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THE DEVELOPMENT OF COMPUTER COMPETENCIES USING ARTIFICIAL INTELLIGENCE

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Abstract

The paper informs about possibilities how to improve educational process with the help of artificial intelligence. Theoretical part provides an overview of the development of cognitive research on feed-forward neural networks (perceptrons) and teaching support systems. It expresses the preconditions, expected results, concepts, objectives, hypotheses and research methods of the thesis. The practical part describes the construction of a complete teaching system based on the original GLM (Grudzień Learning Module). This module, which contains elements of artificial intelligence, served to achieve the main objective of the experiment and to compare the effects of conventional teaching and individualized instruction based on the proposed methodology. Further part of the paper describes the course of the experiment, pedagogical discussion of results, conclusions and observations. The benefits of the scientific results of the experiment, expandability of the system and subsequent works are mentioned as well.

Keywords

professional competencies, computer competencies, neural networks, eLearning project, expert systems, artificial intelligence

Introduction

The research problem

I am a teacher of vocational subjects and science in Zespół Szkół Ekonomiczno-Gastronomicznych in Cieszyn. In my daily work with students, I am concentrated on activities that can improve the speed of acquisition of teaching materials and improve students' knowledge. This objective can be reached by specially prepared ways as eLearning courses aimed at individualization of instruction.

Educational systems found in literature are either commercial solution that are too expensive to be implemented in schools, or devoted to teaching a particular subject. I have not found a system that was so versatile that it can be adapted to the taught subjects.

In the article, I propose teaching with the use of copyright the GLM module, which uses part of the artificial intelligence to select the appropriate learning path (learning trajectory) for a student. The module is so flexible that it can be adapted to teach each subject. Together with the module, a complete management system of teaching equipment computer technology in the field of informatics techniques is prepared.

Objectives of the work

The aim of the research is the development and testing of new author's module, which uses neural networks and expert system for individual teaching of students (Grudzień, 2010a; Grudzień, 2010b; Grudzień, Smirnova-Tribul'skaja, 2012).

The second objective was to develop a scientifically substantiated eLearning system of vocational education course *Computer technology equipment* in the teaching of computer technician using artificial intelligence techniques. This system is coherent with the program of instruction 312[01]/T/SP MENiS/2004.06.14 announced by the Polish Ministry of Education as the framework program of teaching computer technology.

The expected result of the work is to improve the learning process of obtaining better results in the professional courses of computer technology equipment. It is assumed that in the final test, students using the proposed system will have better results than those who did not use this system.

Methods of work

Research methods included the following elements:

1) analysis of scientific – methodological and psychological-pedagogical literature related to e-learning teaching;
2) analysis of school curricula of vocational subjects in the field of informatics techniques;
3) analysis and testing of eLearning teaching in selected courses;
4) analysis of students' work, analysis of questionnaires, observations and comments;
5) comprehensive diagnosis and monitoring of students gain knowledge through mathematical and statistical methods;
6) conducting pedagogical experiment and presentation of results using mathematical and statistical methods.

The current status of solving issues

Development of cognitive methods

The following theories are methodological basis of the research: pedagogical – in the field of education development by Davydov's and Jelkonin's, creating mental frameworks Galperin's, differentiation of the current development zone and the nearest development zone of Vygotsky and Laurie, and the principle of unity of the psyche, consciousness and activity Vygotsky, Leontiew and Rubinstein.

According to research (Kostjuk, 1988; Ljublinskaja, 1971; Menchinskaja, 1989), intellectual development of external and internal factors can be defined. External factor may be the number of teaching hours or their regularity. Internal factors can be independence and flexibility of learning or individual qualitative characteristics of intelligence. Other works (Kabanova-Meller, 1981; Kruteckij, 1968) mention the influence of already acquired knowledge to further education.

Jel'konin (Jel'konin, 1989) and Davydov (Davydov, 1986) have demonstrated that intellectual development is dependent on the environment and the content of teaching. The same was confirmed by Pellegrino (Pellegrino, Chudowsky & Glaser, 2001), which recommended the use of such methods, which affect the increase in the level of knowledge of students.

Intellectual activity is closely related to certain properties of the nervous system. These properties are responsible for the learning skills of the individuals (Jegorova, 1973; Lejtes, 1971; Lubovskij, 1989). According to experimental research (Kalmykova, 1979; Menhinskaja, 1989), there are cases that all differences of students' knowledge levels are not possible to equalize, even with proper educational environment.

To determine the difficulty in learning, a good diagnostic tool is necessary. For this purpose were used quantitative indicators based on measuring the number of tasks carried out in the time unit (Zykova, Marcinovskaja et al. 1980). As an alternative, Eysenck (Eysenck, 1992) suggested measuring IQ to determine the speed of the functioning of mental processes.

While looking for the most reliable indicators of intellectual development, not only quantitative indicators were used. The emergence of new mental structures can be studied as a result of the learning process (Fidman, 1977). The research by Nepomnjashhaja (Nepomnjashhaja, 1983) shows that individual intelligence is variable and its components depend on the teaching methods.

Teaching should be done in an optimal manner so that the best possible use of the student's potential. This requires individualization of teaching methods and the choice of appropriate sensitivity to student teaching methods (Pen'kov, 1989). If we define all the knowledge and skills that a student can use alone as an area of current development, and the intrinsic relationship between education and development as the next area of development (Vergeles, 1972), we can try to define the teaching route. This route should be such that while the extension of the current development is to expand the range of tasks that can be performed under the supervision of student's teachers and in collaboration with more skillful peers (Davydov, 1986).

Modern approaches to education require the use of new techniques and technology of effective teaching. In secondary schools, there are new didactic and methodological challenges caused by computerization of teaching (Kapounová, Pavlíček, 2003; Smyrnova-Trybulska, 2009).

Groundbreaking research on the development of the intellect components based on comprehensive utilization of informatics techniques in teaching mathematics was done in Ukraine (Smirnova, 1996) and its sequel is one of the objectives of this research work.

Unidirectional neural networks (perceptrons)

As a resource of modelling and neural bases of calculations, the article by McCulloch and Pitts (McCulloch, Pitts, 1943) should be considered, where the first model of artificial neuron was described. Work by Minsky (Minsky, 1963; Minsky, 1967) allowed to accept the proposition that the threshold network constructed from artificial neurons can be considered as machines with a certain number of states, and that these networks are able to perform universal computation.

Parallel to the threshold logic, the theory of continuous systems using differential equations to describe the activity in neural mass was developed. This work was carried by Buerle (Buerle, 1956) and Wilson and Cowan (Wilson, Cowan, 1973).

Rosenblatt team, who focused on networks called perceptrons, dealt with finding the weights for specific computational tasks. Neurons were organized into layers with unidirectional connections. In these works, it was shown that the algorithm of learning network (iterative algorithm changes in weights so that the network performed the required computational tasks) is convergent. Additional research on the networks called Adaline was conducted and discovered by Widrow and Hoff (Widrow & Hoff, 1960).

The book *Perceptrons* (Minsky & Papert, 1969) provided stagnation in neural network research. The authors demonstrated that a simple perceptron networks are not able to learn problem solving linearly inseparable. This situation lasted until finding the back propagation algorithm discovered independently by Werbos (Werbos, 1974), Williams (Williams, 1987) and Parker (Parker, 1985; Parker, 1987) and LeCun (LeCun, 1985).

Modification of network learning algorithms, which are designed to accelerate this process are described by Hertz, Krogh and Palmer (Hertz, Krogh & Palmer, 1991).

A broad assessment of various types of networks, including feedback (Hopfield, Hamming, Elman, RTRN, BAM) and self-organizing networks with competitors (ART, radial, probabilistic) are presented by Cichosz (Cichosz, 2000), Tadeusiewicz (Tadeusiewicz, 1993), Rutkowski (Rutkowski, 2005) and Osowski (Osowski, 1996).

Learning support systems

First steps associated with the use of intelligent machines can be attributed to Pressey (Pressey, 1926), who used the machine instruction tests with multiple choice answers. But at that time, the level of technology did not allow the functioning to implement in accordance with the teaching theory.

Along with the expansion of the first computers, the first systems to enhancing learning appeared (Bloom, 1956; Carroll, 1963; Skinner, 1957). At first, they based on the theory of programmed instruction (PI programmed instructions).The system determined entry skills and competencies defining the output of the student. The student's individual problems led to teaching scheme and tested their knowledge. In the case of incorrect answers, there were presented and treated right solutions of teaching other content (Bunderson & Olsen, 1983). As the developed system of PI, systems called CAI (computer aided instructions) or CBT (computer based training) emerged. CAI systems based on Skinner's theory of stimulus response. The next stage of development systems strengthening education systems was ICAI (intelligent computer assisted instruction).

The next step in the evolution of enhancing teaching systems is ITS (intelligent tutoring systems). These include: knowledge of the field (expert model), knowledge of the student (the student model) and knowledge of teaching methods (tutor model). Moreover, they also require that these systems led to diagnose student’s errors and prevent them (Kyllonen, Christal & Shute, 1989).

Another type of training systems are based on the reasoning of the cases - case based reasoning (CBR) (Schank, 1982; Kolodner, 1988). Unlike the ACT model systems, which in some cases give very detailed description of the problems of the student, CBR systems are content with a certain approach and focus on the main issues.

Since the 1980s, the simulation tools of various kinds, containing different types of artificial intelligence have been developed.

Along with the emergence of broadband access to the Internet has opened opportunities to work in Virtual Reality environments. This environment is a platform in which, except for maybe the implementation of all the above teaching methods are easy to implement social element of teaching - cooperation and exchange of experience among course participants.

Main topics of the latest research are located around the following questions:

- systems based on network usage (Israel & Aiken, 2007; Conejo et al., 2004);
- systems focusing on the interaction between users (Rosatelli & Self, 2004; Walker et al., 2004);
- systems using the new student model, such as Bayesian model (Vu Minh et al., 2010; Chao-Lin, 2008);
- modelling of teaching (Aleven et al., 2009);
- open learner model (Bull & Kay, 2007);
- ill-defined domains (Lynch et al., 2009).

Practical part

The construction and method of module operation

The teaching in this work by the proposed algorithm works in steps:

1) preparation of learning objects in accordance with the standards and requirements of the Framework educational program;
2) pre-setting system;
3) collection of psychological data about the student, in this case the intelligence structure test;
4) enabling the access to the course to students (teaching with support);
5) collecting data about each student (results of tests, questionnaires , etc.);
6) intelligent system improvement based on data from previous phases;
7) return to step 3.

The algorithm works is an endless cycle, which means continuous improvement of the system based on data from other students.

The proposed management system of teaching is consistent with the model of the Intelligent Tutoring System, which consists of 4 parts: the student model, expert module, tutorial module and a graphical user interface.

In the proposed solution author's teaching management module GLM comprises tutorial module and a part of a graphical user's interface. Teaching management module GLM consists of two parts: Web GLM, which shows the proposed trajectory for student learning and GLM.exe, which learns neural network and generates PHP code for web parts GLM.

The expert module containing learning objects, tests, surveys and the remainder of the graphical user interface is supported LMS Moodle. Student's model data from the intelligence structure test.

Preliminary work of GLM module

Before beginning of teaching users system administrator creates in module GLM.exe ordered set of neural networks. These networks are unidirectional networks based on the perceptrons with a sigmoid activation function. The number of neural networks is equal to the number of learning objects contained in the built up part of the course. Networks are numbered from 0 to n. In each neural network is contained as many neurons as there are networks (and learning objects). Each neuron receives a number which corresponds to the learning object (a number of associated neural network). The weights of the network are configured in such a way that, when any of the input data, the most stimulated neuron is a neuron of a number one greater than the number of the current network. (This setting is intended to provide user's guidance through all learning objects).

Gradually, using already created data and GLM.exe module, part of Web GLM containing in its code the copy of the previously established networks is automatically formed. Web GLM is located on the server supporting the learning management system. This solution was adopted for technical reasons. Preparatory works are completed.

The module work cycle

Subsequently, the approach to the next stage of the work that is already part of the cycle. For proper execution, modules GLM are necessary components of the intelligence structure test (IST). After psychological tests, carried out by authorized and trained psychologist, a student will receive a code. The code consists of nine letters of the Latin alphabet, which corresponds to the results of the intelligence structure test.

It is worth noting two parts of the algorithm – part I designed for the student to teaching conduction and data collection, and part II, where it comes to an intelligent, automated improvement of the module GLM operation.

Improving the operation of GLM module relies on advancing its ability to create individual learning trajectories for a particular student.

In each section, there are visible cycles – these have an important function in data collection for the training set and neural network teaching in GLM module.

After starting the system the user enters the coded IST results in the form. This data is sent to Web GLM module that checks the correctness and decodes. The decoded data Web GLM directs to the first neural network (numbered 0), associated with the first learning objects (also with the number 0). The start of the network is recorded by Web GLM. The user can see a link to a learning object associated with the network. Neurons generate answers to the mains input. Web searches GLM neuron with the greatest stimulation and reads the identifier. If this identifier is zero, Web GLM completes the creation of the result page for the user. Otherwise it is running in another network with the same number of neurons identifier (in this case 1). Starting next network causes the further reference to the learning object, and so on. This cycle is repeated. Learning trajectory is generated containing links to learning objects user.

The user, in addition to information about the proposed learning trajectories, has access to all learning objects. GLM module gives the student a proposal for the selection of the current optimal learning trajectories.

After studying learning objects (through trajectory designed by GLM module or not), the user accesses the tests. If the test failed, the user is returning back to the study materials. This cycle is repeated until it reaches the level of correct answers provided by the system’s administrator.

Upon successful completion of the test (or tests), the student is asked to determine what learning objects and in what order they should be in learning trajectory and which are unnecessary.

On the basis of a questionnaire, the learning set record of the neural network which will be continued to speak as a student learning trajectory record (SLTR) is created. SLTR contains user’s intellectual structure test data and the proposed educational path.

SLTR are written as a training file of GLM.exe module. After collecting adequate data amount (the system administrator subjectively evaluates it) it begins the process of modifying the learning trajectory by neural networks learning.

For each stage of learning, each SLTR is transformed into the learning record of selected neural networks. The record, which learns network, includes input data and expected output data from the selected network. The selected networks are neural networks associated with learning objects with numbers presented in the learning trajectory.

Input data for each learning record in each neural network (record of the training set) are the intelligence structure test results. Estimated output data for a particular network include: value one for neuron number identical with the number of the next learning object located in SLTR and a value of zero for the remaining neurons.

After preparing and loading training set, neural networks start learning, which takes place under supervision (supervised learning). Teaching process continues until they reach the neural network error responses smaller than the set in the parameters of learning or to exceed the maximum number of stages of learning set by the system's administrator.

The most important element, module GLM, is a part associated with the modification of neural networks. In this area, it follows the weighting change caused by networks teaching.

GLM module is taught on the basis of data derived from intelligence structure tests and questionnaires completed by the student. The result of this teaching method is the ability of GLM module to create better learning trajectories for students.

After completion of all networks, learning for different input data may be subjected of maximum stimulation different neurons, when these do not have the number of further learning objects. For new users, the learning trajectories become dependent on the input data, i.e. the intelligence structure test results.

Stimulation of other neurons causes changes in the sequence of induced neural networks and consequently changes the learning trajectory. Trained neural networks are retained for future education.

This means that the outcome of learning neural networks (in other words, changes of weights) is improved by learning trajectory for other students with similar intelligence structure test results.

The next step is to create a modified version of Web GLM containing a neural network with the updated weights and place it on a production server. It is the end of the cycle.

Work algorithm of the system is returned to the place of gathering user data. Another student, awarding the same or similar data user (IST) receives generated and modified learning trajectory. This learning trajectory is already better adapted to the needs and abilities of the student.

As in the previous case, the student has access to all learning objects, but the learning trajectory designed by GLM module is already approaching the optimal trajectory.

Comparing the learning trajectories generated by neural networks at the beginning and during the learning process of the module, the differences are easily perceived. After each new student acceding to the learning, module improves its ability to create learning trajectories.

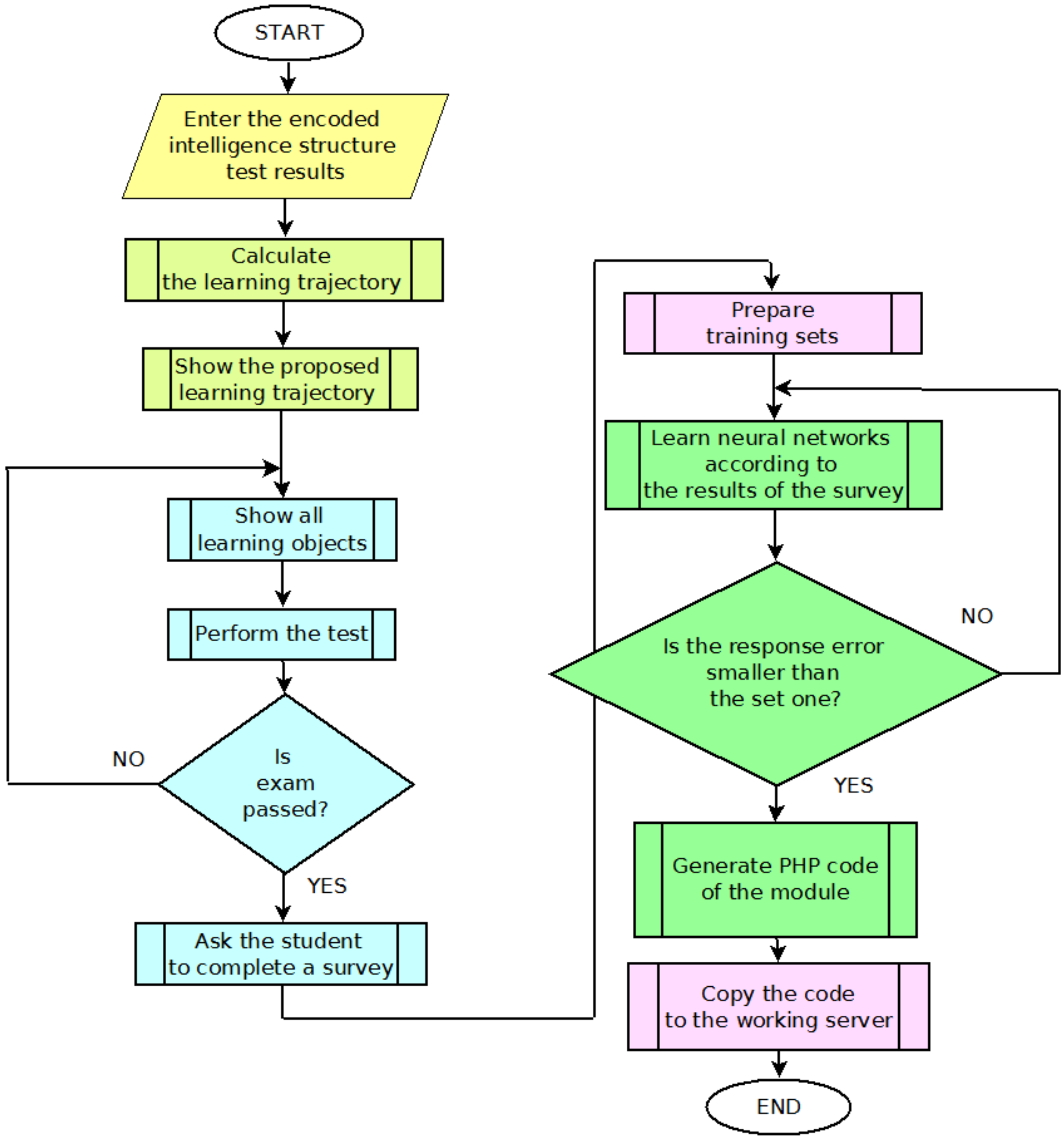

Fig. 1:Detailed algorithm of the whole system of teaching management for individual student.

Summary

The main experiment

The research sample consisted of 116 pupils were divided into two groups - experimental (56 students) and control (60 students). Teaching of the computer science in the experimental group was conducted through e-learning course, which was prepared on the basis of the development of experimental teaching methodology. In the control group, the training took place on the basis of conventional (traditional) methods of teaching.

The object of investigation was the question of knowledge of numerical systems which are often the subject of computer technology equipment (CTE): theoretical issues, logic gates, combinational circuits, multiplexers and demultiplexers, asynchronous sequential circuits, synchronous sequential circuits, generators and special circuits. The test included questions of various types: multiple choice test, single choice test, true/false answers, short answers, numerical and calculation answers. For both groups were made following the pre-test before beginning the experiment: intelligence structure test examining the components of intellect and test determines the level of professional skills of students before the courses start.

Immediately after the experiment was carried out, the test to check the level of professional skills of students and the knowledge of the area were covered in the course. The results achieved in the test were processed using statistical software R.

Methods of processing and method of solution

The course of the research was to test the hypothesis that using the proposed eLearning system to teaching vocational subjects will increase the professional competence of students compared with students who work with conventional methods of learning The null hypothesis set following: there is no difference between students who work with the proposed eLearning system of teaching, compared with students who work with conventional methods of teaching.

The results and discussion of the main experiment

The results of the two groups pre-test – the control and experimental – are at the most competency tests in the range of 0 % to 20 %. The test results of Kolgomorov-Smirnov and Wilcoxon do not allow to reject the null hypothesis. Also degree of central tendency is similar. From a statistical point of view, not the premise for the claim that the two groups represent different populations. This assertion is correct, when we analyse individual tests, as well as the overall result of the pre-test both groups.

Completely different results of tests performed during the experiment. Taking into account the results throughout the course, large differences in their distribution can be observed. Although both groups have unimodal distribution, scores of the control group are negatively skewed, and the results of the experimental group positively skewed. Distribution of the experimental group is more flat compared with the distribution of the control group. Extremely low p values of Kolgomorov-Smirnov test and Wilcoxon test confirm observations based on histograms. Based on the statistical rights, calculated p values and adopted significance level α ($\alpha = 0.05$), the null hypothesis is rejected and the alternative hypothesis is accepted on the difference distribution.

The values of central tendency measures clearly show better results of students who learned of the proposed methodology using GLM module. Accepted scientific hypothesis about improvement the quality of teaching is confirmed on the basis of research results.

Statistical method	Control group	Experimental group
The arithmetic average	23	48
Median	25	50
Standard deviation	13	21
Bilateral criterion of Kolmogorov -Smirnov test	D = 0.6643 , p- value = 1.581 -11	
Bilateral criterion of Wilocoxon test	W = 538 , p- value = 2.831 -10	

Tab. 1:The results of the statistical calculations of experimental group and control one.

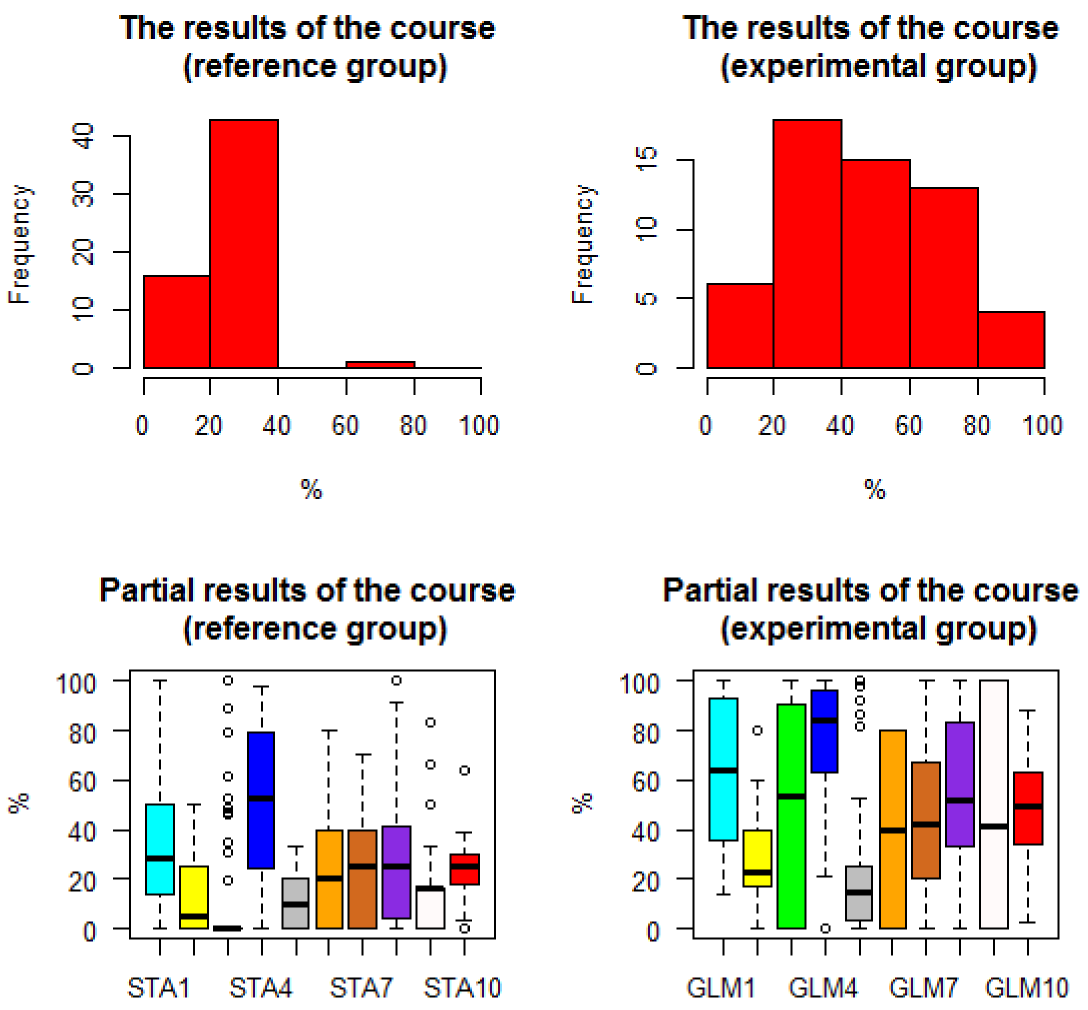

Fig. 2:The test results of the course - histograms and box plots.

Conclusions and recommendations of further research of work

Learning trajectories generated by the module gradually improve themselves by the impact of neural networks learning, which are an integral part of the module. The experiment leads to the following conclusions:

- based on the statistical results, adopted a significance level of $\alpha = 0.05$ and test results of Kolgomorov-Smirnov and Wilcoxon it is confirmed that using the GLM module has an influence on the distribution shape of the competence tests results of the participants of the computer technology equipment course;
- based on the analysis of the characteristics of central tendency measures competency tests it is confirmed that using GLM module enhances students' competencies in this course.

Observations and conclusions gained during the implementation of pedagogical experiment in this study yielded a number of questions that may be the topic of further research. Among other possible areas of theoretical research include:

- verification of the permanence of knowledge in groups taught by the conventional method as the optimization of learning trajectories,
- carrying out similar research in other disciplines – natural and humanistic sciences;
- work precisely determining how they affect learning trajectories of human cognitive sphere;
- anticipation of expertise competency tests based on psychological tests;
- extraction of logical rules from the network, e.g. to determine how learning objects are characteristic to a particular student;
- verifying whether the distribution of learning outcomes is the Poisson distribution of students, which would suggest a low occurrence of the phenomenon of student self-education;
- verifying whether the type of statistical distribution of competency test results changes at different student motivating system;
- perform neurocognitive research on the influence optimal trajectory learning the work of various regions of the human brain.

There is also plenty of practical improvement of the system of teaching functioning using GLM that includes artificial neural networks. Enumerated should be:

- automatic data collection, especially with regard to student learning trajectories.

Learning trajectories generated by the module to gradually improve the impact of learning neural networks, which are an integral part of the module:

- implementing the extended monitoring of user activity;
- adaptation of the whole course mobile devices, especially mobile phones;

- changing the activation function of the neuron and its learning method to speed up the functioning of the learning process of neural networks;
- changing the type of neural networks, such as the self-organizing ones;
- extraction of logical rules from the network to create rapidly working expert system.

Further work will be continued.

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