treagust, 2007), it can be concluded that the applications of ES show the important advantages and greater possibilities in teaching compared to the traditional methods. They are also beneficial to the speed of learning, quality, retention and application of knowledge, pupils' attention and interests in learning the teaching content. Technology-enhanced instruction has tremendous potential for promoting student learning around complex and abstract science topics such as genetics (O'Day, 2006; Starbek, Starčič Erjavec, & Peklaj 2010; Stith, 2004).

Conclusion and Implications

The integration of educational software into the learning environment can provide valuable learning experiences when it is designed and utilized in a pedagogically appropriate manner, based on accepted pedagogical principles, in terms of both learner's and teacher's needs. The study examined the effects of individual learning using software on the students' achievement in learning genetics in biology classes. Considering the overall achievement on the posttest and retest in general, it can be concluded that the application of ES and contemporary pedagogical method increased the efficiency of teaching biology (genetics) in comparison with the traditional teaching method. The study confirmed a statistically significant increase in the quality of experimental group students' knowledge in all individual cognitive domains. The teaching model applied in this research showed positive characteristics regardless of the type of units. It proved to be suitable to stimulate analytical thinking of students, discussion during the presentation of the new material, higher interaction of students with the teacher and increased activity of students compared to the traditional approach.

On the other hand, learning with educational software in primary, secondary and high schools in Serbia does not have an appropriate application yet. In order to appropriately apply this model in teaching biology and other sciences, and ensure its appropriate place in education process, it is necessary to make major changes in the organization of the school work, and it is necessary to have better equipped schools with computers and educational software for different subjects, which will be adapted to the age and intellectual abilities of students.

There are, however, limitations to the conclusions that could be observed. Samples were selected by sampling procedure. The subject of the research was limited only to teaching biology for grade 12 of the high school, the teaching topic being Mechanisms of Heredity. Accordingly, the results could not be generalized to other topics in biology, nor to the content of other subjects. The effectiveness of the application of educational software in teaching biology was measured solely on the basis of the software that was applied in this pedagogical experiment.

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Učinkovitost primjene edukativnih računalnih programa u nastavi biologije

Sažetak

U radu se prikazuje komparativna analiza učinkovitosti upotrebe edukativnog računalnog programa i tradicionalnih nastavnih metoda u nastavi biologije u srednjoj školi. Stratificirani slučajni uzorak sastojao se od 173 učenika 12. razreda srednje škole u Zrenjaninu u Srbiji, a koji su bili nasumično svrstani u kontrolnu i eksperimentalnu skupinu. Učenici u eksperimentalnoj skupini učili su nastavne sadržaje biologije („Mehanizmi nasljeđivanja") uz pomoć edukativnog računalnog programa, a učenici u kontrolnoj skupini učili su iste sadržaje primjenom tradicionalnih nastavnih metoda. Istraživanje je provedeno s pomoću istraživačkog dizajna s predtestom i posttestom u ekvivalentnim skupinama. Svi instrumenti (predtest, posttest i retest) sadržavali su pitanja iz tri različite kognitivne domene: znanja, razumijevanja i razmišljanja. Analiza rezultata posttesta i retesta pokazala je da su učenici iz eksperimentalne skupine postigli znatno veću kvalitetu i kvantitetu znanja u sve tri kognitivne domene nego što je to bio slučaj kod učenika iz kontrolne skupine. Može se zaključiti da edukativni računalni programi imaju pozitivan učinak na poboljšanje učeničkih postignuća u nastavi biologije.

Ključne riječi: *postignuće; genetika; učinkovitost poučavanja; tradicionalna nastava.*

Uvod

Nastava biologije i drugih prirodoslovnih predmeta u školama u Republici Srbiji još je uvijek pretežno organizirana i provodi se na klasičan način, što znači da su učeničke aktivnosti tijekom nastavnih sati organizirane kao pasivno slušanje, receptivno učenje i učenje napamet. Na taj se način zapostavlja učeničko mišljenje, pogotovo kreativno mišljenje i traženje novih ideja. Trenutno se obrazovni sustav mijenja od onoga usmjerenoga na nastavnika prema sustavu usmjerenom na učenika. U nastavi usmjerenoj na učenika nastavnik ima ulogu pomagača i stvara takve uvjete za učenje u kojima učenici aktivno sudjeluju u eksperimentima, interpretiraju i objašnjavaju podatke i razgovaraju sa svojim kolegama o tome kako su razumjeli određene rezultate eksperimenata. „Primjenom zanimljivih didaktičkih scenarija on/ona potiče razvoj učenikovih kognitivnih, afektivnih i psihomotornih domena učenja" (Borić i Škugor, 2014, str. 150). Učenicima je učenje prirodnih znanosti aktivno i konstruktivno jer uključuje istraživanje i praktične aktivnosti (Ronoh, Wachanga, i Keraro, 2014).

Poučavanje i učenje biologije uz pomoć informacijske i komunikacijske tehnologije predstavlja alternativu tradicionalnim nastavnim metodama koje se uglavnom temelje na predavanjima. Nastava usmjerena na učenika koja je računalno potpomognuta može osnažiti učenike i omogućiti pozitivno iskustvo učenja koje možda na drugi način ne bi bilo moguće (Dumont, Istance, i Benavides, 2010).

Upotreba edukativnih računalnih programa, potpomognuta odgovarajućim strategijama poučavanja i učenja poput učenja utemeljenog na istraživanju (Gelbart, Brill, i Yarden, 2009), problemskog učenja (Annetta, Minogue, Holmes, i Cheng, 2009) ili učenja utemeljenog na otkrivanju (Kyza, Constantinou, i Spanoudis, 2011), ima posebnu važnost u poučavanju i učenju. Sve te strategije vode prema individualizaciji nastave, pružaju znanje svim učenicima pojedinačno, daju stalnu povratnu informaciju i omogućuju kontinuirano praćenje napretka učenika. Upotrebom nekih posebnih tehnika ostvaruje se kontrolirana funkcija poučavanja, nastavni se proces regulira, a potiče se unutarnja motivacija učenika za učenje (Mandić, 2010). Didaktički dobro dizajnirani računalni programi omogućuju postupan napredak u skladu s učenikovim mogućnostima i na svakoj razini u učeniku bude osjećaj kompetentnosti. Učenici s većom kompetencijom mogu izostaviti dijelove gradiva koje dobro poznaju i/ili su im lagani, a učenici s manjom kompetencijom moraju naučiti to gradivo da bi mogli razumjeti daljnje informacije koje se na njega nadograđuju (Voskresenski, 2004). Edukativni računalni program mora se osmisliti na način da zadovoljava potrebe svih sudionika u obrazovnom procesu. Učenicima upotreba računalnog programa mora biti jednostavna, a sam program mora sadržavati visok stupanj zornosti nastavnog materijala koji se na taj način prezentira. Osim toga, računalni program mora biti zanimljiv i stimulativan kako bi motivirao učenike za učenje (Virvou, Katsionis, i Manos, 2005). Mogu se koristiti računalne animacije kako bi se učenicima pružila točna i detaljna slika dinamične prirode staničnih procesa, koje je često teško razumjeti iz tekstualne prezentacije informacija (Rotbain, Marbach-Ad, i Stavy, 2008).

Za vrijeme izrade edukativnih računalnih programa u obzir je potrebno uzeti određene teorije učenja koje pružaju osnovu za određivanje procesa učenja, a time i olakšavaju izradu takvog programa. Možemo kao primjer uzeti teorije konstruktivizma jer konstruktivizam naglašava izgradnju novog znanja kod učenika, a usredotočen je i na aktivna iskustva usmjerena na učenika (Vernadakis i sur., 2011). Konstruktivizam polazi od pretpostavke da se učenje može ostvariti samo onda kada su učenici aktivno uključeni u temu, izgrađujući svoje vlastito znanje na temelju individualnog iskustva i primjenjujući to znanje izravno na svoju okolinu. Zbog te potrebe za aktivnim uključivanjem učenika mnoge konstruktivističke nastavne metode poput istraživanja, problemskog učenja ili učenja putem otkrivanja koriste se mnoštvom aktivnosti usmjerenih na učenika (Vilotijević, Mandić, i Nikolić, 2010). Struktura okruženja u kojem se učenje odvija, prema konstruktivističkoj teoriji, trebala bi promicati mogućnosti koje potiču i podržavaju proces razumijevanja (Hartle, Baviskar, i Smith, 2012). Računalni program bi učenicima trebao pružiti mnoge mogućnosti za izražavanje i evaluaciju vlastitih ideja i dovesti ih u situacije „kognitivnog konflikta" da bi se inicirala konceptualna promjena i olakšala izgradnja znanstvenog znanja.

Brojna istraživanja potvrdila su učinkovitost upotrebe edukativnih računalnih programa u prezentaciji gradiva u nastavi biologije. Kara i Yesilyurt (2007) istraživali su učinak koji tutorijali i edukativno-zabavni računalni programi vezani uz genetičke pojmove imaju na postignuća učenika i na njihove pogrešne predodžbe i stavove. Rezultati su pokazali da računalni programi osmišljeni u obliku tutorijala doprinose boljem razumijevanju pojmova iz područja genetike, a da upotreba računalnih programa izrađenih u obliku edukativnih igara razvija pozitivne stavove učenika o biologiji. Williams, Montgomery i Manokore (2012) istraživali su razumijevanje učenika vezano uz temu nasljeđivanja i srodnih pojmova, kao što su stanice i razmnožavanje, koristeći se jednom nastavnom cjelinom kurikula iz internetskog okruženja za znanstvena istraživanja (Web-based Science Inquiry Environment) koja ja izrađena da bi se učenicima prva dva razreda srednje škole olakšalo učenje o genetskom nasljeđivanju. Rezultati njihova istraživanja pokazuju značajan napredak koji su učenici ostvarili od predtesta do posttesta. Računalne simulacije koje su se koristile u nastavi biologije omogućuju ponavljanje eksperimenata, odmah daju povratnu informaciju, pružaju fleksibilno okruženje koje učenicima omogućuje da nastave rad prema svojim planovima (Cakir, 2011) i podupiru razumijevanje i prijenos znanja (O'Keefe, Letourneau, Homer, Schwartz, i Plass, 2014). U domeni genetike Gelbart, Brill i Yarden (2009) su uočili značajan pozitivan utjecaj računalnih simulacija na ishode učenja, u usporedbi s konvencionalnim nastavnim metodama. Oblici procjenjivanja znanja koji se koriste interaktivnim simulacijama imaju bolju mogućnost prepoznavanja uspješnosti učenika u različitim vrstama znanja i vještina nego što je imaju statični ili aktivni *online* oblici procjenjivanja znanja (DeBoer, Quellmalz, Davenport, Timms, Herrmann-Abell, Buckley i sur., 2014). U nastavnom kontekstu dokazano je da simulacije pomažu u razumijevanju nastavnih sadržaja i razvijanju vještina rješavanja problema u područjima kao što je genetika (Buckley, Gobert, Horwitz, i O'Dwyer, 2010).

Mnogi istraživači su u svojim istraživanjima utvrdili da se edukativni računalni programi sve više koriste i da imaju pozitivan utjecaj na učenička postignuća: učenici uče većom brzinom, omogućeno je razumijevanje apstraktnih fenomena i procesa, a motivacija za učenje raste (Djurić i Stanisavljević, 2011; Efe i Efe, 2011; Hancer i Tüzman, 2008; Kara i Yesilyurt, 2008; Philip, Jackson, i Dave, 2011). Zahvaljujući prikazanim prednostima i pozitivnom utjecaju edukativnih računalnih programa na nastavnu praksu i njezino unapređenje diljem svijeta, neophodno je raditi na organiziran način da bi se što prije uvela upotreba računala i računalnih programa u nastavu biologije i ostalih prirodnih znanosti u Republici Srbiji.

Genetika se smatra jednom od najvažnijih tema u današnjem društvu, ali je istodobno ona tema o kojoj je teško poučavati i koju je teško naučiti (Lewis i Wood-Robinson, 2000; Marbach-Ad i Stavy, 2000). Istraživanja provedena o učeničkom razumijevanju genetike i nasljeđivanja pokazuju da su te teme učenicima teške za učenje jer su kompleksne i apstraktne prirode (Lewis i Wood-Robinskon, 2000; Tsui i Treagust, 2007). Općenito je učenicima problem razumjeti kompleksne genetičke fenomene kao što su veze između gena, alela i segregacije kromosoma (Banet i Ayuso, 2000; Lewis i Kattmann, 2004). Učenicima je teško uočiti veze između genetičkog materijala (DNK i RNK) i bjelančevina (Duncan i Reiser, 2007) i razumjeti pojmove genetskog nasljeđivanja (Lewis i Kattmann, 2004; Venville, Gribble, i Donovan, 2005). Prema Venvillu i Dawsonu (2010), učenici imaju fragmentirano shvaćanje genetike i genetske tehnologije koje nije dobro povezano s razumijevanjem živih bića i biologije. Na primjer, mnogi učenici smatraju da biljke nisu živi organizimi (Venville i Donovan, 2008), a neki smatraju da predmeti kao što su računala, automobili i likovi iz animiranih filmova sadrže deoksiribonukleinsku kiselinu – DNK (Venville, Gribble, i Donovan, 2005). Ne povezujući genetičke pojmove, učenici često ostaju na najnižem kognitivnom stupnju – prisjećanju činjenica (Griffiths, 2008). Drugi je problem taj što genetika ostaje konceptualno i lingvistički teška za učenje i poučavanje (Annetta, Minogue, Holmes, i Chang, 2009; Tsui i Treagust, 2007).

Mnoga su istraživanja pokazala učinkovitost upotrebe računalnih programa koji sadržeu simulacije, animacije, tutorijale i igrice koje pridonose zornosti, vizualnoj prezentaciji i konceptualizaciji genetičkih pojmova (Corn, Pittendrigh, i Orvis, 2004; Law i Lee, 2004; Tsui i Treagus, 2003), kao i pravilnom razumijevanju sadržaja genetike (Gelbart, Brill, i Yarden, 2009; McClean, Johnson, Rogers, Daniels, Reber, Slator i sur., 2005; Rotbain, Marbach-Ad, i Stavy, 2008). Neki su od njih naveli da su se postignuća, motivacija i stavovi o učenju učenika s različitim stilovima učenja promijenila na bolje upotrebom edukativnih računalnih programa (Tsui i Treagust, 2003).

Glavna svrha ovog istraživanja bila je empirijski ispitati može li poučavanje i učenje uz pomoć edukativnih računalnih programa poboljšati učenikovo razumijevanje genetičkih pojmova. Uzimajući u obzir važnost pravilnog shvaćanja sadržaja genetike, koja je osnova života i biologije kao znanosti, cilj je ovog istraživanja bio odrediti učinak koji edukativni računalni programi i tradicionalna nastavna metoda utemeljena na predavanjima imaju na učenike. Na osnovi toga postavljena su sljedeća pitanja istraživanja:

1) Postoji li značajna razlika između rezultata koje su učenici ostvarili na posttestu (općenito) u eksperimentalnoj i kontrolnoj skupini?
2) Postoji li značajna razlika između rezultata koje su učenici ostvarili na retestu (općenito) u eksperimentalnoj i kontrolnoj skupini?
3) Postoji li značajna razlika između rezultata koje su učenici ostvarili na posttestu (u svakoj pojedinačnoj kognitivnoj domeni) u eksperimentalnoj i kontrolnoj skupini?
4) Postoji li značajna razlika između rezultata koje su učenici ostvarili na retestu (u svakoj pojedinačnoj kognitivnoj domeni) u eksperimentalnoj i kontrolnoj skupini?

Metode

Dizajn istraživanja

Istraživanje je bilo polueksperimentalnog tipa jer je ekvivalentnost kontrolne i eksperimentalne skupine postignuta nasumičnim razvrstavanjem učenika u eksperimentalnu ili kontrolnu skupinu. Dizajn istraživanja koji je istraživač odabrao sastojao se od predtesta i posttesta provedenog u ekvivalentnim skupinama.

Uzorak

Populacija u istraživanju uključivala je svih jedanaest razrednih odjela 12. razreda srednje škole u Zrenjaninu u Srbiji, od ukupno 330 učenika. Za potrebe ovog istraživanja slučajni uzorak sastojao se od 6 razrednih odjel (173 učenika), čija je dob bila u rasponu od 17 do 18 godina. Tri razredna odjela s 87 učenika svrstana su u eksperimentalnu skupinu, a preostala tri razredna odjela s 86 učenika činila su kontrolnu skupinu. Svih šest razrednih odjela iz iste škole podučavao je isti nastavnik tijekom eksperimenta, a svi su također imali isti nastavni plan i program za nastavu biologije, s dva nastavna sata tjedno. Tako su se osigurali uvjeti da se razlike u kvaliteti i kvantiteti znanja učenika u eksperimentalnoj i kontrolnoj skupini na kraju eksperimenta mogu objasniti utjecajem eksperimentalnog faktora, a utjecaj ostalih faktora u istraživanju sveden je na minimum.

Postupak istraživanja

Pilot-istraživanje provedeno je u školskoj godini 2011./2012. sa svrhom utvrđivanja težine pitanja i jasnoće posttesta. Uzorak se sastojao od 160 učenika – 80 učenika u eksperimentalnoj skupini (E) i 80 učenika u kontrolnoj skupini (C). Indeks razlike i indeks težine izračunat je za svako pitanje u testu. Pri određivanju unutarnje konzistencije testa znanja koristila se metoda alfa mjerenja pouzdanosti. Kao rezultat tog procesa utvrđeno je 5 neodgovarajućih pitanja koja su uklonjena iz originalnog završnog testa.

Eksperiment je proveden u školskoj godini 2012./2013. tijekom redovne nastave biologije u drugom polugodištu. Eksperiment je ukupno trajao 9 tjedana za obje grupe istodobno.

Na početku istraživanja, prije uvođenja eksperimentalnog faktora u eksperimentalnu skupinu, sastav obiju skupina ujednačen je u smislu općeg školskog uspjeha učenika, njihovih ocjena iz biologije na kraju 11. razreda srednje škole i predtesta znanja iz biologije. Nakon što su obje skupine ujednačene, proveden je pedagoški eksperiment. U eksperimentalnoj i u kontrolnoj skupini tijekom istraživanja koristile su se različite nastavne metode.

U eksperimentalnom modelu nastave, tijekom prezentiranja nastavne teme „Mehanizmi nasljeđivanja", nastava se izvodila u specijaliziranoj učionici informatike u kojoj su se učenici mogli samostalno koristiti računalima i edukativnim računalnim programom. Učionica ima dovoljno stolova i računala za sve učenike, što im je omogućilo individualni rad na računalu. U prvom tjednu edukativni se računalni program koristio dva puta u dva nastavna sata organizirana kao blok-sat. Svaki nastavni sat trajao je 45 minuta tijekom kojih se edukativni računalni program koristio kao jedini nastavni materijal. Edukativni računalni program također se koristio u dva nastavna sata tjedno tijekom sljedećih sedam tjedana. U devetom tjednu proveden je posttest postignuća. Tijekom svih nastavnih sati biologije nastavnik je pratio napredak svih učenika u korištenju edukativnim računalnim programom, istodobno im pružajući pomoć pri zadacima ako je to bilo potrebno.

U isto vrijeme, u kontroliranom modelu nastave, nastavni je proces izvođen u specijaliziranoj učionici za biologiju u školi. Koristila se tradicionalna nastavna metoda koja se sastojala od tri nastavne strategije: frontalnog predavanja, rasprave i naizmjeničnih nastavnikovih pitanja i učeničkih odgovora. Svakoga tjedna nastavnik je prvo učenicima usmeno prezentirao gradivo s ciljem privlačenja njihove pažnje i objašnjavao im strukturu bioloških pojmova. Nastavna pomagala i sredstva koja su se koristila u istraživanju obuhvaćala su udžbenik, ploču i kredu. Ponavljanje usvojenog znanja provodilo se rješavanjem problemskih zadataka i davanjem usmenih odgovora na pitanja iz udžbenika. Učenici su samostalno rješavali problemske zadatke, a rješenja su, nakon razgovora, zapisivali na ploču i u bilježnice.

Nakon završetka eksperimentalnog istraživanja analizirane su razlike između postignuća učenika u eksperimentalnoj i u kontrolnoj skupini, uzimajući u obzir rezultate koje su postigli na posttestu. S Pomoću retesta u obje skupine provedena je analiza zapamćenog znanja i vještina učenika 60 dana nakon provedenog posttesta.

Instrumenti

Glavni mjerni instrumenti koji su se koristili u ovom istraživanju bili su nestandardizirani testovi znanja izrađeni za ovo istraživanje. Instrumenti koji su izrađeni i koji su se koristili u istraživanju bili su predtest, posttest i retest. Svaki od tih testova sastojao se od pitanja grupiranih u tri različite kognitivne razine (razine znanja): razinu znanja činjenica (Razina I), razinu razumijevanja pojmova (primjena znanja i razumijevanja upotrebom punih naziva – Razina II), kao i razinu analize i razmišljanja (Razina III). Kognitivne domene određene su prema TIMSS 2007 modelu istraživanja (Martin, Mullis, i Foy, 2008), koji se koristio za kategorizaciju pitanja u testu. Na svakom pojedinačnom testu na Razini I maksimalan broj bodova koji se mogao ostvariti bio je 20; na Razini II učenici su mogli ostvariti maksimalno 55 bodova, a na Razini III učenici su mogli ostvariti maksimalno 25 bodova. Dakle, ukupan maksimalan broj bodova koji su učenici mogli ostvariti na svim testovima bio je 100.

Predtestom se željelo utvrditi imaju li obje grupe učenika jednako osnovno znanje i sposobnosti za učenje genetike. Drugi test, posttest, sastojao se od 23 zadatka, s maksimalnim ukupnim rezultatom od 100 bodova. Treći test, retest, bio je identičan završnom testu i proveden je da bi se odredila trajnost i kvaliteta usvojenog znanja učenika u obje skupine. Testovi znanja izrađeni su kao setovi zadataka objektivnog tipa.

Cronbach alfa vrijednosti za predtest α=0,835, za posttest α=0,821 i za retest α=0,820 pokazale su visoku pouzdanost testova. Prema Greenu i Salkindu (2007), koeficijent pouzdanosti trebao bi biti barem 0,70 da bi se test mogao smatrati pouzdanim.

Tijekom istraživanja svi sudionici bili su testirani istodobno u školskom okruženju, a svaki je test trajao 45 minuta.

Nastavni materijali

Edukativni računalni program *Mehanizmi nasljeđivanja* osmišljen za ovo istraživanje izrađen je u Adobe Captivate 5.5 programu. Taj program podržava prenošenje stavki u Flash CS5 gdje se one mogu dodatno poboljšati. To je moguće zbog toga što se Adobe Captivate temelji na programskom jeziku Action Script 3 koji se koristi Flashom. Koristeći se tim programima zajedno, mogu se postići uistinu impresivni rezultati u kratkom razdoblju. Projekt se može koristiti u različitim formatima: Flash (swf), Windows Executable (*.exe), MAC Executable (*.app), MP4 Video (*.mp4), Export to PDF. Za potrebe ovog istraživanja koristila se opcija .exe, jer ona omogućuje pokretanje programa na svakom računalu na kojem je instalirana bilo koja inačica operativnog sustava Windows. Cijeli materijal u računalnom programu napisan je na srpskom jeziku.

Edukativni računalni program *Mehanizmi nasljeđivanja* pripremljen je kao zamjena za udžbenik tijekom prezentacije nastavnih sadržaja iz biologije. Kada se program pokrene, pojave se hiperpoveznice na dijelove programa: *Uvodno predavanje, Nastavni materijali, Zanimljive činjenice, Galerija, Zadaci* i *Test*. Odjeljak *Uvodno predavanje* sadrži problemske zadatke koji omogućuju povezivanje prethodno stečenog znanja učenika s novim materijalom koji je potrebno usvojiti tijekom nastave. Odjeljak *Nastavni materijali* ima svoj vlastiti popis naslova i sadržaja i hiperpoveznice na sve nastavne jedinice: Uvod u genetiku (važnost istraživanja u genetici), Osnovna pravila nasljeđivanja, Vrste nasljeđivanja, Kromosomska osnova nasljeđivanja, Rekombinacija, Mutacije, Aberacija kromosoma, Populacijska genetika, Umjetna selekcija i poboljšanje biljaka i životinja, Genetička kontrola razvoja, Ljudska genetika i Genetički uvjetovano ponašanje ljudi. Pritiskom na određenu hiperpoveznicu otvara se odabrana nastavna jedinica. Sadržaj svih nastavnih jedinica ilustriran je slikama u boji, a neki dijelovi sadrže i animacije. Nakon svake nastavne jedinice slijedi formativan test koji se sastoji od različitih tipova pitanja i problemskih zadataka. Nakon što odgovori na pitanje, učenik dobiva informaciju o tome je li njegov/njezin odgovor točan, kao i dodatne informacije koje mu/joj mogu pomoći da dođe do točnog odgovora. Posebna karakteristika testova je mogućnost automatske promjene poretka ponuđenih odgovora, jer program svaki put nudi novi set odgovora. Na taj se način eliminira mogućnost mehaničkog učenja i prepisivanja, jer svaki učenik na svojem računalu ima drugačiju kombinaciju odgovora. Svako pitanje, ovisno o njegovoj složenosti, nosi određen broj bodova. Unutar računalnog programa postoji i poseban odjeljak, *Zanimljive činjenice*, koji je osmišljen za učenike čiji je interes širi od gradiva propisanog kurikulom, čime se postiže individualizacija nastavnog procesa. *Galerija* se sastoji od 150 slika i 95 shematskih prikaza koji su povezani s lekcijama/

nastavnim jedinicama. Odjeljak *Zadaci* izrađen je u obliku interaktivnih animacija s uputama i zadacima koje učenici moraju riješiti. U slučaju pogrešnog odgovora, učenik dobiva povratnu informaciju o tome, kao i dodatne upute koje mu/joj mogu pomoći riješiti problemski zadatak. U odjeljku *Test* (sumativan test) nalaze se 72 pitanja za provjeru znanja o materijalu iz cijele nastavne teme na kraju prezentacije. Tipovi zadataka koji se najčešće koriste jesu: točno/netočno, zadaci višestrukog izbora, dopunjavanje rečenica (utipkaj odgovor) i spajanje (spajanje s točnim odgovorima). Nakon što odgovori na pitanje i pritisne gumb za slanje odgovora, učenik dobiva određenu povratnu informaciju, ovisno o točnosti odabranog odgovora. Ako je učenik točno odgovorio na pitanje, aplikacija će to potvrditi. Ako je odgovor netočan, poruka može sadržavati kratko objašnjenje tako da učenik može zapamtiti i razumjeti gdje je pogriješio. To je puno praktičnija mogućnost nego ponuditi učeniku sva točna rješenja na kraju testa, jer se on u određenom trenutku usredotočuje samo na jedno pitanje. Nakon odgovaranja na zadnje pitanje u sumativnom testu, pokazuje se slajd s rezultatima koji sadrži sljedeće podatke: broj postignutih bodova, maksimalan broj bodova, broj točnih odgovora, ukupan broj pitanja i postotak uspješnosti.

Analiza podataka

Da bi se ispitale moguće razlike između eksperimentalne skupine i kontrolne skupine u svakom od testova, učenikov broj točnih odgovora uzet je kao njegov/njezin ukupan rezultat u pojedinačnim testovima i u grupama pitanja kojima su se mjerile različite kategorije razina znanja: znanje činjenica (Razina I), razumijevanje pojmova (Razina II), analiza i razmišljanje (Razina III). Za svaki od testova izračunata je deskriptivna statistika: aritmetička sredina i standardna devijacija. Za ispitivanje utjecaja glavnih faktora – skupine (oblika nastave) i vremena, kao i njihove interakcije s kvalitetom i kvantitetom znanja učenika, proveden je 3X2 oblik analize varijance (ANOVA) s ponovljenim mjerenjima. Koristila se univarijatna analiza varijance da bi se ispitala razlika u kvaliteti i kvantiteti znanja između skupina učenika u određenom vremenu – kao predtest, posttest i retest. Provedena su dva t-testa za nezavisne uzorke da bi se pratila značajna interakcija i procijenile razlike do kojih je došlo zbog dviju različitih nastavnih metoda koje su se koristile u skupinama u svakom razdoblju. K tomu, izračunata je i veličina učinka d, da bi se izmjerila snaga rezultata t-testa.

Kao nezavisna varijabla uzet je oblik poučavanja i učenja. Ona je uključivala edukativni računalni program i tradicionalni oblik nastave, a postignuća učenika na testovima sačinjavala su zavisne varijable. Svaka varijabla testirana je s pomoću alfa razine značajnosti 0,5 i 0,001. Statistička obrada podataka tih testova provedena je primjenom programskog paketa SPSS 19.0.

Rezultati istraživanja

U ovom poglavlju rada prikazani su rezultati istraživanja u zasebnim dijelovima. U prvom dijelu prikazani se rezultati odnose na prvo i drugo pitanje istraživanja, a u drugom dijelu prikazani su rezultati vezani uz treće i četvrto pitanje istraživanja.

Da bi se odredili rezultati vezani uz prvo i drugo pitanje istraživanja, najprije je provedena analiza t-testa između rezultata učenika ostvarenih na predtestu, posttestu i retestu, i u eksperimentalnoj i u kontrolnoj skupini. Rezultati t-testa prikazani su u Tablici 1.

Tablica 1

Prema Tablici 1., utvrđeno je da je prosječan rezultat na predtestu za učenike iz eksperimentalne skupine bio 69,137, a za učenike iz kontrolne skupine rezultat je bio 70,128 bodova. Razlike u srednjim ocjenama znanja između dviju skupina nisu bile značajno različite na predtestu; t(171)=-1,117, p =,265. Na temelju pokazatelja predtesta, eksperimentalna i kontrolna skupina bile su dobro usklađene na početku obrazovnog istraživanja što se tiče prethodnog znanja učenika i njihovih vještina u području biologije.

Odmah nakon što je provedeno pedagoško istraživanje, proveden je i post-test u svim razrednim odjelima koji su činili eksperimentalnu i kontrolnu skupinu. Rezultati završnog testiranja učenika u eksperimentalnoj i kontrolnoj skupini (Tablica 1.) pokazuju da su učenici iz eksperimentalne skupine prosječno postigli 79,847 bodova, a da su učenici iz kontrolne skupine prosječno postigli 70,338 bodova. Analizirajući ukupna postignuća na retestu, Tablica 1. pokazuje da su učenici iz eksperimentalne skupine prosječno postigli 75,437 bodova, a da su učenici iz kontrolne skupine prosječno postigli 62,581 bodova.

Ponovljena mjerenja dobivena s pomoću ANOVA-e pokazala su da su se učenička postignuća znatno promijenila tijekom vremena, F(2, 342)=96,475, p<,001, a da je utjecaj interakcije između faktora vremena i skupina učenika također bio značajan: F(2, 342)=121,327, p<,001. Nadalje, univarijatni test pokazao je da postoje statistički značajne razlike u postignućima skupina učenika općenito, bez obzira na vremenski moment F(1,171)=14,432, p<,001. Stoga se može reći da postoji razlika u rezultatima testova postignuća učenika u eksperimentalnoj skupini, u usporedbi s rezultatima učenika u kontrolnoj skupini.

Proveden je t-test nezavisnog uzorka kako bi se ispitala značajna interakcija i procijenile razlike između nastavnih metoda koje su se koristile u radu sa skupinama u svakom vremenskom razdoblju. Prema rezultatima posttesta, postoje statistički značajne razlike u postignućima učenika iz eksperimentalne i učenika iz kontrolne skupine na posttestu, a koje idu u prilog učenicima eksperimentalne skupine t(171)=8,518, p<,05. K tomu, izračunata je veličina učinka *d* da bi se izmjerila snaga rezultata t-testa. U tom slučaju vrijednost *d* od 1.294 upućuje na visoku vrijednost veličine učinka, koja također ide u prilog učenicima eksperimentalne skupine. Statistički značajna razlika koja ide u prilog eksperimentalnoj skupini postignuta je i na retestu: t(171)=10,905, p<,05; d=1,66.

S ciljem ispitivanja kvalitete znanja učenika zadaci u testovima bili su podijeljeni u tri skupine kojima su se mjerile različite kategorije znanja: znanje činjenica (Razina I), razumijevanje pojmova (Razina II), analiza i razmišljanje (Razina III). Tablica 2. prikazuje relevantnu deskriptivnu statistiku.

Tablica 2

Primjena različitih oblika poučavanja rezultirala je značajnim razlikama u kvaliteti znanja učenika u završnoj fazi u svim kategorijama znanja (Tablica 2.). Više učenika iz eksperimentalne skupine moglo je dostići razinu razumijevanja pojmova (prosječno 46,138 bodova, što je 82,39% maksimalnog broja bodova), u usporedbi s učenicima iz kontrolne skupine (prosječno 41,105 bodova, što je 73,40% maksimalnog broja bodova). Razinu analize i razmišljanja doseglo je 70,21% učenika eksperimentalne skupine, a 58,62% učenika iz kontrolne skupine uspjelo je riješiti zadatke na toj razini (Tablica 2.).

Analiza učeničkih postignuća u eksperimentalnoj skupini na pojedinačnim razinama znanja u retestu pokazuje najveća postignuća na drugoj razini znanja (prosječno 44,310 bodova, što je 79,13% maksimalnog broja bodova) i na prvoj razini (prosječno 15,781 bodova, što je 78,91% maksimalnog broja bodova), a malo je slabije postignuće uočeno na trećoj razini znanja (prosječno 15,345 bodova, što je 63,94% maksimalnog broja bodova). Učenici iz kontrolne skupine imali su najveća postignuća na prvoj razini znanja (prosječno 13,884 bodova, što je 69,42% maksimalnog broja bodova), manja postignuća na drugoj razini znanja (prosječno 37,605 bodova, što je 67,15% maksimalnog broja bodova), a najslabija su im postignuća bila na trećoj razini znanja, tj. na najtežim zadacima (prosječno 11,093 bodova, što je 46,22% maksimalnog broja bodova).

Dobiven je značajan utjecaj glavnog faktora vremena na rezultate testova za prvu razinu znanja: $F(2, 342)=27{,}806$, $p<{,}001$. To znači da su rezultati testova nakon provedbe eksperimentalnog postupka bili znatno bolji nego prije njegove provedbe.

Štoviše, na Razini I također je utvrđena značajna interakcija između faktora vremena i skupina učenika: $F(2, 342)=27{,}767$, $p<{,}001$. To pokazuje da su se rezultati učenika u različitim vremenima testiranja (predtest, posttest i retest) razlikovali u eksperimentalnoj i u kontrolnoj skupini. Utvrđena je veća srednja razlika u rezultatima testova postignuća učenika u eksperimentalnoj skupini od predtesta do retesta, nego što je to bio slučaj kod učenika u kontrolnoj skupini.

Rezultati univarijatne analize varijance pokazali su statistički značajne razlike u srednjim rezultatima skupina $F(1{,}171)=26{,}961$, $p<{,}001$. Razlika u rezultatima (Tablica 2.) upućuje na temeljitije znanje koje je usvojeno s pomoću edukativnog računalnog programa u prezentiranju sadržaja genetike, u usporedbi s tradicionalnim načinom učenja. Prema rezultatima t-testa za eksperimentalnu i kontrolnu skupinu postoje statistički značajne razlike u postignućima učenika na Razini I na posttestu [$t(171)=6{,}460$, $p<0.05$; $d={,}988$] i retestu [$t(171)=6{,}665$, $p<{,}05$; $d=1{,}019$], a koje idu u prilog eksperimentalnoj skupini. Rezultati nezavisnog t-testa pokazali su da je u eksperimentalnoj skupini srednji rezultat na testu zapamćenog usvojenog znanja bio veći od onoga koji su ostvarili učenici u kontrolnoj skupini. Dakle, učenici iz eksperimentalne skupine, koji su se koristili edukativnim računalnim programom, na razini poznavanja činjenica zapamtili su više od onoga što su učili. To znači da su rezultati pokazali značajno veću količinu zapamćenog znanja u eksperimentalnoj skupini.

Deskriptivna statistika na Razini II na predtestu, posttestu i retestu pokazala je da je eksperimentalna skupina, koja se koristila edukativnim računalnim programom, imala viši stupanj postignuća u usporedbi s kontrolnom skupinom (Tablica 2.). Dobiven je značajan utjecaj glavnog faktora vremena na rezultate testova na drugoj razini znanja: F(2, 342)=120,066, p<,001. Značajna interakcija između skupine i vremena F(2, 342)=87,562, p<,001 i rezultati univarijatne analize varijance pokazali su značajan utjecaj glavnog faktora skupine F(1,171)=40,472, p<,001. Razina razumijevanja pojmova u eksperimentalnoj skupini na posttestu t(171)=8,007, p<,05 bila je značajno viša nego u kontrolnoj skupini. Učinak se može opisati kao velik: d=1,225. Rezultati t-testa za rezultate retesta, t(171)=9,563, p<,05, s velikom vrijednošću veličine učinka d=1,462, pokazali su da upotreba edukativnog računalnog programa ima velik utjecaj na više učenikove kognitivne razine učenja, u usporedbi s kontrolnom skupinom u kojoj je većina učenika dosegla samo razinu znanja.

Ponovljena mjerenja dobivena s pomoću ANOVA-e za treću razinu znanja pokazala su da su se učenička postignuća znatno promijenila tijekom vremena F (2, 342)=80,037, p<,001. To upućuje na činjenicu da su se rezultati učenika u različitim vremenima testiranja razlikovali s obzirom na to kojoj su skupini pripadali. Učinak interakcije između vremena i skupine bio je značajan: F(2, 342)=69,623, p<,001. Univarijatni test povezan s utjecajem glavnog faktora skupine bio je značajan F(1,171)=45,724, p<,001. T-test je pokazao značajnu razliku u srednjoj vrijednosti postignuća u korist eksperimentalne skupine na trećoj razini na posttestu [t(171)=7,764, p<,05;d=1,187] i retestu [t(171)=11,258, p<,05; d=1,721].

Rasprava

U prethodna tri razreda srednje škole učenici su trebali steći znanje o strukturi DNK i RNK, replikaciji DNK, transkripciji RNK i sintezi bjelančevina. To znanje provjeravano je na predtestu. Na temelju rezultata predtesta eksperimentalne i kontrolne skupine (Tablica 1.) nema statistički značajne razlike u ostvarenom broju bodova između eksperimentalne i kontrolne skupine na predtestu, ni s obzirom na pojedinačne razine znanja (Tablica 2.) ni općenito. Na temelju pokazatelja predtesta, skupine su dobro usklađene na početku obrazovnog istraživanja s obzirom na predznanje i vještine učenika u području biologije.

Rezultati su pokazali da su učenici koji su poučavani upotrebom edukativnog računalnog programa ostvarili statistički značajna postignuća na testovima, s obzirom na znanje. Dakle, statistički značajna razlika u korist eksperimentalne skupine ostvarena je na posttestu i na retestu općenito.

Prema postignućima učenika iz eksperimentalne skupine na posttestu i retestu, individualni oblik rada prevladava u učenju i omogućuje im samostalnost u radu i pokazivanje kreativnosti. Osim toga, učenici su učili s pomoću kvalitetnog računalnog programa u kojemu je nastavni materijal bio puno bolje prikazan i ilustriran nego u udžbeniku iz biologije kojim su se inače koristili. Svaki se učenik koristio računalnim programom u skladu s vlastitim sposobnostima i mogućnostima, tempom koji mu je odgovarao, sve dok nije temeljito naučio sve obvezno gradivo. Učenici koji su smatrali da imaju kontrolu nad vlastitim procesom učenja, aktivno su sudjelovali i iskoristili prilike za učenje i izvore učenja, te su većom ocjenom ocijenili učinkovitost nastave nego oni učenici koji nisu imali takvo iskustvo učenja (Lowerison, Sclater, Schmid, i Abrami, 2006).

Postignuća učenika iz kontrolne skupine na posttestu i retestu nisu pokazala značajne promjene, u usporedbi s njihovim postignućima na predtestu znanja (Tablica 1.). Puno slabiji rezultati učenika ostvareni su na posttestu, u usporedbi s uspjehom učenika u eksperimentalnoj skupini, što se može objasniti primjenom tradicionalne nastavne metode u kontrolnoj skupini u prezentaciji nastavnog gradiva u sklopu teme „Mehanizmi nasljeđivanja". Stoga intenzivno uvježbavanje i ponavljanje, kao i drugi oblici usmjerene upotrebe koje omogućuje računalni program, pomažu učenicima kako bi razvili mehanizam brzog prisjećanja informacija koje im mogu pomoći u stvaranju čvrste osnove za učenje u budućnosti (Roblyer, 2003).

Sadržaj nastavnih jedinica prilično je složen i težak za usvajanje i razumijevanje, a od učenika zahtijeva maksimalnu angažiranost i aktivnost tijekom nastave. Među učenicima u kontrolnoj skupini, zbog primjene tradicionalnog modela nastave, do te aktivnosti nije došlo, što je rezultiralo slabijim uspjehom na testovima znanja.

Utvrđena je velika razlika kada su analizirane određene razine znanja koje su učenici postigli na posttestu. Puno bolje rezultate postigli su učenici iz eksperimentalne skupine kada su rješavani teži zadaci i pitanja (kognitivne razine I i II) na posttestu, u usporedbi s rezultatima postignutima na predtestu. Drugim riječima, uočena je veća kompetencija u rješavanju složenih zadataka, što je iznimno važno. Učenike se poticalo na to da rade na podacima kako bi uočili njihovo značenje i došli do razumijevanja, stvorili nove mentalne prikaze nastavnog sadržaja i konstruirali i rekonstruirali novo znanje utemeljeno na vlastitim iskustvima. Rezultati istraživanja pokazuju da uočena razlika u postignućima učenika na posttestu nije samo razlika u kvantiteti, nego i u kvaliteti njihova znanja, vještina i navika u području biologije. Rezultati prijašnjih istraživanja potvrđuju tu tvrdnju (Akwee i sur., 2012; Efe i Efe, 2011; Županec i sur., 2013). Podaci pokazuju da je velik broj učenika u eksperimentalnoj skupini također mogao riješiti i zadatke koji su zahtijevali analizu, rastavljanje gradiva u manje dijelove, klasificiranje, komparaciju, utvrđivanje razlika između genotipa, objašnjavanje veza između genetskog materijala i njegovih proizvoda (bjelančevine, osobine). Za razliku od njih, učenici iz kontrolne skupine nisu mogli formulirati i izgraditi nova znanja na temelju postojećih znanja i vještina. Stoga se može reći da bi računalna tehnologija i edukativni računalni programi trebali „poticati aktivno, autonomno učenje, a kurikul bi trebao biti prilagođen potrebama i sposobnostima pojedinačnih učenika" (Glušac, Makitan, Karuović, Radosav, i Milanov, 2015, str. 136).

U sklopu teme „Mehanizmi nasljeđivanja" učenici trebaju usvojiti nove pojmove o genima, razumjeti veze između fenotipa i genotipa, između gena, alela i kromosoma (Lewis i Wood-Robinson, 2000), razumjeti nasljeđivanje genetskih osobina (Banet i Ayuso, 2000; Lewis i Kattmann, 2004; Venville i Treagust, 1998) te usvojiti nove principe i zakone (npr. Mendelov zakon segregacije, Hardy-Weinbergov model ravnoteže). Školska praksa pokazuje da učenici u tome često imaju problema. Edukativni računalni programi olakšavaju učenicima stvaranje veza između stvarnih fenomena i apstraktnih modela i prikazuju genetičke fenomene na dinamičan način upotrebom videomaterijala i animacija. Takvi prikazi mogu pomoći učenicima u shvaćanju dinamične prirode fenomena, aktiviranju postojećih znanja (Wu, Lin i Hsu, 2013) i mogu utjecati na njihovu uspješnost u istraživanju, objašnjavanju i razumijevanju genetike.

Višestruki oblici prikaza znanja kao što su dijagrami, animacije, mape i grafovi mogli bi imati važnu ulogu u izradi računalno utemeljenog ocjenjivanja te su često integrirani u prezentaciju gradiva (Wu, Kuo, Jen, i Hsu, 2015). Višestruke vanjske reprezentacije uvelike se koriste u poučavanju i učenju (Tsui i Treagust, 2004). U ovom istraživanju višestruke reprezentacije i interaktivno okruženje za učenje genetike osmišljeni su na način da učenicima pruže stimulirajuće i stvarne probleme iz područja genetike koje trebaju riješiti (Tsu i Treagust, 2004).

Učenje genetike na taj način kod učenika razvija samostalnost u radu, inicijativu, slobodu izbora, vješte rasprave i prezentiranje rezultata rada. Također trebaju i aktivno sudjelovati u nastavi i učenju, pa okruženje u kojemu se učenje odvija mora podržavati aktivno, suradničko i autonomno učenje. Uvođenjem inovativnih didaktičkih modela u nastavni proces postiže se modernizacija i poboljšava kvaliteta nastavnog procesa, čime se ispunjavaju mnogi zahtjevi – npr. njegova učinkovitost i racionalizacija. Imajući na umu važnost biologije za obrazovanje suvremenog čovjeka, nastava biologije mora slijediti suvremene trendove.

Primjena edukativnih računalnih programa u nastavi biologije ima vrlo pozitivan učinak na područje razumijevanja, mogućnosti primjene i zadržavanja znanja. Prema rezultatima brojnih autora (Cvjetićanin, Pećanac, Sakač, i Djurendić-Brenesel, 2013; Ferguson i Chapman, 1993; Lee, 2001; Rotbain i sur., 2008; Tsui i Treagust, 2007), može se zaključiti da primjena edukativnih računalnih programa pokazuje važne prednosti i veće mogućnosti u nastavi u usporedbi s tradicionalnim metodama. Oni također imaju pozitivan učinak na brzinu učenja, kvalitetu, zadržavanje i primjenu znanja, pažnju i interes učenika za učenje nastavnih sadržaja. Nastava uz potporu tehnologije ima nevjerojatan potencijal za unapređenje učenja o složenim i apstraktnim znanstvenim temama poput genetike (O'Day, 2006; Starbek, Starčič Erjavec, i Peklaj 2010; Stith, 2004).

Zaključak i implikacije

Integriranje edukativnih računalnih programa u okruženje za učenje može pružiti dragocjena iskustva učenja kada su oni osmišljeni i kada se koriste na pedagoški prihvatljiv način, na temelju pedagoških principa i u skladu s potrebama i učenika i nastavnika. Istraživanje je ispitalo učinak koji učenje pojedinca uz primjenu računalnog programa ima na postignuće učenika u učenju genetike na nastavi biologije. Uzimajući u obzir ukupna postignuća na posttestu i retestu općenito, može se zaključiti da primjena edukativnog računalnog programa i suvremenih pedagoških metoda povećava učinkovitost nastave biologije (u području genetike) u usporedbi s tradicionalnom nastavnom metodom. Istraživanje je potvrdilo statistički značajno povećanje kvalitete znanja učenika iz eksperimentalne skupine u svim pojedinačnim kognitivnim područjima. Nastavni model primijenjen u ovom istraživanju pokazao je pozitivne karakteristike bez obzira na vrstu nastavne jedinice. Pokazao se prikladnim za stimuliranje analitičkog mišljenja kod učenika, rasprave tijekom prezentacije novog gradiva, veću interakciju učenika i nastavnika, kao i veću aktivnost učenika u usporedbi s tradicionalnim pristupom.

S druge pak strane, učenje uz pomoć edukativnih računalnih programa još se uvijek ne primjenjuje na prikladan način u osnovnim i srednjim školama i gimnazijama u Srbiji. Da bi se na pravilan način taj model nastave primijenio u nastavi biologije i ostalih prirodnih znanosti i da bi se osiguralo njegovo odgovarajuće mjesto u obrazovnom procesu, neophodno je napraviti velike promjene u organizaciji rada škole i opremiti škole računalima i edukativnim računalnim programima za različite nastavne predmete, a koji će biti prilagođeni dobi i intelektualnim sposobnostima učenika.

Međutim, mogu se primijetiti i ograničenja u zaključcima. Uzorak je odabran postupkom slučajnog uzorka. Predmet istraživanja ograničen je samo na nastavu biologije za 12. razred srednje škole, za nastavnu temu „Mehanizmi nasljeđivanja". Stoga se rezultati ne mogu generalizirati i za druge teme u biologiji, kao ni za sadržaj drugih nastavnih predmeta. Učinkovitost primjene edukativnog računalnog programa u nastavi biologije izmjerena je isključivo na temelju računalnog programa koji se koristio u ovom pedagoškom istraživanju.