Results of Competence Based Training in the Modules Related to "Algorithms and Data Structures" in the Profession of "Application Programmer"

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Abstract **– The article describes a pedagogical research, conducted to determine the benefits of Competence Based Training (CBT) as part of a more general paradigm for Competence based education (CBE), in the modules related to Algorithms and data structures (ADS) in the profession of "Application programmer (occupation "Application programmer"). For the purposes of the study, CBT was conducted in several groups under the National Program "IT Career Training" (NPITC). A comparison was made with groups from the regular form of training in the same profession, where a traditional approach to education is applied. The results of the study show that the implementation of CBE under the National Program "IT Career Training" provides no worse training than the traditional approach used in vocational schools. Even in the study area of Algorithms and data structures, the experimental group showed significantly better results than the control group, which means achieving a higher level of acquiring knowledge and skills, as well as more successful formation of specific competencies to work with ADS and application of the paradigms FPS (Functional programming style) and OOP (Object-oriented programming).**

Keywords **– Competence Based Education, competencies.**

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1. Introduction

Modern secondary and higher education in Bulgaria face a number of challenges that require new approaches and strategies for its implementation. The Preschool and School Education Act (PSEA) and the Vocational Education Act (VEA) set the ideas of the competence approach in education (CA). This approach is based on the ideas of Robert White [1], who defines competence as the main motive for acquiring knowledge and skills. McClelland [2] uses the term 'competence' as a successful combination, a set of knowledge, skills, attitudes and behaviours of employees to achieve results. Boyatzis [3] proposes a new strategy in the field of human resources management. Raven [4] provides a comprehensive interpretation of competencies as "motivated abilities".

The concepts of the competence approach find a place in the educational system in Bulgaria. One of the main goals set out in the Preschool and School Education Act (PSEA) is the acquisition of competencies necessary for a successful personal and professional realization and active civic life in modern communities. On the basis of the European Qualifications Framework for Lifelong Learning (EQF), the National Qualifications Framework (NQF) has been established in the Preschool and School Education Act (PSEA). In the field of information and communication technologies (ICT), secondary education in Bulgaria aims to develop digital competencies, which are in the Digital Competence Framework for citizens (DigComp 2.1), and in terms of vocational training, the reference frame is the European e-Competence Framework (e-CF) for the ICT professionals.

Representatives of the ICT sector in Bulgaria use similar frameworks (Staribratov, 2020) for the preparation of Strategic Requirements for the reform

of the education system [1], through which to introduce a competence based approach to training in professions related to computer science.The recommendations are accompanied by descriptions of competence models, profiles and roles in the software industry based on the EQF and the Comité Européen de Normalisation Workshop Agreement (CWA 16458: 2012).

The National Agency for Vocational Education and Training (NAVET), together with representatives of the ICT sector and the Ministry of Education, create a State Education Standard (SES) for the occupation of "Application programmer".

The study of the new profession in vocational high schools begins in the school year 2018/2019. Additionally, the profession is studied under the National Program "IT Career Training" (NPITC) in 5 centers in the country [5]. Stepping on a competence based regulatory framework, the question arises about the implementation of an appropriate CBE.

2. The essence of CBE and CBT

The new approach involves student-centered learning. The defining principle is the constructivist one - the learner to be a researcher and to participate in the evaluation of his / her own achievements, as well as to reflexively identify his / her knowledge gaps. Assessment does not only aim to give quantitative estimates, but serves mainly to correct the pedagogical interaction in order to improve learning outcomes. The aim is to form competencies, not just teaching a given subject matter. The training aims to achieve learning outcomes, described as expected demonstrated behaviours in successful performance of the activity.

The competence approach in teaching requires that the syllabi of the curriculum be created in accordance with the principles of CBE and the principles of constructivist theory. A number of authors propose methodologies for creating CBE syllabi, as well as methodological approaches and teaching models. According to Nikolov [6], the methodology should include the following phases: (1) Conceptualization; (2) Planning; (3) Data collection; (4) Data analysis and creation of a catalogue of competences; (5) Development of a syllabus for CBE and (6) Development of applications and a pilot test. When you start to design the training, the goal is to define the competence. In the process of training design, competence behaviours are linked to learning activities. Competence behaviours are used as measurable indicators of learning progress during assessment.

According to O'Sullivan [7], models should include a number of key activities: (1) to understand how students learn; (2) to comply with the principles of learning and teaching; (3) to facilitate learning, not to control it; (4) to model confidence, critical thinking, respect, competence and responsibility; (5) to support knowledge and skill gain and work etiquette, belonging to the areas of training; (6) to encourage and expect responsible students studying behaviour; (7) to provide timely, concrete feedback on the student's progress, starting with the student's self-assessment; (8) to customize teaching according to needs; (9) to increase the range and difficulty of tasks when students show a progress. complexity of implementation as the learner progresses during the program.

CBE focuses on the needs and styles of the student, providing the time the student needs to gain, repeat or make a demonstration of a given type of competency, while supporting the learning process. CBE can be implemented through a variety of educational tools. In this context, syllabi are results-oriented and based on evidence, as the different types of learning strategy must be connected to their field of study. CBE emphasizes on a powerful or rich learning environment that allows students to engage in meaningful learning processes.

According to O'Sullivan [7], Boykova [8] and Mkonongwa [9] the main characteristics of CBE are: (1) Real problem - learners must apply the developed competencies to solve a real problem; (2) Multidisciplinary approach - the competencies are comprehensive (authentic) and as a result the educational approach must also be integrative and comprehensive; (3) Constructive learning – the concept is based on the interaction between students and surroundings, including activities like creating models, production, reporting and etc.; (4) Collaborative learning – this type of learning is related to the search for ways to optimally use the competence of other people in the acquisition and development of their own competencies; (5) Personalized CBE (PCBE) - it is a process of building the learner's personal knowledge and competencies. Information, knowledge and strategies become important for a person only if they become an integral part of his personal set of knowledge and competence. The diversity of the learners' needs, the difficulties that the student encounters, the selection of the most appropriate way of presenting the learning content for the particular student must be taken into account. In this case, a collaboration between students and teachers is needed for determining students' expectations and aims. (6) Explorative training - the student to be in the role of a researcher and discoverer, and the teacher to be a partner, mentor in his path; (7) Reflective Learning - CBE focuses on reflection. Developing skills to identify one's own needs for specific training, ability to build motivation to learn, self-awareness of one's own learning qualities and choosing the optimal approach to learning. It is "learning to learn".

3. What is the Methodological Training Approach According to the ADDIE Model?

This model of training is used throughout the training in the profession of "Application Programmer". The ADDIE (Analize, Design, Develop, Implement, Evaluate) model is applied both in the initial development of the learning content at the syllabus level and in the process of training, when the necessary adaptations of teaching are made in order to facilitate learning and to achieve better results. Passing an iteration of the cycle leads to getting feedback on the student's learning outcomes, both to the teacher and reflexively to the student himself, through the quantitative or qualitative assessment made by the teacher. With each iteration, the student reaches, presumably, a better position to the goal, which is set in the training - the achievement of certain RS.

The training model is presented in Figure 1.

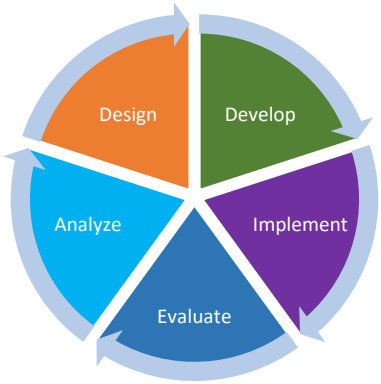

Figure 1. ADDIE model

4. Teaching Tools

To implement the training on the ADDIE model, a system of tasks was used, including tasks for knowledge, skills and competencies, in which each task meets the requirements of a specially developed Framework with the requirements for the types of tasks used in the methodology. In general, the framework imposes requirements, according to Bloom's taxonomy, on the various tasks in terms of the purposes for which they are used and their content.

The ADDIE training methodology is applied both in the initial development of the learning content at the syllabus level and during the training process. The student is at the center of learning, with his cognitive and personality traits, which is why it is often necessary to adapt and personalize, in order to facilitate learning, to achieve better results. The stages of such training are: multiple iterations of: analysis of the needs and capabilities of students (Analyze), planning of learning content (Design), Development of learning content (Development), implementation of training (Implementation), assessment (Evaluation).

5. Purpose of the Study

The study aims to compare the results of the application of two different paradigms in the training on the profession of "Application Programmer" in Bulgaria: CBE in the training of students in the National Program "IT Career Training" (NPITC) and the traditional approach to training applied in vocational high schools, offering training in the same profession. Due to the large amount of material studied, the research focuses on the learning outcomes and the topic is about a basic data structure, such as Dictionary, also known in programming languages as an associative array, associative list, Hash Table and Map.

6. Working Hypothesis

The implementation of CBE under the National Program "IT Career Training" provides no worse training than the traditional approach used in vocational schools. Even in the study area of Algorithms and data structures, the experimental group shows significantly better results than the control group, which means achieving a higher degree of assimilation of knowledge and skills, as well as a more successful formation of specific competencies for working with ADS and application of the FSP (Functional style programming) and OOP (Object oriented programming) paradigms.

7. Learning objectives

The learning objectives are related to the formation and development of professional competencies in the field of Algorithms and data structures, set in the State Education Standards (SES) for the occupation of "Application programmer", part of which are:

- acquiring knowledge and skills for using basic data structures: arrays, lists, dictionaries;
- acquiring skills for detecting and eliminating errors in a program code;
- acquiring skills for independent solving of specific tasks;
- solving practical tasks with dictionaries and nested dictionaries to establish the quality of the acquired competencies.

8. Research Methodology

In the study participated a representative sample of:

- 124 students, who are divided into 2 subsamples of 62 students - IT career and regular form of education - when conducting the test of knowledge and skills.

- 80 students, divided into 2 subsamples of 40 for each of the forms of education in the implementation of practical task 1 and task 2.

The results from the initial test show that all of the participants start the training under the same conditions.

After the training courses in IT career and the standard training in regular form for students 10th-12th grade finished, the final test was done. The hypothesis testing was based on two types of subsamples (Table 1):

- Reference subsample (noIT) – regular form of education. The standard methodology typical of the traditional approach to teaching in vocational high schools, based on contextual learning, is used.
- Experimental subsample (IT) – National Program "IT Career Training". A methodological approach that includes the ADDIE model for CBE is used.

Table 1. Subsampling

Subsample	Students' proportion	Percent (%)
noIT	62	50%
IT	62	50%
Total	124	100%

Students are provided with:

- Knowledge and skills test, including multiple-choice questions and open questions, as well as for code correction;
- Practical tasks 1 and 2 - check the degree of acquired competencies for working with dictionaries and associative arrays. The tasks are based on the same algorithm for solving a problem from different practical areas. Task 2 is done at a later stage. The purpose of the second stage is to assess the durability of knowledge, skills and competencies (one of the characteristics of competence according to Khutorski), as well as the ability to apply knowledge and skills in other practical situations (another characteristic of competence - transferability in a new situation).

9. Criteria and Indicators for Assessment of Test Questions

1. Know the meaning of the term associative array (Dictionary in C #)
2. Understand the different ways of adding an item to a dictionary
3. Understand how the value of an element in a dictionary changes by a given key
4. Can perform operations with a data structures (DS) sorted dictionary
   - Understand the specifics of entering data into the sorted dictionary;
   - Understand how to extract data from a sorted dictionary.
5. Can perform basic dictionary operations
   - Know different ways to add elements;
   - Know how to change a value for a given key;
   - Know how to remove an element with the specified key.
6. Processing of collections with LINQ
   - Know the functionality of lambda functions;
   - Apply the language's built-in tools to arrange collections in a reverse order.
7. Apply built-in language functionalities to work with collections
   - Understand the meaning of Lambda functions;
   - Apply (Knows about) the functions of LINQ for retrieving subsets of collections;
   - Know the built-in functions of the C# language for displaying a collection as a string.
8. Can detect logical errors in a code
   - Know different ways to initialize collections;
   - Be able to sort collections according to a given criterion with a lambda function;
   - Extract subsets of a collection;
   - Can apply aggregate functions;
   - Display the data in an appropriate format.
9. Can integrate LINQ in dictionary processing
   - Apply LINQ to iteration in a collection;
   - Retrieve subsets from a dictionary with the help of LINQ;
   - Convert collections to a list;
   - Use LINQ to retrieve data.
10. Be able to follow the logic of a code, related to dictionary processing with LINQ
    - Know DS (data structure) dictionary;
    - Extract subsets of a dictionary;
    - Apply aggregate functions.

10. Criteria and Indicators for Evaluation of the Tasks

1. Select an appropriate data structure
2. Enter the data correctly in the compound DS (the dictionary of dictionaries)
3. Apply appropriate processing of the selected DS (data structure)
   - sort the internal DS;

- convert the internal collection into a proper DS;
- sort the external DS;
- convert the external collection into a proper DS;

4. Retrieve data properly
   - correctly retrieve the value for each key of the summary DS;
   - correctly retrieve data of the internal DS.

11. Processing the Results of the Final Experiment

Knowledge and Skills Test Results

The table below presents the mean and success rate of academic performance for the independent subsamples.

Table 2. The mean and success rate in subsamples

Subsample	Number	Mean	Success
noIT	62	15.89	68%
IT	62	21.40	98%

The means and the success rates of both subsamples differ with 5.51 and 30% (for successful completion of the test, a score of 12 out of 26 is needed), respectively. To verify if the following results are obtained by the applied teaching approach and instruments or by a chance, statistical tests were used.

For this purpose, checking the both subsamples for normality permits a proper comparative method to be chosen.

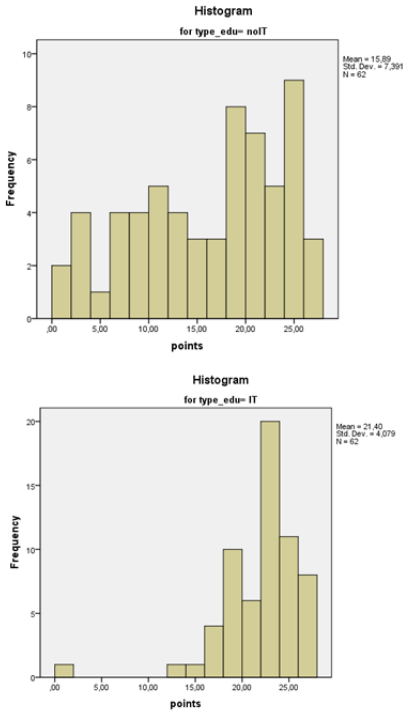

Figure 2. Histogram charts for the reference subsample (noIT) and experimental subsample (IT)

Table 3. Test for normal distribution of subsamples

	type_edu	Shapiro-Wilk		
		Statistic	df	Sig.
result	IT	,813	62	,000
	noIT	,926	62	,001

On the base of the value (<0.05), returned for Sig. (significance level) in Table 3, it can be concluded that the distribution of the subsamples is different from normal distribution.

Consequently, the two subsamples can be compared non-parametrically by choosing such method.

Table 4. Mann-Whitney test

Ranks

	type_edu	N	Mean Rank	Sum of Ranks
result	IT	62	76,19	4724,00
	noIT	62	48,81	3026,00
	Total	124		

Test Statistics[a]

	result
Mann-Whitney U	1073,000
Wilcoxon W	3026,000
Z	-4,257
Asymp. Sig. (2-tailed)	,000

a. Subsampling Variable: type_edu

In this context, the Wilcoxon rank-sum test was chosen which returns a value for Asymp.Sig.(2-tailed) below 0.05 confirming the higher mean and success rate for the IT subsample are not random and result from the applied methodology (Table 4).

Results from the Practical Tasks

The practical tasks aim to establish permanent competencies according to the specified criteria. The obtained results allow to make a comparison between the results of the same subsample, performing both tasks over a certain period of time. The successful fulfillment of the indicated criteria, set in the two tasks, allows to draw a conclusion for successfully acquired competencies.

The means and the success of the two independent subsamples for the separate tasks are presented in Table 5 and Table 6.

Table 5. The mean and success rate in subsamples - task 1

Subsample	Number	Mean	Success
noIT	40	17.00	62.50%
IT	40	24.40	97.50%

Table 6. The mean and success rate in subsamples - task 2

Subsample	Number	Mean	Success
noIT	40	18.83	75.00%
IT	40	24.40	97.50%

The tables show that the average score and the success rate of the experimental group have remained at a high level, which shows a permanent acquisition of knowledge and skills and their transformation into competencies. In the reference subsample we have a slight growth of indicators, which ensures that the acquired knowledge and skills of successful students in this group have formed as competencies. The difference in the average score between the subsamples is significant 5.57, and the percent of successful students differs with 35% in favour of the experimental group.

12. Conclusion and summary

1. 124 students took part in an educational research for testing knowledge and skills and 80 students for performance at time intervals on two similar practical tasks, testing the same competencies;
2. The obtained data were processed with the IBM SPSS program, using the Wilcoxon rank-sum test to reject any randomness in the results;
3. Based on the described actions and obtained results, additional concluding remarks can be made:

    3.1. The assessment of knowledge and skills shows the two subsamples do not differ due to chance and proves the working hypothesis that the implementation of CBE under National Program "IT Career Training" provides no worse training than the traditional approach used in vocational high schools. Even in the studied area of Algorithms and data structures, the experimental subsample shows significantly better results compared to the reference subsample, which means achieving a higher degree of assimilation of knowledge and skills, as well as a more successful formation of specific competencies for working with ADS and application of the FSP and OOP paradigms.

    3.2. The results of the two practical tasks show a permanent acquisition of knowledge and skills and their transformation into competencies, regardless of the applied methodological approach.

The conducted educational research confirms the idea that competence-based learning, as part of the competence-based education, at the center of which is the learner, leads to better learning outcomes. The ADDIE model is suitable for the implementation of CBT and CBE respectively.

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