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Educational Innovations in the Function of Improving Students' ICT Competences

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Abstract

Information technology has lately become an integral part of the educational system. Application of modern digital technologies in teaching has changed teaching methods. This research is based on forming a teaching model in order to improve the level of ICT knowledge and skills of students applicable in the area of technical sciences. The objective of this research is to establish a methodology to improve and adapt curricula with the goal of enhancing digital competences of learners according to European standards and the needs of teaching at technical faculties.

Key words: *Computer Education Software (CES); digital competence; modular teaching system; programmed teaching.*

Introduction

At the end of 1990s, the European Commission started the initiative to increase the level of computer literacy in Europe. This resulted in a document "European Reference Framework, Key Competences for Lifelong Learning", which has an important role when it comes to improving Digital competences or ICTC (Information and Communication Technologies Competences) in European countries (European Commission, 2003).

According to Bobera, Sakal, Tumbas, and Matković (2015, p. 278), "Universities should invest significant effort to bring their ways of learning closer to the Net Generation, consisting of current students as well, who come to universities with

naturally and instinctively developed skills in multitasking, networking, group work and use of collaborative environments".

Information and Communication Technologies (ICT) in the system of higher education are used as teacher support in the realization of traditional teaching or as a substitute to such teaching (Benţa, Bologa, & Dziţac, 2015). Technical aspects which affect the use of ICT in education are: availability of computers at technical faculties, availability of various computer programs at technical faculties, adequate technical support and infrastructure for ICT use in education, adequate instructional support, adequate training with regard to the use of ICT in education, etc. (Rogošić, 2015). In order to enable students to acquire digital competences, it is necessary to improve their computer knowledge and skills (Gastelú, Kiss, & Domínguez, 2015).

In this paper, we are going to explain a teaching model based on ICT related to Computer Education Software (CES) and programmed teaching related to modular teaching created with the goal of improving digital competences of students with the possibility of application at technical faculties (Woo, Gosper, McNeill, Preston, Green, & Phillips, 2008).

The topic is of interest as it evaluates the level and method of application as well as the unique characteristics of teaching IT courseware at technical faculties with the goal of improving the general learning context and improving students' digital competences, i.e. it uses the advantages of this system of teaching over the traditional system.

Method of Programmed Teaching in a Modular Teaching System

Principles and methods of the logical structure of the teaching contents and accompanying tasks are studied in this paper. Along with that the psychological structure of the presentation of teaching content, amount of teaching content and tasks, the algorithm of operations and learning systems, ways and methods of content learning, and the ways it can be corrected are addressed. The research results will help us to gain better insight into the effects of programmed teaching. There are areas of educational activity where programmed teaching has shown certain advantages over some traditional forms of teaching and learning.

In order to carry out a programmed teaching model it is necessary to provide the following conditions:

1. Computer classrooms equipped with modern technology and application of CES which comply with current development standards of digital aims.
2. Specifically prepared material (supervised material) needed for studying certain thematic area, adapted to the modular teaching system; programming support for learning (courseware) (Obrazovni portal, 2015), and creating appropriate course books needed for studying certain modules and lessons within a module.

3. Assessing and testing students according to the modular teaching system.
4. Working on the interaction between a student, a teacher and the syllabus, also known as educational interaction.

Teaching methods have recently been based on software made for CES-a (Virvou, Katsionis, & Manos, 2005). It makes it possible to adapt the empirically created and detailed educational contents to students' individual abilities, pace and style of working, and to their psychological characteristics to a maximum possible degree. It also enables the use of the designed material in a graded and logically connected sequence, in which learning of one part is a condition for the learning of the following one, providing the necessary connection from the student to the teacher, and connecting students' work results with unhindered advancement and active participation in the learning process (Mandić, 2003). Based on this, it is possible to follow consistently the didactic principles of teaching, also providing safer control of both the teacher's and student's work. In programmed teaching, detailed insight can be made into the work of each student, their activity can be followed more easily, and the intensity of their activity and participation can be measured; this kind of teaching meets the needs and interests of young people, and allows for learning in accordance with their strengths and abilities (Blaho, Foltin, Fodrek, & Murgas, 2011).

Research has shown that, thanks to its technical foundation and the function it has, supervised teaching changes the role of the teacher, but cannot replace the teacher. In the conditions of well planned, organized programmed teaching, the teacher is mainly the organizer, planner, orchestrator, researcher, and evaluator of students' work, as well as their educator, rather than a walking and speaking textbook or a living encyclopedia. Those who look at programmed teaching results with great optimism claim that it assumes scientific organization of pedagogical work, satisfies the logic of learning, opens up new learning possibilities, stimulates students' activity, enables their advancement at their own pace, makes teaching more attractive, provides economy and efficiency of teaching and therewith belongs to such a kind of teaching which is most suitable for the needs and interests of young people. The most recent studies, although not denying the attractiveness and efficiency of programmed teaching, indicate that more steadiness and flexibility should be evident in such appraisals as well. However, nowadays, programmed teaching is not a trend any more, but rather a serious scientific issue in education of the present and future. Research about students' progress in learning has definitely shown that, among other things, it depends on the learning conditions, the quality of learning and on the person learning. Generally speaking, studies show that a well-designed syllabus, with logically composed articles and sequences, gives good results both in the kind of teaching that is mostly syllabus-based, and in situations when programmed teaching complements other kinds of teaching (Mandic, Lalic, & Bandjur, 2010). Research has also shown that in the worst-case scenario, students learn as much of the teaching content as they would learn through other modes of teaching, provided that they spare time in

the process of programmed teaching and enjoy learning by means of programmed materials. Teachers are also becoming convinced that programmed teaching, when connected with other kinds of teaching, is an attractive and useful innovation. They offer resistance only when all the advantages of programmed teaching are not clear to them and when they are not trained to conduct it. If the importance of programmed teaching is overstressed, if it becomes dominant, an aim in itself, if the syllabus is too rigidly stated and formalistically realized, it can also have negative consequences (Pun, 2011). Such consequences are: planning of work is too detailed and formalized, one lives in an illusion that perfection is achieved therewith; a universal recipe is given for learning, and mechanical learning is encouraged to a certain extent because the pupil is not able to see the whole route of gaining knowledge; sometimes the individualized modes of learning are not evident enough; there is fear that learning might be turned into drill; the quantity of information threatens to become more important than the development of creative mental abilities, where creativity might be sacrificed for routine; some kinds of syllabus, such as linear, may, under certain conditions, cause boredom, as there is danger of automation and mechanization of teaching contents and the presentation of one's learning. In some cases, the material side of teaching is overstressed; the educational effects which it offers are underrated and therewith the unity of education and teaching is misbalanced. Besides, programmed teaching sometimes pushes out collective forms of work; it is more difficult to conduct with children being separated in different grades (although it provides better results with younger children than the older children); it does not produce, or at least has not up to now, similar results in all subjects; it is difficult to provide the integrity of various subject contents; to a certain extent it lessens the possibility of cooperation and mutual help among pupils, while in some cases it unnecessarily excludes the teacher from the activities where they are needed (Mandic et al., 2010). On the other hand, the design, verification and implementation of a syllabus require a lot of effort, as well as material investments and pedagogically qualified personnel, which is difficult to provide. That is the reason why many syllabi, subject to criticism, are not designed professionally enough, as they are not tested in practice by authorized experts. However, programmed teaching is still relatively new, and thus insufficiently studied. Therefore, many critical remarks should be taken tentatively and conditionally. It is certain that the weaknesses of programmed teaching that we have discussed so far will not be shown in practice if it is organized professionally.

Computer Education Software Application in Modular Teaching System

CES includes programming languages and tools, organization of teaching and learning based on logical and pedagogical principles. It is intended for teaching and learning in technical sciences and must meet the following requirements (Radosav & Marušić, 2006):

- requirement of educational profile;
- target group of students which largely determines all other characteristics of the development of CES;
- psychological and physical characteristics of the target group;
- requirements of the cognitive psychology theory;
- didactic-psychological and teaching-pedagogical requirements;
- previously defined educational goals and tasks;
- strategy of teaching, level, organization and teaching materials;
- requirements of modern technologies and models of learning and educational technology;
- requirements of information and communication theories and management science;
- relying on knowledge and experience of a teacher, but also on scientific findings and research results of many scientific disciplines;
- knowledge and experience of students and teachers in working with ICT.

Since CES had to fulfill numerous requirements in order to be implemented into the teaching process of technical faculties, the method of its planning is complex and long-term. For the purpose of modelling a teaching system intended for improving digital competences of students at technical faculties we have created an educational Web portal (Obrazovni portal, 2015).

Figure 1. Online testing

The portal contains educational courseware (syllabus) for students in a modular teaching system, as well as online tests, thus meeting all of the requirements of CES.

The syllabus complies with the European standards, and appropriate courseware adapted to a modular teaching system is an important element in acquiring ICT knowledge. Developing teaching content courseware within a model is done by a teacher. Using terminology of our teaching practice, courseware represents didactically formed teaching material of specific knowledge structured into teaching units,

teaching modules. The overview of teaching modules for the Computer Science course prepared for technical faculties can be seen in Table 1.

Table 1

Content of the teaching modules

Teaching modules	Content of the teaching module
Module 1	Concepts of information and communication technology
Module 2	Using the computer and managing files
Module 3	Word processing
Module 4	Spreadsheets
Module 5	Using databases
Module 6	Presentation
Module 7	Web browsing and communication

Requests sent to students are clearly defined through the following modules:

Module 1. Concepts of information and communication technology

Requires from students to understand the main principles and foundations of information and communication technologies at a general level and to know parts of a computer.

Module 2. Using the computer and managing files

Requires from students to show they know how to use a computer.

Module 3. Word processing

Requires from students to show abilities to use applications for text processing as well as to do text formatting within a document.

Module 4. Spreadsheets

Requires from students to understand the concept of table documents and to show ability to use table documents for precise analysis.

Module 5. Using databases

Requires from students to understand the concept of databases and to be able to use them.

Module 6. Presentation

Requires from students to show the ability to use presentation software.

Module 7. Web browsing and communication

This module is divided into two parts. The first part requires from students to be familiar with the Internet and applications for searching the Internet. The second part requires from students to understand the concept of e-mail and other possibilities of communication.

For the purpose of implementing the teaching model for improving digital competences of students at technical faculties a course book "European standards of digital competence" was written. The course book was made to follow and divide teaching modules into smaller sections (units). At the end of the course book, there are separate tests for each module, see Figure 2 (Obrazovni portal, 2016).

Figure 2. Online testing, Module 1

From the teacher's point of view, feedback from students is also important. Educational interaction in the referential model system does not end with the completion of higher education. What is more, emphasis is placed on lifelong learning based on instruction, construction and discovery of knowledge.

Assessment and Testing of Students Based on Modular Teaching System

The modular assessment system is different from the traditional assessment system. Courses consist of several separate thematic units called modules. Teaching modules consist of content that is carried out through several teaching lessons which, in the end, consist of several teaching concepts. How long a module should be studied depends on the complexity of what is being taught, students' previous knowledge, use of technology and teaching tools needed for the analysis of a module. After each module is processed, students do the test, based on which a teacher tests the students about the module content and gives a grade for each module. Students have to get a passing grade on a test after the finished module. If they fail, they have to take the test again for that module. In the referential modular teaching system, there are seven modules within one semester (see Table 1), and if students have failed in one of them, they have to take the test again until they have passed. At the end of a semester, students get a final grade which is the average of all module grades. Students who failed any of the modules cannot get a final grade, so they have to take the test from the respective module again. In order to get a passing grade at the end of a semester students have to achieve a pass score for each particular module.

Methods

The idea of the research was to experimentally apply the individual modular teaching system at one of the technical faculties, in this case the Faculty of Transport

and Traffic Engineering in Doboj. The need for research arose due to poor motivation of students for the syllabus, poor attendance and bad test results. During an earlier analysis of the students' digital competences we noticed that the knowledge acquired during previous levels of education is not in compliance with European standards. The elementary education system enables students to master elementary IT knowledge and skills, so digital competences, at this level of education, are relatively in compliance with European standards. Non-compliance of digital competences of students with European standards occurs during their secondary education which we determined in the admission test.

At the Faculty of Transport and Traffic Engineering in Doboj we have developed an individual modular teaching system which is based on using combined teaching methods (face to face, Web-based and supervised teaching) and modern technologies like Web Based Learning and Teaching (WBLT). The model of modular teaching system for improving digital competences of students has the following functions: establishing content (courseware); using CES, preparing course books adapted to teaching modules, learning, teaching, testing, monitoring and knowledge assessment.

There were 120 first year students of the Faculty of Transport and Traffic Engineering in Doboj who participated in the experimental research. Students took the admission test based on which students' digital competences were determined. The admission test quesions were mutiple-choice questions formed from a database based on European computer science standard. After the admission test, students were divided into two groups, control and experimental group. The control group, which consisted of 60 students, attended traditional lectures (face to face) based on the model of teaching computer science that had been used for several years. The experimental group of 60 students attended lectures according to modular teaching system for improving digital competences of students. The modular teaching system for improving digital competences was developed solely for the Faculty of Transport and Traffic Engineering in Doboj. After the end of computer science course, studens from both the control and the experimental groups were tested in different ways. Students from the control group were tested in the same way as in the initial test (admission test). Questions in the test were formed based on the analyzed topic during the Computer science course, and the grade (final grade) was given to them based on their achievements. Students from the experimental group were tested according to modular system, i.e. they were tested after each module. After they passed all modules, the experimental group students were given an average grade (final grade). This research is based on comparing students' achievements in the control and the experimental group, which will be explained in data analysis.

Data Analysis

Prior to doing the inferential statistics tests, we analyzed the deviation of data from the normal distribution for the admission test and final grade. We analyzed the data

using the Lilliefors and Shapiro-Wilk test of normality. Based on the results shown in Table 2 ($p < 0.05$) we can conclude with 95% certainty that there are statistically significant deviations from normal distribution. Based on the results of the tests of normality we opted for nonparametric data analysis (Mann-Whitney U test and Wilcoxon matched pairs test).

Table 2

Tests of normality

	Group	Lilliefors test		Shapiro-Wilk test	
		N	*p*	N	*p*
Admission test	Experimental group	60	.000*	60	.000*
	Control group	60	.000*	60	.000*
Final test	Experimental group	60	.000*	60	.000*
	Control group	60	.000*	60	.000*

*$p < 0.05$

By analyzing the data for the admission test shown in Table 3 and Table 4 we found that Mean ± Standard Deviation of the experimental group was 5.166667 ± 0.526152, and of the control group it was 5.1 ± 0.47657. Therefore, we can conclude that there is no significant statistical difference between the results of the experimental and the control group (Z = -1.011590, $p = 0.311734$). This shows that students from both groups have similar computer knowledge.

Table 3

Descriptive statistics for the admission test

		N	Range	Min.	Max.	Mean	Std. Error	Std. Deviation	Variance
Admission test	Experimental group	60	2.00	5.00	7.00	5.1667	0.067926	0.526152	0.277
	Control group	60	3.00	5.00	8.00	5.1	0.061525	0.476570	0.227
Valid N (listwise)		60							

Table 4

Mann-Whitney U test for the admission test

	N	Mean ± SD	Z	*p*-value (2-tailed)
Experimental group	60	5.1667 ± 0.526152	-1.011590	0.311734*
Control group	60	5.1000 ± 0.476570		

*$p > 0.05$

Final grades in the experimental and control group were analyzed using the Wilcoxon matched pairs test (final test *vs.* admission test).The test results shown in Table 5 for the experimental and the control group indicate that students from both groups improved the level of digital competences (final grade *vs.* admission test).

Table 5

Wilcoxon result of the final grade vs. admission test

	N	Final grade	N	Admission test	Z	*p*-value (2-tailed)
Experimental group	60	7.4667± 0.98233	60	5.1667 ± 0.526152	-6.113815	0.0000*
Control group	60	6.4167± 0.84956	60	5.1000 ± 0.476570	-7.096084	0.0000*

*$p < 0.05$

However, by comparing Mean ± Standard Deviation we saw that there is statistically significant difference in students' achievements (final grade) between the experimental and the control group. In further analysis of students' achievements (final grade) we got the following results and showed them in Table 6 and Table 7.

Table 6

Descriptive statistics for the final grade

		N	Range	Min.	Max.	Mean	Std. Error	Std. Deviation	Variance
Final test	Experimental group	60	4.00	5.00	9.00	7.4667	0.126818	0.98233	0.965
	Control group	60	3.00	5.00	8.00	6.4167	0.109678	0.84956	0.722
Valid N (listwise)		60							

Table 7

Mann-Whitney U test for final grade

	N	Mean ± SD	Z	*p*-value (2-tailed)
Experimental group	50	7.4667± 0.98233	-5.526359	0.000000 *
Control group	76	6.4167± 0.84956		

*$p < 0.05$

The results presented in Table 7 (Z = -5526359, $p = 0.000000$) show that there is a significant statistical difference in the achievement (final grade) of students in the experimental group compared to students in the control group. In other words, students who were placed in the modular teaching system increased their digital competence to a much higher level and achieved far better results compared to control group students, who had traditional form of teaching. Based on the data shown in Table 8 we can analyse the final achievements of the experimental group of students according to teaching modules. By analysing average grades we noticed that students achieved best results in Module 3, and worst in Module 6 (see the shaded lines in Table 8).

Table 8

Descriptive statistics for final grade according to modules

Modules	N	Range	Min	Max	Sum	Mean	Std. Error	Std. Deviation	Variance
Module 1. Concepts of information and communication technology	60	4.00	5.00	9.00	436.00	7.2667	.13832	1.07146	1.148
Module 2. Using the computer and managing files	60	5.00	5.00	10.00	430.00	7.1667	.14684	1.13745	1.294
Module 3. Word processing	60	5.00	5.00	10.00	488.00	8.1333	.17542	1.35880	1.846
Module 4. Spreadsheets	60	5.00	5.00	10.00	472.00	7.8667	.16717	1.29493	1.677
Module 5. Using databases	60	5.00	5.00	10.00	468.00	7.8000	.16261	1.25954	1.586
Module 6. Presentation	60	4.00	5.00	9.00	408.00	6.8000	.13191	1.02180	1.044
Module 7. Web browsing and communication	60	5.00	5.00	10.00	448.00	7.4667	.13751	1.06511	1.134
Valid N (listwise)	60								

Discussion and Conclusions

This research proved the assumption that the modular teaching system which was used at the Faculty of Transport and Traffic Engineering in Doboj was more efficient than traditional teaching, which had previously been used. The admission test results showed minimal differences in ICT knowledge. After attending the modular and traditional courses, both groups increased their digital competences. However, after more detailed data analysis of students' achievements (final grade), we concluded that the experimental group showed better progress in raising digital competences compared to the control group.

Improving digital competences of learners in the modular teaching system could literally be reduced to modernization of methods and forms of teaching process, which significantly affects compliance of teaching with life, theory with practice and adjustment of content with possibilities, previous knowledge, needs and interests of learners. This organization system at technical faculties enables faster access to knowledge and information, good course books and teachers, choice of width and depth of course materials as well as speed of acquisition. Also, it enables assessment of acquired knowledge and comparison with previous knowledge, and with knowledge of other learners all over the world. By implementing the assessment system, we control

future steps in the organization of teaching and adapt it to set goals and tasks. By applying the modular teaching system intended for use at technical faculties, we enable learners to acquire knowledge and skills independently and to develop curiosity and desire to learn in order to actively participate in the teaching process and their own intellectual development.

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Obrazovne inovacije u funkciji poboljšanja IKT sposobnosti kod studenata

Sažetak

Informacijske su tehnologije u posljednje vrijeme postale sastavni dio obrazovnog sustava. Primjena suvremenih digitalnih tehnologija u nastavi utjecala je na promjenu metoda poučavanja. Ovo se istraživanje temelji na oblikkovanju modela poučavanja sa svrhom poboljšanja razine studentskih IKT znanja i vještina primjenjivih u području tehničkih znanosti. Cilj je ovoga istraživanja uspostava metodologije za poboljšanje i prilagodbu kurikula kako bi se studentske digitalne kompetencije poboljšale i bile u skladu s europskim standardima i potrebama nastave na tehničkim fakultetima.

Ključne riječi: *digitalne kompetencije; modularni sustav poučavanja; programirano poučavanje; Software za računalno obrazovanje (CES).*