Scientific Bulletin of Naval Academy

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Available online at www.anmb.ro

Productive strategies for development of specific mathematical competences for numbers and operation with them in the primary school

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Abstract

The application of productive strategies in education in mathematics facilitates development of specific mathematical competences in the Grade 1-4 students regarding natural numbers and operation with them. Subject of this article is presentation of the concepts about: competences, specific objective mathematical competences and the options for their development in and through education in mathematics in Primary School. A methodology system for work both with productive strategies, approaches, methods and with reproductive such strategies was created. This system is currently being applied in the educational process in mathematics. During the experimental work a longitudinal quality and quantity research of the above topics was performed. The conclusions of the research was that as a result of the experimental work the percentage of the students who made mistakes in writing down and comparing natural numbers decreased. The same can be said for the students who made mistakes during the arithmetical operations addition, subtraction, multiplication and division as well as mistakes in finding unknown component in a concrete equation. It was confirmed that as a result of the experimental work the specific mathematical competences related to the area of competency "Numbers" were developed in the primary school students in their completeness.

Key words: specific mathematical competences, productive strategies

1. Introduction

Over the recent years the Bulgarian system of education was subjected to new requirements emanating from the changed economic conditions. The school reform in Grades 1.-4. Was directed towards improvement of the quality of education in compliance with the new reality.

Nowadays is necessary to change the aim of the educational process including knowledge, skills, etc. and direct it to competences, competencies as an ability of the student in the Primary School to act efficiently in various situations including those from the educational subject of mathematics.

The changes are related to the following: the role of the teacher along the educational process in mathematics for Grades 1.-4. which includes organization, choice of a suitable strategy, technology, approaches and methods of education aiming at development of specific mathematical competences from competency cluster "Numbers".

2.Aim, object, subject and aim of the study

Subject of the research work is to systematize and develop basic theoretical concepts for specific competences and based on this to present methodology system of work and to study the level of development those specific competences from competency cluster "Numbers" in and through education in mathematics for Grades 1. – 4.

Object of the research is the educational process in mathematics for Grades 1. – 4.

The research work studied the effect of the combined productive and reproductive strategies used in it as well as their respective approaches and methodsand resulting from the applied newly developed methodology system of work on the process of development of specific competences from competency cluster "Number" in the education in mathematics for Grades 1. – 4.

To achieve the goal of the research work the following tasks were completed:

- Study and theoretical analysis of: research work of foreign and Bulgarian authors related to the competency approach and the competences; theoretical concepts regarding strategies (productive and reproductive), pedagogy technologies and productive methods.
- Study and research of legal documentation, development and systematizing of both specific mathematical competences and the specific interrelation typical for them.
- Study of the main characteristics of the productive strategies and their use in the process of development of technologies and methodology system of work. Study of their application in the education in mathematics with the intention to facilitate the development of specific mathematical competences from competency cluster "Numbers".
- Study the efficiency of the applied productive strategies in the methodology system of work in the educational process in mathematics for Grades 1. – 4. Comparative analysis and assessment of the results from the empiric study, summary, conclusions.

Following criteria were introduced for the purposes of the empiric study: knowledge and skills to read, to compare natural numbers, to recognize Roman numbers and know the decimal place-value system; knowledge and skills to add and subtract natural numbers, to multiply and divide with one-digit and two-digit numbers, to recognize parts of the whole like one-half, one-third, one-fourth and one-tenth., to use the relations between the components of the arithmetic functions for the purposes of finding unknown component.

Over the recent decades the competency approach was widely used in the EU countries, USA, Russia, etc. The foundation of the orientation of the education system towards competences was laid in the 70-s in the United States.

Y. A. Zimnaya analyzed number of research works dedicated to the problems of competences and competency and separated three conditional stages for introduction of competence-based education. The first stage (1960 – 1970) is characterized with introduction of the category "Competence" and creation of pre-conditions for differentiation between competence and competency; The second stage (1970 – 1980) is characterized with the use of the category competence/competency in the theory and the practice of the language education (especially in the foreign language education) as well as in other scientific areas. The third stage started after 1990. [15] During this stage of development of the competence-based education a circle of competences was drawn in number of documents issued by UNESCO, the Council of Europe and the Bulgarian Ministry of Education and Science. These competences were considered as expected result from the education.

As a result of analysis of pedagogy literature it was found out there is a significant number of studies related to the issue of competences. [11], [1], [2], [15], [14], [4], [5] etc.

Identification and conceptual segregation of the understanding for competency and competence is also done by the Russian pedagogy researcher V. A. Houtorskiy. His understanding is that the competence is "an estranged pre-set social requirement (norm) to the education of the student, necessary for his efficient productive activity in certain area". [5]. According to him some competences are more important and more general than others. He believes that following the separation of the education to "general subjective" (for all subjects) and "subjective" (for every separate educational subject) the following hierarchy with "three levels" of competences can be built: "key competences – they are referred to the general (meta-subjective) content of the education. These competences are getting established on educational areas and educational subjects level for each Grade; general subjective competences – they are referred to certain circle of educational subjects and areas of education; subjective competences – this is a special case to the above two levels of competences. They are getting developed and are described within the frame of the educational subjects". [5] The last type of competences are characterized by Delcheva as specific competences.

For example, for the primary school the key educational competences are concretized through specific competences on the level of educational areas and educational subjects studied in Grades 1. – 4.

For the purposes of the research work this hierarchy and levels of competences was acknowledged. Particular attention was put on the specific (subjective) mathematical competences. During the education in mathematics for Grades 1.-4 the following knowledge, skills and competences from competency cluster "Numbers" is getting developed in the students: knowledge and skills to read, to compare natural numbers, to recognize Roman numbers and know the decimal place-value system; knowledge and skills to add and subtract natural numbers, to multiply and divide with one-digit and

two-digit numbers, to use the relations between the components of the arithmetic functions for the purposes of finding unknown component.

The research performed detailed analysis of the following: requirements of the educational content in mathematics for primary school and the educational program in mathematics for Grades 1. – 4. Based on this following was developed and introduces: specific mathematical competences from competency cluster "Numbers" and their specific interrelations. Further this research presents part of the interconnections developed during the process of experimental work between:

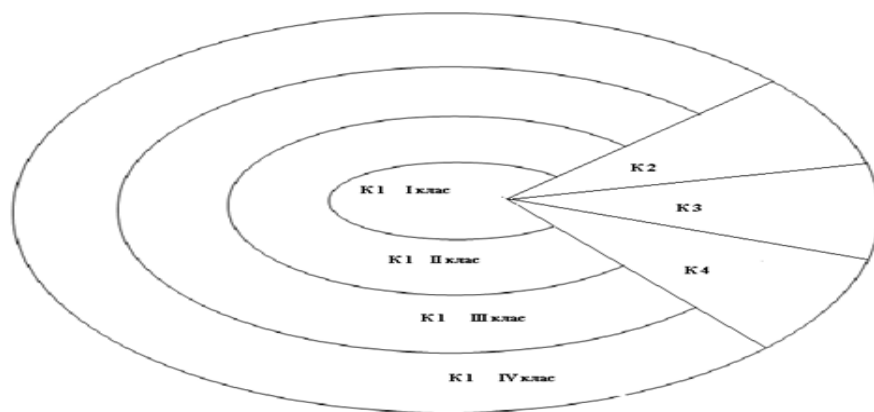- Specific mathematical competences from different clusters of mathematical competency

Figure 1. Interrelation between the specific mathematical competences from competency clusters „Numbers", „Plane figures", „Measuring", „Modeling"

The above figure demonstrates the interrelations between competency clusters "Numbers" (K1), "Plane figures" (K2), "Measuring" (K3) and "Modelling" (K4) which are based on the spiral principle meaning that the educational content is studied in concentric "shapes" located ascendingly in three-dimensional space (Madzarov) and on the principle of integrity meaning that arithmetical knowledge and skills are getting acquired together with those from the area of geometry and algebra where leading ones are the arithmetic knowledge and skills.

- Specific mathematical competences and basic terminology from competency cluster "Numbers" in the educational content in mathematics for Grades 1.-4.
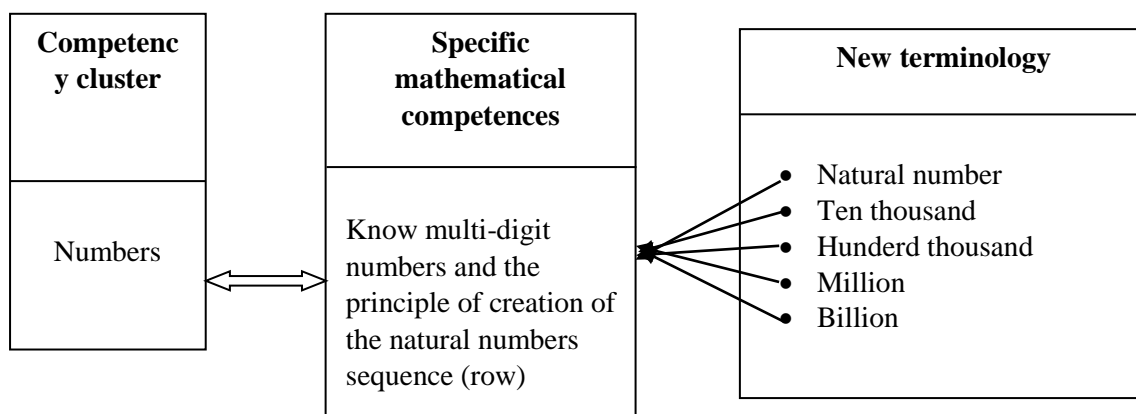

Figure 2. Interrelations between specific mathematical competences from competency cluster "Numbers" and some new terminology

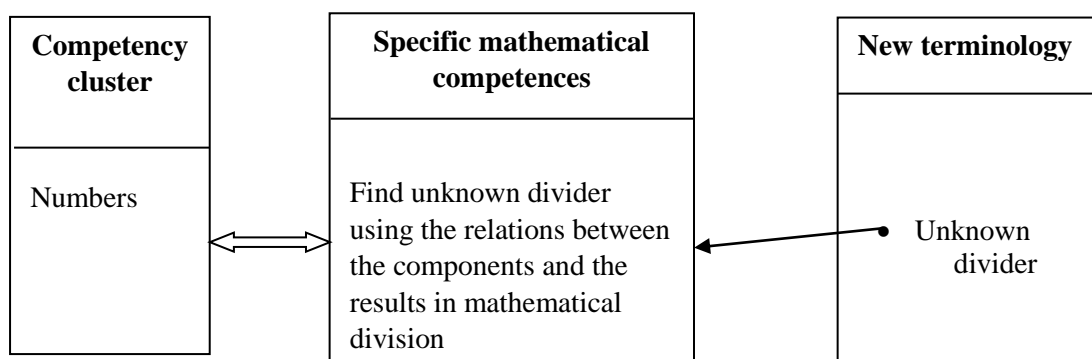| Competency cluster	Specific mathematical competences	New terminology
Numbers	Find unknown divider using the relations between the components and the results in mathematical division	• Unknown divider

Figure 3. Interrelations between specific mathematical competences from competency cluster "Numbers" and some new terminology

The newly developed methodology system of work combined productive strategies, approaches and methods with reproductive ones. The system is systematically applied during mathematical classes from the compulsory and the optional educational programs.

Efficient didactical approaches of education are successfully used in the UK, France and the US where priority is given to active studying through "discovering" over the educational process. Their application in the education in mathematics is determined from one side by the abstract nature of the educational content in mathematics for Grades 1.-4, by the terminology for natural number, by the studied parameters and by the knowledge in geometry and from the other side by the concrete visual thinking of the young students.

Based on the research work of Giordan, the classification of the general methods of education (reproductive and productive) introduced by I. Lerner and the two approaches for education (reproductive and productive) it is possible to create two types of strategies – reproductive and productive.

After studying the existing research works related to productivity, productive thinking and productive activities of the students, it was found out that there are number of publications on the issue. [12], [13], [7] etc. The use of productive strategies in the education in mathematics for Grades 1.-4 is directed to creation of suitable pedagogy environment for efficient activities related to generation of ideas, application of solutions, research work, proving, planning and assessment by the students over the course of mathematical task solving. The most distinguishing feature is the transfer of the acquired knowledge, skills and habits by the students during for solving mathematical tasks in new situations or "in a familiar situation to find new, knowledge, new rules for action (to construct the algorithm by themselves). However, this goes not exclude action by sample or pre-set algorithm." [7]

There are two types of productive strategies which are applied in the research work for work on project or on a specific task/topic: problem-productive strategy and productive strategy. [12] The mathematical tasks used in the methodology system of work are structured in series of tasks and represent the main tool for development of specific mathematical competences. They include mathematical tasks which form different elements of the specific mathematical competences from competency cluster "Numbers". Also, they are complimentary to each other and create complex repeating situation. [8]

3.Results

Over the period between 2004 and 2012 the author performed a study related to development of specific mathematical competences from competency cluster "Numbers" in the education in mathematics for Grades 1.-4. The study involved two school classes with statistically equal levels of educational achievements. One of the classes was the experimental one where the new methodology system of work was applied. The other class of students was the referent one where the traditional methodology of work was applied. [10]

The diagnostic tool was developed after studying and analyzing the international projects TIMSS, PIRLS and PISA from one side, and from the other – after analyzing the options for tests for external assessment of the educational achievements in mathematics of Grade 4 students as well as the

requirements for compliance with the Bulgarian state provisions for education in mathematics for Grades 1. – 4. Two tests were used in the empiric study: one to determine the entry diagnostic and the second – to determine the exit diagnostic of the knowledge, skills and competences of the students in competency cluster "Numbers". The research work studied the objectiveness, the validity and the reliability of the tests as well as the level of difficulty and the segregation strength of the mathematical tasks included in them.

The results of the tests were analyzed including performance of comparative analysis. The results of the comparative analysis of the entry and the exit diagnostic are presented in the below Graphs: knowledge and skills for: knowledge and skills to read, to compare natural numbers, to recognize Roman numbers and know the decimal place-value system; knowledge and skills to add and subtract natural numbers, to multiply and divide with one-digit and two-digit numbers, to recognize parts of a whole amount like one-half, one-third, one-fourth and one-tenth parts, to use the relations between the components of the arithmetic functions for the purposes of finding unknown component.
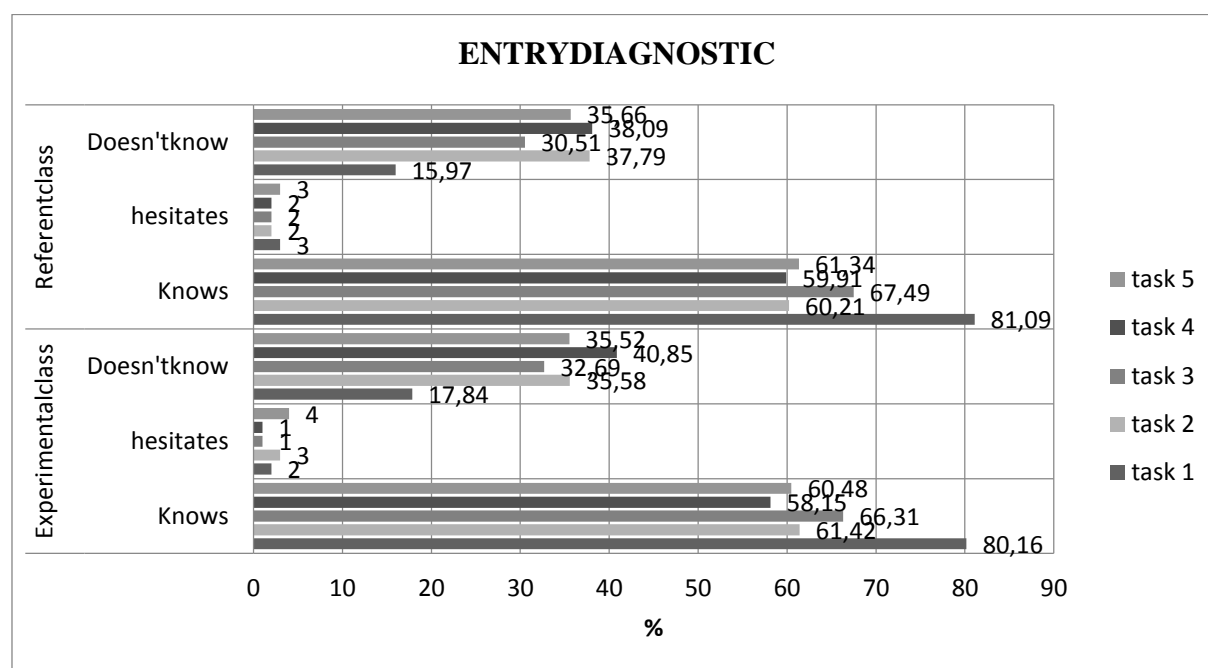

Figure 4. Results from the entry diagnostic of the experimental and the referent classes
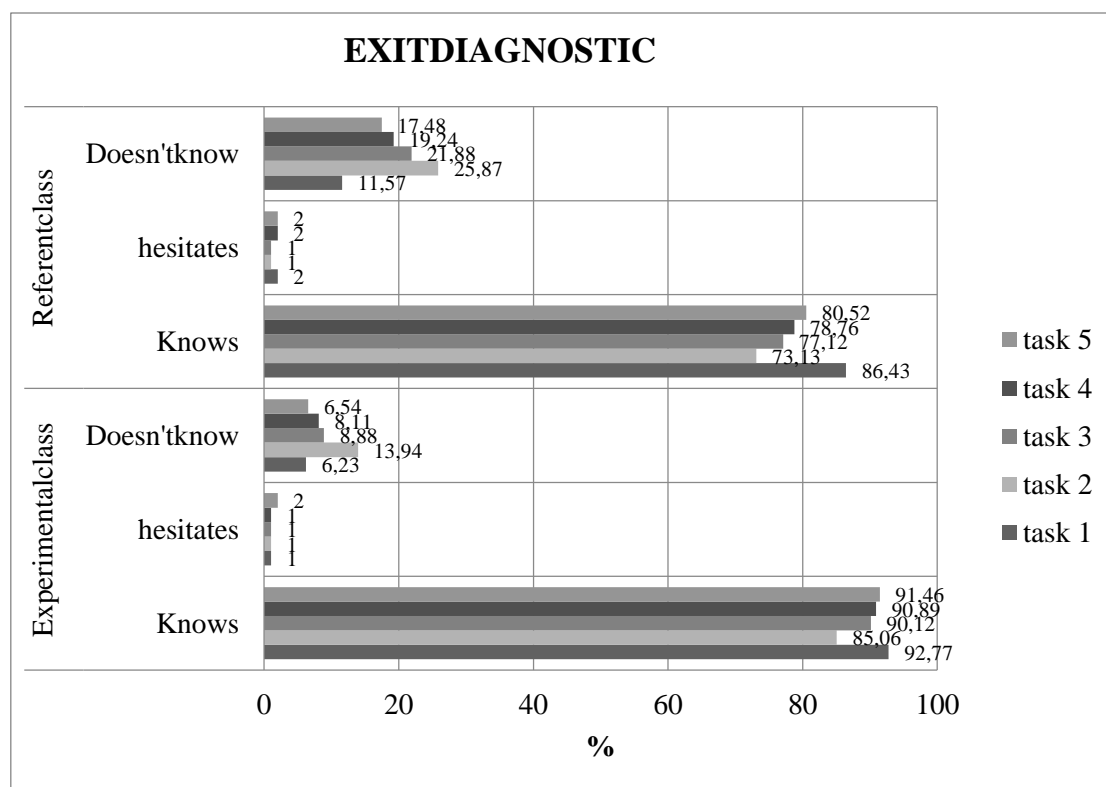
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Figure 5. Results from the exit diagnostic of the experimental and the referent classes

The results from the entry diagnostic demonstrated that there is no statistically significant difference between the relative groups of students from the experimental and the referent class subjected to the research in respect of their knowledge, skills and competences.

As a result of the experimental work it was found out that in the exit diagnostic there is significant difference between the results of the experimental and the referent class. 6,3 % of the students from the experimental class made mistakes in reading, writing, comparing of natural numbers, recognition of the Roman numbers and recognition of the decimal place-value system. This percentage in the referent class is 11,57%. The percentage of students who make mistakes in addition and subtraction of natural numbers decreased down to 13,94% for the students from the experimental class and down to 25,87% for the students from the referent class. The level of knowledge, skills and specific mathematical competences of students who correctly multiply and divide with one-digit and two-digit numbers increased from 66, 31% to 90,12 % for the students from the experimental class and from 67,49% to 77,12% for the students from the referent class. The students who fail to recognize parts of a whole amount like one-half, one-third, one-fourth and one-tenth represented 8,11% from the experimental class and 19, 24% from the referent class. The percentage of students who correctly found unknown component using the relations between the components of the arithmetic functions increased from 13,21% to 30,98% for the students from the experimental class and from 9,14% to 19,18% for the students from the referent class. The difference in the results was proved to be statistically significant.

4.Conclusions

Based on the results received from the research work following conclusions can be made: owing to the applied new methodology system of work, the students from the experimental class developed higher level of knowledge, skills and specific mathematical competences from competency cluster "Numbers" in comparison with those developed by the students from the referent class.

As a result of the identification of the specific mathematical competences from competency cluster "Numbers" for the educational content for Grades 1. – 4. following was achieved: clear idea regarding the starting point of the methodology work of the teacher aiming at development of a concrete competence. One can see the directions which require specific methodology activity for development

6

of competences and competencies in the students. Interrelations and influence of the development of a concrete competence on another one are clearly visible.

Application of productive strategies in the education in mathematics for Primary School established education that was oriented towards the students and developed the skills of the students to: define problems, to look for and find different ways solving of a mathematical task, to determine the most rational way for solving of a given mathematical task. Additionally, the application of productive strategies facilitates the process of development of mathematical competencies, specific and key competences in the primary school students.

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