Зборник Института за педагошка истраживања
Година 45 • Број 2 • Децембар 2013 • 422–444
УДК 371.3::57 ; 371.315.7 ; 159.955.6-057.874

ISSN 0579-6431
Оригинални научни чланак
DOI: 10.2298/ZIPI1302422Z

EFFECTIVENESS OF COMPUTER-ASSISTED LEARNING IN BIOLOGY TEACHING IN PRIMARY SCHOOLS IN SERBIA*

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Abstract. The paper analyzes the comparative effectiveness of Computer-Assisted Learning (CAL) and the traditional teaching method in biology on primary school pupils. A stratified random sample consisted of 214 pupils from two primary schools in Novi Sad. The pupils in the experimental group learned the biology content (Chordate) using CAL, whereas the pupils in the control group learned the same content using traditional teaching. The research design was 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, applying, and reasoning. Arithmetic mean, standard deviation, and standard error were analyzed using the software package SPSS 14.0, and t-test was used in order to establish the difference between the same statistical indicators. The analysis of results of the posttest and the retest showed that the pupils from the CAL group achieved significantly higher quantity and quality of knowledge in all three cognitive domains than the pupils from the traditional group. The results accomplished by the pupils from the CAL group suggest that individual CAL should be more present in biology teaching in primary schools, with the aim of raising the quality of biology education in pupils.
Key words: Achievement, Computer-Assisted Learning (CAL), traditional teaching, primary education, Chordate.

* *Note*. This article is the result of the project *Quality of Educational System in Serbia in the European Perspective* (No. 179010) financially supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia (2011–2014).
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INTRODUCTION

Education is one of the most important elements responsible for the development of the society. Therefore, its adaptation to the changes brought about by today's information age is very significant. In order for this adaptation to be successful, it is not enough to simply change and modernize the content of learning. It is also fairly important to introduce the teaching models based on information resources. One of the teaching models based on the use of information system resources is Computer-Assisted Learning (CAL). CAL has existed for over four decades, and its broader application has been made possible only with the appearance of personal computers.

CAL is an educational method which uses computers as an environment in which learning occurs, which enhances the learning period and pupils' motivation, and can be useful for pupils because of their different learning speeds. This educational method has been formed by combining computer technology and learning principles by oneself (Hancer & Tüzeman, 2008). "Regarding the organization of the learning process, in CAL pupils are led by the strategy of small (short) steps, i.e. by the step-by-step strategy, being directly informed about their own progress and with the teacher's adjustment to every pupil. In this way, every pupil learns independently, individualized and at his/her own speed" (Pejić, 2006: 46). CAL allows learners to be able to take increasingly more responsibility to choose, control, and evaluate their own learning activities, which can be pursued at any time, at any place, through any means, at any age. Simply put, learners can decide what they want to learn and in what order (Pilli, 2008). Further, CAL is visually attractive, since it presents concepts using demonstrations that are made attractive by animation, colour and sound. In addition, CAL captures and holds pupils' attention by providing opportunities for competition, with the pupils' previous performance as the opponent (Mahmood, 2006). CAL also eliminates misconceptions by providing immediate feedback, since immediate feedback prevents incorrect learning concepts. In Computer-Assisted Learning rote learning is minimized and meaningful learning can occur (Renshaw & Taylor, 2000).

Many science teachers, educators, and researchers have proposed to employ CAL in biology teaching. However, as pointed out by Hancer and Tüzeman (2008), not all biological contents are appropriate for implementing the CAL application. This has been confirmed by many studies that examine the effectiveness of CAL over the traditional teaching models in the implementation of various biological contents. Çepni et al. (2006) investigated the effects of the Computer-Assisted Instruction Material (CAIM) related to the topic *Photosynthesis* on pupils' cognitive domain levels (knowledge, comprehension and application). The results of the research showed that the overall success of pupils in the CAIM group in the overall achievement test was significantly higher in comparison to the success of pupils from the traditional group. Analyzing the success of pupils on individual cognitive domains, it was found that both groups gained about the same number of points at the level of knowing the facts, while in the domains of understanding and application of knowledge, pupils from the CAIM group achieved significantly better results compared to the pupils from the control group. Yusuf and Afolabi (2010) investigated the effects of Individualized Computer Assisted Instruction (ICAI) and Cooperative Computer Assisted Instruction (CCAI) on secondary school pupils' performance in biology compared to Conventional Instruction (CI) in the topics *Food chain, food web, energy flow, nutrient, movement, and pyramid of numbers*. It was found that the performance of pupils exposed to CAI either individually or cooperatively was significantly better than the performance of their counterparts exposed to CI. Comparing the efficiency of ICAI and CCAI, significantly higher achievement of pupils was accomplished with CCAI method. During the implementation of the teaching unit *Eye sight and sense* at the higher education studies, Katircioglu and Kazanci (2003) monitored the effectiveness of the group performing individual work with a programmed multimedia presentation and the group with teacher's help in addition to slide show compared to the control group. The results of this study showed that pupils of experimental groups achieved significantly greater success than the pupils from the control group. Efe and Efe (2011) examined the effectiveness of CAL compared to the traditional teaching in the implementation of *A Cell* teaching topic in the first grade of secondary school. The pupils who were taught by CAL software which contained a large number of simulations were more successful in solving problems in six cognitive domains. The authors emphasized that pupils should be enabled to learn the contents by using this type of software given they use visualization in order to easier understand the structure of cells, the function of various cell organelles, cell division, transport of oxygen, food and water through the cell membrane, active and passive transport, membrane potential. In addition, as cited in Hancer and Tüzeman (2008), CAL is more efficient than the traditional methods concerning the increase of academic achievement of pupils in the realization of lessons: *Digestion and Excretion Systems* (Pektas *et al*., 2006), *Floral Plants* (Akcay *et al*., 2005), *Increase and Inheritance of Alives* (Yoldas, 2002), *Reproduction of plants and animals* (Soyibo & Hudson, 2000). On the other hand, there are studies in biology teaching which demonstrated higher effectiveness of traditional teaching in comparison to CAL in the realization of lessons: *Cell division* (Owusu *et al*., 2010), *Photosynthesis* and *Introduction to Genetics* (Morrell, 1992), *Enzymes* (Güler & Saglam, 2002).

CAL application in biology teaching is little known in our country. Possible reasons for that include the lack of computer equipment in biology cabinets, a small amount of published educational software, and insufficient training of biology teachers for using computers in teaching (Drakulić i sar., 2011; Terzić i Miljanović, 2009a). CAL is insufficiently applied in biology teaching in our educational system, as confirmed by several papers in this field. Grujičić and Miljanović (2005), and Terzić and Miljanović (2009b) examined the effectiveness of cooperatively applied multimedia application in biology teaching, in the implementation of *Angiosperms* in the fifth grade of primary school, and *Biology of the Development of Animals* in the third grade of secondary school, respectively. The results of their research showed that the use of computers in biology teaching was much more efficient than traditional teaching in terms of quality, durability and applicability of knowledge.

Accordingly, there is still plenty of room to explore the effects of CAL on pupils' achievement in the implementation of some other biological contents as well, especially the contents which are abstract and hard to understand for pupils. One such content is the teaching subtopic *Chordate*, which is implemented in the sixth grade of primary school (Curriculum of biology for the sixth grade, Official Gazette of the Republic of Serbia, No. 5/2008), as confirmed by pupils' low achievement in these contents on the international testing TIMSS 2003 (Ševkušić i sar., 2005). In order to enhance pupils' achievement in this field, the purpose of this research is to find a teaching model that will make the content Chordate more accessible, more interesting and easy to understand.

The aim of this paper is to examine the effect of individual CAL vs. traditional teaching on pupils' achievement in biology teaching in primary school. CAL teaching was applied in the experimental group of pupils (E), and traditional teaching was applied in the control group of pupils (C).

Research hypotheses. The following research hypotheses were tested in the research:

- H1: The pupils in Group E will achieve better results on the posttest in each individual cognitive domain (knowing of the facts, applying of knowledge and reasoning) than the pupils in Group C.
- H2: The pupils in Group E will achieve better results on the posttest in general than the pupils in Group C.
- H3: The pupils in Group E will achieve better results on the retest on each individual cognitive domain than the pupils in Group C.
- H4: The pupils in Group E will achieve better results on the retest in general than the pupils in Group C.

METHOD

Research Design. The research was true-experimental in nature because the equivalence of the control group and the experimental group was provided by a random assignment of pupils either to the experimental or the control group. The experimental group consisted of pupils from one school, while the control group consisted of pupils from another school, so that they did not communicate with each other. Both groups of pupils had the same characteristics: GPA at the end of the first semester of the sixth grade – very good, GPA in biology at the end of the first semester of the sixth grade – very good, and the average score achieved in the pretest – 68 points. This demonstrated the equivalence of the control group and the experimental group. The research design followed by researchers was the Pretest-Posttest Equivalent groups Design.

Limitations and delimitations. The following limitations and delimitations can be observed regarding this study:

(1) Samples were selected by a stratified sampling procedure.
(2) The subject of the research was limited only to biology teaching for the sixth grade of primary school, the teaching subtopic *Chordate.* Accordingly, the results cannot be generalized either to other biological topics, or to the contents of other subjects.
(3) The effectiveness of the CAL method was measured solely on the basis of the software that was applied in this pedagogical experiment.
(4) The sample of the research included pupils whose average age was 12, who had different ethnic backgrounds from two different schools. Therefore, two biology teachers participated in the realization of the experiment.
(5) Pupils of both groups were informed in advance that their achievement was going to be tested by the knowledge tests after the realization of the subtopic Chordate.

Sample. A stratified random sample consisted of 214 pupils from two primary schools in Novi Sad, Serbia. In total, 106 pupils of the sixth grade were in the experimental group, and 108 pupils were in the control group. Stratification of the sample was carried out according to the pupils' GPA at the end of the first semester of the sixth grade, the pupils' GPA in biology at the end of the first semester of the sixth grade, and the pretest. Both groups of pupils who did not belong to any stratum were equally involved in all school activities during educational research, but their test results were not considered in the statistical data analysis.

Research Instruments. 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 applying of knowledge (Level II), and the level of reasoning (Level III). On each individual test, within the Level I the maximum number of points that could be gained was 30, within the Level II the pupils could gain 40 points, and within the Level III pupils could gain a maximum of 30 points. Thus, the total maximum number of points which pupils could gain on any of these tests was 100. The values of Cronbach's Alpha for the pretest (α=0,805) and the posttest (α=0,9) indicated a high internal consistency of tests.

Research Procedure. The experiment was carried out in the school year 2011/2012., during regular biology classes, on the contents of the lesson subtopic Chordate in the second semester of the sixth grade of primary school. The duration of the experiment was 10 weeks in total for both groups, simultaneously.

At the beginning of the research, prior to teaching the subtopic Chordate, both groups E and C were tested with the pretest in order to synchronize the previous knowledge of pupils in both groups. After pretesting, teaching of the subtopic Chordate was implemented with the experimental model in Group E, and the control model in Group C. Teaching of the subtopic Chordate was implemented in both groups during 19 lessons (12 lessons for teaching new material + 1 lesson for the exercise presentation + 6 lessons for the reinforcement of the lesson). It included teaching of the following lesson units: (1) Chordate – basic characteristics of Chordate on the basis of the example of Amphioxus, in comparison to the previous groups of animals; (2) Vertebrate – structure and diversity; (3) Fish – a way of life, structure and correlation with the habitat (a carp); (4) The practicum exercise – Dissection of fish; (5) Variety of fish and their significance; (6) Amphibians – a way of life, structure and correlation with the habitat (a frog). Reproduction and development; (7) Diversity of amphibians and their significance; (8) Reptiles – a way of life, structure and correlation with the habitat (a lizard); (9) Diversity of reptiles and their importance, extinct reptiles; (10) Birds – a way of life, structure and correlation with the habitat; (11) Variety of birds and their significance; (12) Mammals – a way of life, structure and correlation with the habitat; (13) Variety of mammals and their importance (Curriculum of biology for the sixth grade, Official Gazette of the Republic of Serbia, No 5/2008).

Control model: Implementation of the complete educational subtopic Chordate took place in the biology cabinet. Both teaching and reinforcing of the lesson were implemented in traditional instruction, including three instructional strategies: frontal lectures, discussion and intermittent asking of questions by the teacher, and responding by pupils. Teaching aids and devices used in the research were the textbook, a blackboard and chalk. The practicum exercise Dissection of fish was implemented in frontal teaching and demonstration by the teacher.

Experimental model: In this model, teaching of the subtopic Chordate took place in the computer classroom by applying CAL (using educational software). The classroom had the same number of workplaces and computers, enabling pupils to work individually on the computer. Within the implementation of the subtopic Chordate, the pupils from Group E did the practicum exercise Dissection of fish in the biology office. Every pupil did the exercise independently, based on the instructions given in the instruction handout according to the programmed instruction model. During all biology classes, the teacher monitored the course of work on software of all pupils, at the same time providing assistance with course assignments, if necessary. In the final part of each lesson, i.e. when lessons were both taught and reinforced (7 minutes before the end of the lesson), the teacher interrupted the work of pupils on the software and had a discussion with them in order to gain an insight into understanding and mastering of the implemented educational contents.

Upon the completion of experimental research (after the implementation of the subtopic Chordate in different ways in Group E and Group C), differences in pupils' achievement in Group E and Group C were analyzed by examining their achievements on the posttest. The retest was applied 90 days later (the same posttest), with the aim of identifying the durability and quality of knowledge in both groups of pupils.

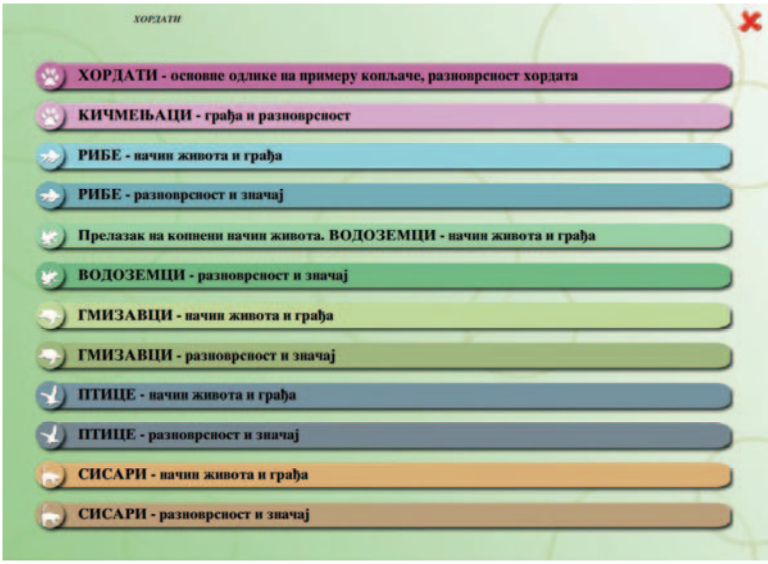
Design and method of application of educational software in the experimental group of pupils. Educational software designed for the purpose of the research was created in Macromedia Flash 8.0. Keeping the software in .exe format enabled its simple use on all computers without installing any additional software. Entire written material (the teaching content) in software was written in Serbian (the native language), and enriched with numerous illustrations, which were prepared in Adobe Photoshop.

Upon running the software, a home page was shown to the pupil (Figure 1), providing illustrations of all groups of animals used during the pedagogical experiment.

Figure 1: Software Home Page

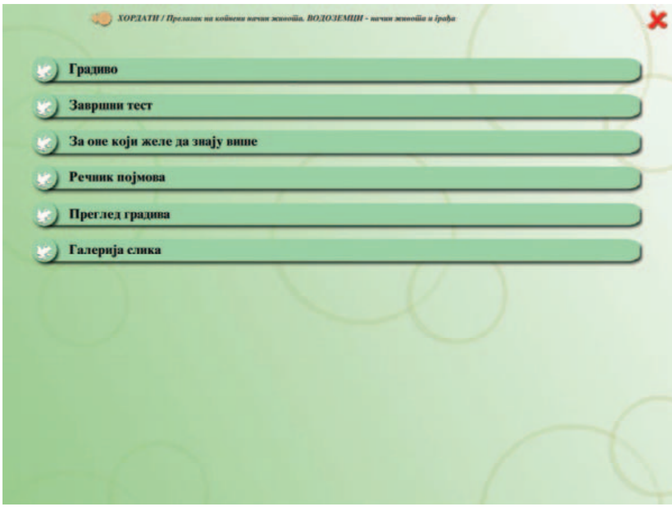
By clicking on the button "START", pupils opened the second page (Figure 2), displaying hyperlinks for all 12 listed lesson units of the subtopic Chordat.

Figure 2: Teaching units included in the subtopic Chordate



All teaching units were programmed according to the same principle, i.e. uniformly. With one click on any of the teaching units, pupils opened the page with six sections, through hyperlinks: *Lesson content*, *Final test, For those who want to know more*, *Glossary*, *Content overview*, and *Gallery* (Figure 3).

Figure 3. Divisions of every teaching unit



The first step of every lesson, when teaching the content in Group E, was to instruct the pupils to open the section *Lesson content* through hyperlink. The lesson content presented the content of the teaching unit including a few pieces of information (from 7 to 10), which followed one after another gradually, thus enabling the pupils to adopt the teaching content individually and gradually, at their own pace, until they fully adopted it. Due to rich illustrations, most information was presented in two or three pages. When pupils read the text and viewed illustrations on the first information page, they moved to the next page of the same information by using a button in the right corner. Also, they could return to read the previous slide by pressing the button in the left corner of the slide. As pieces of information in the software were displayed clearly, concisely and picturesquely, this enabled the pupils of average and weaker intellectual abilities to read them easily and quickly as many times as they needed in order to fully adopt and understand them. Figures 4 and 5 show pieces of information entitled "External structure of amphibians (frogs)" as a part of the teaching unit "Amphibians – a way of life, structure and correlation with habitat (frog). Reproduction and development".

Figure 4: *Information "External structure of amphibians (frogs)" – the first slide*

Figure 5: *Information "External structure of amphibians* (*frogs*)"
– the second slide

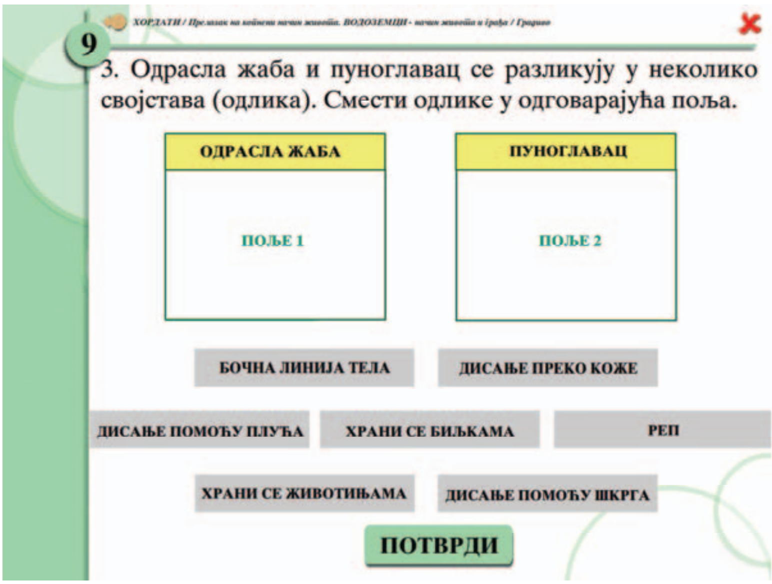
In the section Lesson content, the tasks followed the information that was read, and after solving the task the pupil received feedback about the correct answer. If the pupil answered the question incorrectly, he/she received additional information in order to realize the mistake, and was also committed to return to the previously read information in order to re-read it more carefully and adopt it. After a repeated reading of the information, the pupil answered the same question. If pupil's response was accurate, he/she automatically moved on to solve the next task. Only when the pupil correctly answered all the questions within single information, he/she could move on to reading the next piece of information i.e. a new piece of the Lesson content, until he/she fully adopted the content of the lesson. The tasks that followed after the pieces of information had different forms: *Multiple Choices Single Answer* (Figure 6), *Fill-in numbers* (Figure 7) or *Fill-in expressions* (Figure 8), and *Multiple Fill-ins expressions* (Figure 9). Thus, the interaction or "feedback" was fully realized in this software.

Figure 6: A task form "Multiple Choices Single Answer"

Figure 7: A task form "Fill-in numbers"

Figure 8: *A task form "Fill-in expressions"*

Figure 9: *A task form "Multiple Fill-ins expressions"*



The next step of every lesson, when teaching the new content, was independent testing of the knowledge of the entire unit by solving the *Final test*. The answers to test questions consolidated all individual pieces of information into a single unit. In the final test, the pupil received feedback upon solving each question if he/she answered correctly, and was automatically moved on to the next question. The procedure was the same at the end of the test. In the Final test, the pupil who incorrectly answered the question did not have a possibility to correct it. As each question in the Final test carried a number of points, the pupil was shown the total points score after solving the last task, including the grade assessing the acquisition of the teaching unit. When pupils finished solving the final test, they were offered to open the *Gallery.* It contained images that illustrated the teaching content, as well as new images which could not be found in the section Lesson content. The purpose of additional, i.e. new illustrations was to enable pupils to understand more clearly the anatomy of an animal body, and to identify similarities and differences among groups of animals. After examining the Gallery, pupils were asked to single out and write down in their notebooks the most important arguments given in the *Content overview.* Pupils who were particularly interested in biology had the possibility to read interesting phenomena and additional findings related to each group of animals within the section *For those who want to know more*. The section *Glossary* provided explanations of key biological concepts and phenomena for each teaching unit.

In order to determine the actual value of the Computer Assisted Programmed Learning, educational software for the implementation of the subtopic *Chordate* was used as a total replacement of textbooks for the sixth grade. The software presented the same biology contents according to the authors Bukurov et al. (2008). All pupils from Group E were given an electronic version of the educational software at the beginning of the experimental research, in order to use it at home for learning and confirming the teaching contents.

Data Analysis. The research analyzed the following statistical parameters: arithmetic mean (AM), standard deviation (SD), standard error (SE). T-test was used for testing differences in data obtained on knowledge tests (the pretest, the posttest and the retest) between E and C groups (Cepni *et al.*, 2006; Efe & Efe, 2011; Güneş & Çelikler, 2010; Hançer & Tüzeman, 2008). Significance was accepted when $p<,05$. All analyses were conducted in the SPSS 14.0 software.

RESULTS AND DISCUSSION

Upon analyzing the results of the pretest, the posttest, and the retest, the changes in pupils' achievement in two groups were analyzed and explanations of the obtained differences were given. Statistical indicators of *the pretest* are presented in Table 1.

Table 1: The significance of differences in E and C group from the pretest of knowledge according to the levels and in general (t-test)

Cognitive Domains	Group	N	AM	SD	SE	Significance of differences
Knowing the facts	E	106	24,584	4,177	,406	t (212)=,210; p >,05
	C	108	24,472	3,654	,352	
Applying of knowledge	E	106	27,594	7,262	,705	t (212)=,125; p>,05
	C	108	27,481	5,944	,572	
Reasoning	E	106	16,009	5,167	,502	t (212)=-1,16; p>,05
	C	108	16,851	5,367	,516	
Total achievement on the test	E	106	68,189	13,712	1,332	t (212)=-,349; p >,05
	C	108	68,805	12,141	1,168	

Considering pupils' achievement of both groups in individual levels of knowledge, the pupils from both group E and C had the best achievement on the first level of knowledge (group E achieved 24.584 points on the average, which amounted to 81,93% of the maximum number of points, while group C achieved 24.472 points on the average, which amounted to 81,57% of the maximum number of points). Both groups had underachievement on the second level of knowledge (E: 27.594 points, which amounted to 68,98% of the maximum number of points, C: 27.481 points, which amounted to 68,70% of the maximum number of points), while both groups had the lowest achievement on the third level of knowledge (E: 16.009 points, which amounted to 53,37% of the maximum number of points, C: 16.851 points, which amounted to 56,17% of the maximum number of points).

Based on the results of the pretest of E and C groups (Table 1), there were no statistically significant differences in the obtained number of points between E and C groups in the pretest (p>,05) according to individual levels of knowledge and in general. 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 knowledge and skills in biology.

After the implementation of the subtopic Chordate by using different models of work in the experimental and the control group, the *posttest* was given, the results of which can be seen in Table 2.

Table 2: The significance of differences between E and C groups on the posttest according to the levels and in general (t-test)

Cognitive Domains	Group	N	AM	SD	SE	Significance of differences
Knowing the facts	E	106	26,764	3,337	,324	t (212)=5,02; p<,05
	C	108	24,675	2,717	,261	
Applying of knowledge	E	106	33,641	4,829	,469	t (212)=8,56; p<,05
	C	108	27,315	5,908	,569	
Reasoning	E	106	25,424	3,757	,365	t (212)=14,17; p<,05
	C	108	16,879	4,969	,478	
Total achievement on the test	E	106	85,830	9,886	,960	t (212)=11,92; p<,05
	C	108	68,870	10,879	1,047	

The analysis of pupils' achievement from E Group on individual levels of knowledge shows that achievement is highest on the first level of knowledge (approximately 26.764 points, which amounts to 89,20% of the maximum number of points), while it is lower on the third (on the average 25.424 points, which amounts to 84,73% of the maximum number of points), and the second level of knowledge (on the average 33.641 points, which amounts to 84,10% of the maximum number of points). The analysis of the pupils' achievement from Group C on individual levels of knowledge shows that achievement is highest on the first level of knowledge (on the average 24.675 points, which amounts to 82,27% of the maximum number of points), lower on the second level of knowledge (on the average 27.315 points, which amounts to 68,28% of the maximum number of points), and lowest on the third level of knowledge (on the average 16.879 points, which amounts to 56,27% of the maximum number of points).

Based on the results of the t-test for E and C groups presented in Table 2, there are statistically significant differences in favour of the experimental group in each individual level of knowledge (p<,05), thus confirming the hypothesis H1: *The pupils from Group E will achieve better results on the posttest in each individual cognitive domain* (*knowing of the facts*, *applying of knowledge*, *and reasoning*) *in comparison to the pupils from Group C*, *as a result of greater effectiveness of individual CAL in biology teaching compared to traditional teaching.*

Considering the overall achievement on the posttest in general, Table 2 shows that the pupils from Group E achieved 85.83 points on the average, while the pupils from Group C achieved 68.87 points on the average. Therefore, statistically significant difference in favour of Group E is realized on the posttest in general (t=11,92>1,96), thus confirming the hypothesis H2: *The pupils from Group E will achieve better results on the posttest in general, in comparison to the pupils from Group C, as a result of greater effectiveness of individual CAL in biology teaching compared to traditional teaching.*

The obtained values of t-coefficients were considerably larger than the limits (in the tasks at all individual levels of knowledge, and in the test in general). The differences were particularly significant in the tasks of the second and third level of knowledge. The pupils from Group E had significantly better results in solving more difficult questions and tasks of the level II and the level III on the posttest in relation to the pretest, which means that they expressed greater ability to solve complex issues and tasks compared to the pupils from Group C, which was particularly important. The results of the research showed that obtained differences in pupils' achievement between Groups E and C on the posttest were not only differences in quantity but also in quality of their knowledge, skills and habits in biology. Statistically significant differences between Groups E and C on the posttest in general and within individual levels of knowledge were a result of the proper selection of the educational content (the lesson subtopic Chordate), and its efficient implementation by using innovative models of teaching (individual CAL in Biology Teaching) in Group E as opposed to the traditional teaching approach applied in Group C.

Retesting of pupils was conducted 90 days after the posttest in order to verify the durability of the acquired knowledge of the pupils from E and C groups concerning the subtopic *Chordate*. Retest results are shown in Table 3.

Table 3: The significance of differences between Group E and Group C on the retest of knowledge according to cognitive domains and in general (t-test)

Cognitive Domains	Group	N	AM	SD	SE	Significance of differences
Knowing the facts	E	106	26,584	2,480	,241	t (212)=4,60; p<,05
	C	108	24,944	2,720	,262	
Applying of knowledge	E	106	33,132	4,479	,435	t (212)=10,84; p<,05
	C	108	26,379	4,626	,445	
Reasoning	E	106	25,453	3,660	,355	t (212)=14,20; p<,05
	C	108	16,389	5,480	,527	
Total achievement on the test	E	106	85,169	8,740	,849	t (212)=13,38; p<,05
	C	108	67,713	10,258	,987	

The analysis of pupils' achievement in Group E on individual levels of knowledge shows that the highest achievement is on the first level of knowledge (on the average 26.584 points, which amounts to 88,60% of the maximum number of points), while a slightly lower achievement is on the third level of knowledge (25.453 points, which is 84,83% of the maximum number of points), and on the second level (in the average 33.132 points, which is 82,83% of the maximum number of points). Pupils from Group C have the highest achievement on the first level of knowledge (on the average 24.944 points, which amounts to 83,13% of the maximum number of points), lower achievement was on the second level of knowledge (on the average 26.379 points, which amounts to 65,95% of the maximum number of points), while the lowest achievement was on the third level, i.e. on the most difficult tasks (on the average 16.389 points, which amounts to 54,63% of the maximum number of points).

Based on the results from the t-test for E and C Groups (Table 3), there are statistically significant differences in the retest in favour of the experimental group in all three individual cognitive domains ($p<,05$), thus confirming the hypothesis H3: *The pupils from Group E will achieve better results on the retest in each individual cognitive domain in comparison to the pupils from Group C, as a result of higher quality and durability of their knowledge, gained in individual CAL compared to the traditional teaching of biology.*

Analyzing the overall achievement on the retest in general, Table 3 shows that the pupils from Group E achieved 85.169 points on the average, while the pupils from Group C achieved 67.713 points on the average. Therefore, statistically significant difference in favour of Group E has been achieved on the retest in general as well ($t=13,38>1,96$), thus confirming the hypothesis H4: *The pupils from Group E will achieve better results on the retest in general, in comparison to the pupils from Group C, as a result of higher quality and durability of their knowledge, gained in individual CAL compared to the traditional teaching of biology.*

Therefore, the success of pupils in Group E achieved on the posttest and retest in general, and according to the individual cognitive domains, was significantly higher compared to the pupils from Group C. A key element that contributed to such significant progress of Group E in comparison to Group C was the way of presenting the teaching content to the pupils. In the traditional presentation of the content Chordate, the pupils from Group C found it difficult to understand the system of classification and systematization of animals. Reading the textbook, which provided only one image of the external and internal structure of each group of animals, was hardly enough for the pupils to be able to note similarities and differences among the groups of animals, as well as to understand the adaptation of animals to the specific conditions of the habitat. All the pupils were learning together, at the same pace, without taking into account their different intellectual abilities. All this resulted in their low achievement both on the posttest and the retest.

In the software that was used in Group E, pupils easily understood the hierarchical relationships among the animals, because the programmed material was presented very systematically and clearly, in conversational style, sufficiently informative and illustrative. Thus, for example, the internal systems of organs within each group of animals were presented with an illustration of their internal structure with clearly highlighted constituent parts, so that the pupils could easily note the similarities and differences among individual groups of animals, as well as understand their adaptation to the living conditions. Every pupil was learning the content step by step at his/her own pace, until the full adoption of the planned educational content, which emphasized the principle of the pace individuation of teaching. The existence of feedback in software was a very important motivating factor for them. Therefore, the pupils were not afraid of teacher's criticism after providing wrong answers, but instead were given a chance to renew the teaching contents and fix their own mistakes by themselves.

Due to the high interactivity of the software, manifested in a large number of different types of assignments, it was used for different types of training and competitions of pupils, which was an incentive for learning biology and provided them an immediate control of learning, and an objective evaluation of knowledge. Such software design met the following Mayer's Principles for the design of Multimedia Learning (Mayer, 2001): multimedia principle, segmenting principle, coherence principle, signalling principle, spatial and temporal contiguity principle, personalization principle, and image principle, which confrims its significant contribution to the high achievement of the pupils from Group E.

The inherent impact of teaching methods and media on learning, as well as the pupils' motivation for learning, has been discussed by Kozma (1991), in contrast to Clark (1983) who argues that instructional methods determine how effective a piece of instruction is, and what is the influence of media on the cost and distribution. Kozma stated that media do influence learning, and that the media selection is very important to learning. Kozma does not contend that media alone can influence learning, but rather that the ability of media to influence learning is very dependent on the instructional methods employed by the design. He discusses the ways in which those methods exploit the capabilities and attributes of the media (Hastings & Tracey, 2005). Contemporary computers provide strong support for Kozma's (1991, 1994) unique argument, since computers offer a possibility of using teaching methods that could not be implemented by using some other media.

Although CAL in our schools does not have an appropriate application yet, the results of this and other studies (Çepni *et al*., 2006; Efe & Efe & 2011; Katircioglu & Kazanci, 2003; Yusuf & Afolabi, 2010) have confirmed its greater effectiveness than the traditional biology teaching. In order to appropriately apply the CAL model in teaching biology and other sciences, and ensure its appropriate place in our education process, it is necessary to make major changes in the organization of school work, and its better equipping with computers and educational software for different subjects, which will be adapted to the age and intellectual abilities of pupils. Experiments should be done over a long period of time, so that pupils have enough time to forget the habits of the traditional learning, and become better acquainted with CAL. Furthermore, it is necessary both for the future biology teachers during their schooling at the faculty, and biology teachers who work at schools, to be trained in order to become IT literate, and apply CAL. This is provided in the Regulations on Standards of Competences for the Profession of Teachers and Their Professional Development (Official Gazette of the Republic of Serbia, no. 5/2011).

Conclusions

The study examined the effects of individual CAL on pupils' achievement in the teaching subtopic Chordates by using the software during the biology class for the sixth grade of primary school. Cognitive domains were established according to the model of the study TIMSS 2007 (Martin *et al*., 2008). This model was used to categorize the questions for the pretest and the posttest/retest, which were given both to the control group and the experimental group. The findings revealed that the pupils who were taught with CAL, by using the software, made statistically significant achievements in their test scores on all three levels (knowing the facts, applying of knowledge, and the level of reasoning), as well as in the test in general, both on the posttest and retest. Accordingly, it turned out that CAL was a more effective teaching model than the traditional model when it came to the implementation of the content of the teaching subtopic Chordate in biology teaching in primary school.

A general conclusion of this empirical research is that individually applied CAL of biology has enabled the learning of the subtopic Chordate with a different approach, bringing the pupils into the position to acquire biological principles through their independent work. The programmed material should be constructed in a way to be adapted both to the age and cognitive abilities of all pupils at the same time. Such a model of work requires an increased activity of the teacher who plans, prepares, and constructs educational software, as well as organizes the work of pupils, aware of the fact that despite many advantages of the CAL, it is not the only good solution, and that it should be used when there is a belief that it is the best teaching-method strategy for learning about biological phenomena.

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Примљено 20.08.2013; прихваћено за штампу 13.11.2013.

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ЕФЕКТИВНОСТ ПРОГРАМИРАНЕ НАСТАВЕ БИОЛОГИЈЕ УЗ ПОМОЋ КОМПЈУТЕРА У ОСНОВНОЈ ШКОЛИ У СРБИЈИ

Апстракт

У раду је испитивана ефективност програмираног учења уз помоћ компјутера (ПУПК) у поређењу са традиционалним учењем у настави биологије у основној школи. Стратификовани случајни узорак чинило је 214 ученика из две основне школе у Новом Саду. Ученици експерименталне групе су обрадили биолошке садржаје (наставну подтему Хордати) применом ПУПК, док су ученици контролне групе исте садржаје учили током традиционалне наставе. У истраживању је примењен претест–посттест истраживачки дизајн са еквивалентним групама. Сви инструменти коришћени у истраживању (иницијални тест, финални тест и ретест) су садржали питања груписана у три различита когнитивна домена: познавање чињеница, примена знања и резоновање. Коришћењем програмског пакета SPSS 14.0 анализирани су аритметичка средина, стандардна девијација и стандардна грешка, а за утврђивање разлике између истоврсних статистичких показатеља коришћен је *t* тест. Анализа резултата финалног теста и ретеста показала је да су ученици експерименталне групе остварили значајно већи квантитет и квалитет знања на сва три когнитивна домена него ученици контролне групе. Остварени резултати ученика експерименталне групе препоручују већу заступљеност програмиране наставе биологије уз помоћ компјутера у основној школи чији је циљ да се повећа квалитет биолошког образовања ученика.

Кључне речи: постигнуће, програмирана настава уз помоћ компјутера (ПУПК), традиционална настава, основна школа, Хордати.

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ЭФФЕКТИВНОСТЬ ПРОГРАММИРОВАННОГО ОБУЧЕНИЯ БИОЛОГИИ ПРИ ПОМОЩИ КОМПЬЮТЕРА В ОСНОВНОЙ ШКОЛЕ СЕРБИИ

Резюме

В данной работе исследовалась эффективность программированного обучения при помощи компьютера (ПОПК) в сравнении с традиционным обучением на уроках биологии в основной школе. Стратифицированную случайную выборку составило двести четырнадцать учеников из двух основных школ в Нови-Саде. Ученики экспериментальной группы изучили материал по биологии (учебная подтема „Хордовые“) с применением ПОПК, а ученики контрольной группы тот же материал осваивали на традиционном занятии. В исследовании применялся предтестовый и посттестовый исследовательский прием с эквивалентными группами. Все приемы, использованные в работе (инициальное тестирование, финальное тестирование и повторное тестирование) содержали вопросы, сгруппированные в три различные когнитивные области: знание фактов, применение знаний и аргументация. При использовании программы SPSS 14.0 анализированы среднее арифметическое, стандартное отклонение и стандартная ошибка, а для определения различий между однотипными статистическими показателями использовался t-тест. Анализ результатов финального тестирование и повторного тестирования показал, что ученики экспериментальной группы достигли значительно большего количества и качества знаний во всех трех когнитивных областях, чем ученики контрольной группы. Полученные результаты учеников экспериментальной группы указывают на потребность большего использования программированного обучения биологии с помощью компьютера в основной школе, целью чего является повышение качества биологического образования учеников.

Ключевые слова: достижения, программированное обучение при помощи компьютера (ПОПК), традиционное обучение, основная школа, хордовые.