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BOOK 5

"MATHEMATICS, INFORMATICS AND PHYSICS"

VOLUME 11

CONTENTS

Mathematics

Informatics

BOOK 5

"MATHEMATICS, INFORMATICS AND PHYSICS"

VOLUME 11

Physics

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AN EMPIRICAL STUDY OF A MODEL FOR TEACHING ALGORITHMS

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Abstract*: The article describes a pedagogical experiment to assess the applicability of the developed model "Expert, teacher, student" in teaching algorithms. An approach is discussed for verification of theoretical knowledge before and after training. Separately, there are proposed and there are applied criteria by which to form an objective assessment of the acquired practical skills for drawing algorithms. The presented content is a part of a conducted experiment.*

Keywords: *Computer Science, Algorithm, Algorithm Teaching, Algorithm skills assessment.*

INTRODUCTION

Admittedly this century is identified by activating the creation of knowledge and its technological application. The growth of knowledge has two dimensions: instrumental resources and creative capabilities of the researcher to use these tools in the learning process. These dimensions characterize the research infrastructure of any scientific product. Quantity and quality of generated scientific knowledge is a function of the chosen methodology of creative search and analytical capabilities of the researcher. These moments are embodied in the technology of its implementation [6].

At the university level of education we need to ensure the process with a systematic approach in knowledge acquiring. Data structures and algorithms are important foundation topics in computer science education. Students deal with algorithms in many computer science courses and so they must be equipped with solid skills in algorithms [3]. It was suggested a model “Expert, teacher, student” for algorithm teaching, divided in four phases, presenting in [1].

The experiment is selected as a tool of the research approach in order to verify the applicability of the suggested model for algorithm teaching. Each experiment characterizes the organization of special impact on a particular object or group of objects and then registers and analyses the effect of this impact. Pedagogical experiments constitute a subset of experiments, but because they are social in nature, they are subject to the basic principles and limitations of the experiments carried out in a social community. It is characteristic that explore not only "objects " in most cases "subjects " - people formed to varying degrees and in different conditions [4].

Research with students in higher education have additional features resulting from optional attendance form classes on the one hand and on the other - the right of universities to compile separate curricula, which limits the ability to conduct quantitative educational research of higher education.

THE PEDAGOGICAL RESEARCH ORGANIZATION

The pedagogical research followed the sequence [4]:

1. Methodology development and specific organization creation;
2. The survey;
3. Presentation and analysis of results;

4. The positive results integration into methodological theory of the course "Introduction to Programming". Demonstration of the pedagogical research from the study and its implementation in the practice.

The students' work in the courses "Introduction to Programming" and "Introduction to Computing" was observed. In the pedagogical study are included all students from the first course (regular and part-time) of Computer Science and Informatics and Information Technologies applied in the business, studying in Bachelor of Science. The number of students involved in the experiment reaches the required number of subjects tested, ensuring the representativeness for the sample.

For the purpose of the experiment are formed two groups of students. The first one we called ***experimental*** and the second one - ***control***. Students study the disciplines, listed above and they are covered by the 10 groups. Six groups of these are studying full-time and four are part-time groups. Students are divided administratively in determining the control group following the recommendation composition of the control group which is not lower than that in the experimental one [4]. The study involved a total of 119 students, of which 63 male and 56 female.

THE THEORETICAL KNOWLEDGE EVALUATION

In order to obtain information on the average level of knowledge on the subject Algorithms before the training of persons involved in pedagogical research was conducted an entry test. It consists of 30 questions covering knowledge of basic terms and concepts on the subject of algorithms. It is chosen such way of organization of the input test where each student starts the test with 30 points. Each correct answer is worth with a point, for wrong answer - take one point in order to avoid the answer by guessing. The lack of response selected is marked with 0 points and shows that the student has no knowledge on this matter at the time of the test. In this way of the input test organization the maximum score is 2*30 and the minimum is 0. Such exam organization is administered in contemporary international competitions in the field of informatics and computer literacy [3].

Checking the depth of the knowledge on the theoretical aspects in the field of algorithms after the training is done through a final test. It includes questions covering the definition of the algorithm, the properties of the algorithms, the kind of the algorithm and the variables usage.

THE PRACTICAL SKILLS ASSESSMENT

The assessment shows the degree of fulfilment of the objectives of the training and respectively it has reflexive and motivational nature of training for the student. The assessment also has a corrective role for the teacher. Through knowledge and skills assessment the teacher establishes the achieved learning outcomes and he/she realizes the feedback. In general the assessment is the quality control of training. For these reasons there is a necessity of careful selection of the criteria for evaluation. The assessment is an indicator of the extent to which the competencies formed in learner correspond to those required of the target level. By the assessment the teacher obtains information about the individual achievements of learners. He/she determines the training needs and defines the areas that need further work to achieve a level of knowledge and skills corresponding to the target requirements. It is possible to yield an overall picture of the effectiveness of training.

Professional competences in a given subject domain require exhaustive knowledge of the theoretical aspects and principles which are in its basics. Otherwise, there is a risk of acquiring skills that can be attributed to the level of craft knowledge. Three problems are

suggested in order to get an idea of the level of knowledge and practical skills for writing algorithms at the end of the training. The problems' solutions demand knowledge appliance skills. In order to avoid the possibility of manipulating the results there are developed four sets of the above described problems. One of them is the following:

Set 1.

Problem 1. The arrays, called ***a*** and ***b***, contain the sides of ***m*** rectangular triangles. Draw an algorithm by which to be defined the length of the hypotenuse of the triangle with the largest face.

Problem 2. Draw an algorithm to find the number of positive elements which are located above the main diagonal of the two-dimensional array ***Q*** with ***n*** rows and ***n*** columns.

Problem 3. A row contains a few words, which are separated from one other by a space. Draw an algorithm that displays the longest word entered. If there are multiple longest words they have to be displayed all on one line, separated from each other by a space.

Examples:

Input:	tova e primer	*Output:*	primer
Input:	ima mnogo dobri deca	*Output:*	mnogo dobri

There are a set of formed criteria that are assigned with defined number of points for the different components of the solution. The aim is in such way to align the indicators of the final assessment. Criteria that are evaluated for an algorithm are detailed in Table 1. The total points for all three tasks are 60 and they are collected at an absolute covered set of requirements. The proposed problems comprise tasks that require an application of knowledge. The first one checks the acquired skills to work with cyclic algorithms. The maximum number of points which are valued skills shown with this task is 15. These points are distributed on different criteria, as shown in Table 2. The student gets from 0 to set in the table maximum value of points depending on the extent to which his/her decision meet the criteria. This is valid for all three problems for each criterion. The second problem provides feedback for knowledge about commonly used algorithms and skills acquired by students to apply them in solving practical problems. The maximum number of points which are estimated skill shown by this problem is 20, which are distributed on different criteria as shown in Table 2. From the same table it can be seen that the maximum numbers of points a student can receive if correctly solve the third problem is 25. This problem requires the ability to build solutions with a high degree of abstraction and many opportunities for critical thinking and for compiling algorithmic solutions of practical problems.

Table 1 Criteria to determine the level of acquired practical skills for writing algorithms

Criterion	Description
К 1	Correct setting of the input data for the algorithm.
К 2	Correctly set the initial values of the variables (initialization).
К 3	Appropriate choice the kind of cycle (cycles).
К 4	Correct formulation of condition(s) for termination the repetitive operations.
К 5	Correct determination of the repeated actions and the need for the incorporation of cycles.
К 6	Update values of variables involved in the condition(s) of organized cycle/cycles.
К 7	Correctly display the search results in the format of the data.

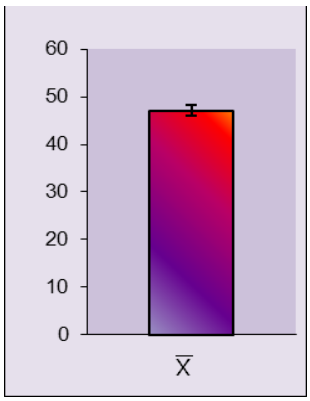
Table 2 Number of points by proposed problems

Criterion	Points Problem 1	Points Problem 2	Points Problem 3
К 1	**1**	**1**	**1**
К 2	**2**	**2**	**3**
К 3	**3**	**2**	**4**
К 4	**2**	**5**	**5**
К 5	**4**	**6**	**6**
К 6	**2**	**3**	**5**
К 7	**1**	**1**	**1**

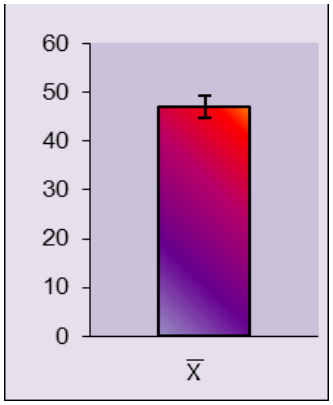
RESULTS OF STATISTICAL PROCESSING OF THE TEST OF THEORETICAL KNOWLEDGE

Points enable a man to get a more accurate picture of actual results shown by the students. That is why the assessments are formed on the basis of a scale in which an interval of points mapped the same assessment [5]. For the students in ***control*** group the number of points falls with the highest probability in the range [37 (36.60); 42 (42.08)], and for those of ***experimental*** one are in the interval [36 (35.90); 40 (40.10)]. It can be concluded that even if there is a difference in theoretical knowledge before training, it is beneficial to the students in the control group, but not essential.

The comparative analysis of the points of the final test on the lecture material shows that the students which are in the control group the number of points falls with the highest probability in the range [46 (45.90) 48 (48.02)], and for those of ***experimental*** group the point are in the interval [44 (44.0) 49 (48.73)]. It can be concluded that there is no significant difference in theoretical knowledge at the end of the training (Fig. 1). Positive finding can be made on that most students receive about 48 out of 60 points, which corresponds to about 80% of acquired knowledge.



Interval of confidence for points achieved in the control group

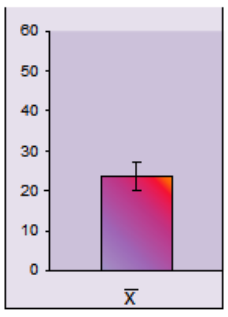


Interval of confidence for points achieved in the experimental group

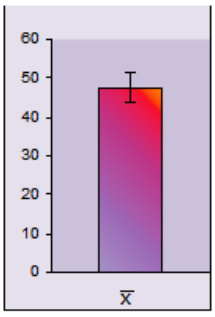
Fig. 1 Confidence intervals for the points obtained by the students of the final test of lectures on "Algorithms"

RESULTS OF STATISTICAL PROCESSING OF THE TEST OF PRACTICAL SKILLS

The comparative analysis of the points of the test to assess the acquired practical skills for drawing algorithms show that for the students in the ***control*** group this number falls with the highest probability in the range [20(19.8); 27(27.15)]. The number of points for the students of the experimental group is in the interval [44(43.7); 51(51.2)]. It can be concluded that there is a significant difference in the level of acquired practical skills at the end of the training. There is also a significant effect of the proposed model for training on building practical skills for drawing algorithms and opportunities for critical thinking in students (Fig. 2).



Interval of confidence for Group 1



Interval of confidence for Group 2

Fig. 2 Intervals of confidence for the points obtained by the students of the final test for practical skills on "Algorithms" assessment

Displaying the control group learners results, namely the average of the points from their practical work 24 (23.5) means that most of them fail to deal successfully with the first proposed problem (15 points) and make a bit of the second one (20 points) or the third problem (25 points). The acquired practical skills of the students in the control group cover 40% of these criteria.

The acquired practical skills of students trained in the model "Expert, teacher, student" (these, who are in the experimental one) have an average value of 47(47.4) points, which corresponds to the correct solution of two problems and some elements of the third. Positive finding can be made about the acquired skills of practical problem solving of the students in the experimental group cover 78% of the defined criteria. Number of students from this group with maximum points is 8 (24%) and those who received an excellent evaluation of the acquired practical skills for drawing algorithms are 12 (35%).

CONCLUSIONS AND FUTURE WORK

Comparing the proposed model training "Expert, teacher, student" and accompanying methodology for use it may be noted the following advantages over the traditional approach appliance in education:

1. At the end of the course students have acquired the necessary knowledge and skills for practical application of their theoretical knowledge to ensure the achievement of quality education.

2. An algorithm animation tool usage in education help to significantly reduce the level of abstraction and facilitates the process of transition from theoretical knowledge to practical skills. This was confirmed experimentally in the presence of the same theoretical knowledge students of the experimental group demonstrated better practical skills.

3. It is provided an opportunity for individual approach in the learning process by allowing each student to monitor the implementation of the algorithm developed by him/her and admitted it detects discrepancies.

4. It is guaranteed a high degree cover necessary material to absorb the basic knowledge and skills.

5. The acquired knowledge and skills provide a solid foundation for achieving permanent knowledge that are a prerequisite for further development in the field of computer science.

6. Problem solving usage as a tool for learning algorithms creates conditions for the implementation of activities related to the development of professional competence in the training of future professionals in the field of computer science.

Further research is needed to refine the ideas regarding this teaching approach and how it can best be used to aid in the delivery of the introductory concepts of programming.

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ЕКСПЕРИМЕНТАЛНО ИЗСЛЕДВАНЕ НА МОДЕЛ ЗА ОБУЧЕНИЕ ПО АЛГОРИТМИ

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Резюме: *Статията описва педагогически експеримент за оценка на приложимостта на разработен модел „Експерт, преподавател, студент" в обучението по алгоритми. Разгледан е подход за проверка на теоретичните знания преди и след обучението. Отделно са предложени и приложени критерии, по които да се формира обективна оценка относно придобитите практически умения за съставяне на алгоритми. Частично е представен конкретно проведен експеримент.*

Ключови думи: *Компютърни науки, Алгоритми, Обучение по алгоритми, Оценка на умения за съставяне на алгоритми*

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