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# CHARACTERISTICS OF KNOWLEDGE INTERCONNECTEDNESS IN TEACHING *

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**Abstract**. *The subject of the paper presents the basic characteristics, forms and levels of knowledge interconnectedness in teaching, especially in mathematics and biology teaching. The analysis was realized by considering the basic theoretical views in this field, as well as by establishing features and levels of knowledge interconnectedness in the context of teaching programs, textbooks and teaching process, and students. Some theoretical assumptions are based on the analysis of theoretical views of the problem of knowledge interconnecting in teaching. It was established that traditional, empirical conception of the process of knowledge attainment, connecting knowledge and knowledge systematization in teaching was mostly presented in didactics and methodologies of particular teaching subjects. Within the framework of the theory of developmental teaching, established by Russian psychologist Davydov and the followers, there is concept of "knowledge systematism", as one of the main concepts which belongs to the conception of teaching activity.*

**Key words**: *teaching contents, knowledge attainment process, knowledge interconnectedness, knowledge system.*

In the present circumstances of tempestuous development of new technologies, the increasing significance is attached to the contents of education of each person, especially to that aspect of contents of education represented by teaching in an institutionalized system of forms of education. Contents of education are gaining importance because of the fact that applying new scientific discoveries requires not only the increasing number of high-rank experts in some fields of work, but it is also necessary for contemporary man to acquire some basic knowledge and develop adequate abilities and skills to enable him to adapt to crucial circumstances and requests to apply new knowledge and new technologies. And, here we are approaching the indexes of strong importance of some intellectual abilities development, es-

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pecially in the field related to development of theoretical thinking operations, as well as the development of knowledge system and system of theoretical-scientific concepts, those directly connected by the development of theoretical thinking operations.

Each person possesses a definite set of knowledge, which may be termed a personal fund of knowledge, or a set of knowledge elements which may differ in scope, contents, depth and quality, as the basic characteristics of personal knowledge. From one case to another, this scope exists from a level of group of chaotic knowledge elements, individual, separated, disorganized and mutually non-interconnected. Those may be knowledge elements about secondary, unessential characteristics of objects, phenomena and processes of the real world. And it may also exist at the level of well-organized and mutually interconnected knowledge elements. When we talk about well-organized and interconnected knowledge in some person, we unavoidably approach the key concept which mirrors the internal characteristic of the nature of knowledge that some person possesses. One of the crucial, internal characteristics of organized and logically consistent knowledge system is represented by *knowledge interconnectedness* which refers to the existence of definite connections and relations between the elements of personal knowledge.

Instead of accumulating a great quantity of knowledge about individual, separated, often useless and mutually non-connected facts, a characteristic outcome of teaching process carried out in traditionally conceptualized teaching, each person should form a consistent system of *mutually connected knowledge and concepts*. Instead of a great quantity of single and non-connected knowledge, the system of interconnected knowledge should enable optimal everyday and work adaptation of individuals, in the sense of the existence of stable foundation for solving everyday immediate problems in situations where direct or indirect applying of knowledge is requested. In the same way, complete and stable knowledge system should enable further development, in the sense of thinking abilities and skills development, and intellectual development, in general. It should be also the means of extending and strengthening the present base of knowledge and concepts, which may be a constituent part of the present knowledge system. Exactly, development process represents one of the essential characteristics of such kind of knowledge system in regard to personal opportunity for strengthening and enriching the existing base of interconnected knowledge and the system of concepts, first of all, in a qualitative respect.

## CHARACTERISTICS OF KNOWLEDGE INTERCONNECTEDNESS

When considering the problem of connectedness of theoretical-scientific knowledge and concepts within the framework of some scientific areas, a key question is imposed that an appropriate answer should be given to: what characteristics of theoretical-scientific knowledge and concepts enable their presence in the framework of complete and logically consistent knowledge system in some field of science? Or, in other words, what kind of base connects elements of scientific knowledge, what is the nature and main characteristics of connections and relations between elements of knowledge in science, what is the nature of connections and relations between the elements of knowledge in different fields of science etc? The answers to these questions provide more profound, many-sided and complete understanding of similarities and dissimilarities in the depth of knowledge interconnectedness in science, on one side, and in teaching contents, on the other side.

Basic differences between knowledge in science and teaching contents of school subjects mirror themselves across three key elements. The first element of differences between them is demonstrated through the fact that science has some circle of its questions, facts, data, concepts, terms, etc. From this abundance of scientific building material, for the teaching contents are chosen those kinds of knowledge and concepts which are sufficient for accomplishing educational goals and assignments at some level of education. The second element of this difference is evident in the fact that science and school subjects differ in the *depth of knowledge attainment* of posed problems. While in science there is the process of discovering and highlighting the phenomena and their internal laws in their whole complexity and depth, in the framework of the school subject, the "alphabet of science" is given, elements that lead to understanding the main phenomena in physical nature and society. The third element of the difference can be seen in the *system of presentation*. In the framework of science there is a strict scientific-logical system in the organization of material, while in teaching we can encounter another kind of system, the one which can be usually defined as *a didactic system*, concerning the fact that teaching contents have to be given in some system according to their internal logical connectedness and, gradually, according to the level of difficulty. The system that constitutes knowledge in some school subject contents is adapted to educational goals and assignments in the field of knowledge attainment in teaching. It is *the system of didactically designed knowledge*, according to the nature of knowledge attainment process at some age level.

The process of acquiring knowledge in science is targeted at discovering some new objective laws, typical of this process, laws related to all phenomena of the reality. In the teaching process students are to get acquainted with well-known facts, rules and laws chosen in the teaching process from the standpoint of necessity for its realization. Acquiring knowledge in science is the process which never flows rectilinearly and where new knowledge is presented in an objective way. In teaching process, on the other hand, by appropriate teacher's managing, it is possible to provide students with bases of necessary knowledge and elements of mankind's culture in a relatively short period of time. In other words, *students in teaching process acquire something that is already well-known*. There are some differences in the scope of knowledge that must be attained. In order to successfully discover something new and unknown, scientists are often in the situation in the research process that they must acquire and analyze a great volume of available knowledge, concepts and facts. In teaching process, however, some activities emerge that do not exist in the process of acquiring knowledge in science, or they exist in some other ways, with other characteristics. Those specific didactic elements consist of developing abilities and skills, strengthening of knowledge, forming of skills and habits, controlling and assessing student success and failure, etc.

*"Systematization" and "systematism" in teaching*. It was considered that one of the bases of didactic principle of systematization, especially in the area of its application referring to knowledge presented in contents of teaching, is mirrored by "knowledge system in science", in science in general, or in particular fields of science. When someone talks about systematization in teaching, it means then that crucial emerging point of this characteristic of teaching is represented by the model of knowledge system that exists in science. However, *the model of knowledge system which exists in science is not immediately applied in the field of teaching; especially it is not possible to transfer this model into traditionally conceived concept of "systematization of teaching"*. The main reason is portrayed by some specifics of knowledge discovery and knowledge attainment processes, which are not the same in regard to the process of knowledge discovery in science.

In the theory of developmental teaching which belongs to Vygotsky's scientific school for its basic scientific assumptions, *systematism of teaching* and *knowledge system in teaching* are discussed. These concepts are differently defined; their definitions were produced in traditional, empirical conception of systematization of knowledge in contents of teaching. According to this theory, the main element of the development of knowledge system in teaching may be found in order of knowledge attainment process in teaching, which goes from attaining general (sometimes not common) and abstract knowledge, to attaining knowledge about particular and individual characteristics of knowledge attainment subject-matter (Эльконин и Давыдов, 1966; Давыдов, 1972, 1986, 1996). On this basis, there is a model of establishing connections and relations between general, particular and single knowledge elements. This model of interconnecting knowledge implies that starting point of knowledge attainment about some object should be represented by discovering some internal, essential, initial and general relation, the "cell" of the system, whose concept makes initial abstraction. The concept of "initial relation" (of the "cell") expresses *concrete general knowledge*, but in the beginning it is abstract in its nature, because it is undeveloped, undivided, and unconnected with particular and individual characteristics of studied object system. The model of knowledge interconnectedness is accomplished in the process of knowledge attainment which possesses internal direction of understanding, from abstract to concrete knowledge, in regard to the depth of understanding. It is one of its crucial characteristics. In this sense, the organized teaching contents have to have the *principle of systematism* present as their main feature, which essentially differs compared to the principle of systematization in traditionally based didactics.

The contents of knowledge and concepts in teaching program should be organized according to the essential scientific standpoints of contemporary didactics, which means that the contents of knowledge and concepts in teaching programs, textbooks and teaching process should possess a set of interconnectedness which is defined as *knowledge systematism*, as an internal characteristic of knowledge system. This is the way how to overcome key shortages of traditional concept of "systematization of knowledge" in teaching. It may enable students to attain knowledge and concepts as a system and then knowledge they possess may have characteristics of a complete knowledge system.

## DOMAINS OF KNOWLEDGE INTERCONNECTEDNESS

Knowledge that students acquire in teaching represents knowledge which is, in some way, didactic and methodologically formed, transformed and adapted to the necessities of knowledge attainment process in teaching. This knowledge, with its characteristics, differs from the knowledge in science. The nature of these differences depends on theoretical conception of teaching, which is the basis for choosing teaching contents in the process of teaching program design. Didactic and methodological designing and forming of knowledge in the framework of teaching programs, textbooks and teaching process includes the necessity for preparing knowledge and concepts in an adequate way for the process of discovering and knowledge attainment in teaching (Matusov, 2001). It has to be done respecting the fact that there are some specifics of knowledge discovery process and learning in teaching, referring to knowledge discovery in the field of science. These kinds of didactic and methodological design of knowledge and concepts in teaching are necessary for several reasons, due to many factors of teaching unavoidably causing it.

The knowledge and concepts in teaching, in the process of their attainment, are connected, "brought to connection", "systematized", in regard to the connection in system on the basis of general suggestions given in instructions for program realization as part of teaching program document. These general suggestions make the starting point for realizing internal subject-matter correlation of teaching material, which is particularly accomplished in the framework of chosen teaching contents with regard to knowledge and concepts within each school subject. The model of knowledge interconnectedness, adequate for the similar model, designed and proclaimed in some way in the teaching program document, is incorporated into the structure of textbook for separate school subjects. In the contents of textbooks, concerning their structure of chosen knowledge and concepts, there is some level of connecting knowledge and concepts. To make the process of knowledge attainment more efficient as well as to better connect it in students' minds, an explicitly formulated goal should help form "knowledge system" in students. In the process of knowledge attainment in teaching, knowledge and concepts become connected throughout the process of their discovery and attaining. Depending on the basic standpoints and attitudes of initial conception of teaching, there are immediately formulated nature and essential characteristics of knowledge and concepts chosen in teaching programs and textbooks. This nature and characteristics determine how the process of knowledge attainment will be carried out in teaching. Consequently, there are three segments on the line of dependence and conditioning, when it comes to knowledge attainment and knowledge connecting in teaching. The first segment is represented by *the theoretical conception of teaching*, the second comprises *teaching program and textbook*, and the third consists of *carrying out the teaching process*. Through these three segments, essential for realizing the teaching process, inter-subjects' correlation of teaching material and interconnecting of knowledge is defined and made possible. There is a system of knowledge and concepts in some fields of science, as something preliminary in relation to teaching program and its realization, which is transformed in some way into teaching contents.

*Knowledge interconnectedness in mathematics teaching*. Connections and relations between different mathematical knowledge and concepts, as well as between different mathematics areas, due to their logical basis, represent something more, deeper and more stable, compared to connectedness of concepts, laws, rules and other forms of knowledge which exist in other scientific fields and disciplines. Forms of knowledge in the science of mathematics are integral part of complete and logically consistent system, of stable structure, which is more stable and more logically consistent than a system of knowledge in any other field of science. Based on these arguments, it may be concluded that the system of mathematical knowledge and concepts undoubtedly mirror an exemplary model, *an ideal system of knowledge* in science. All particular scientific disciplines are tending to such paradigmatic model of knowledge system, in the process of their constituting, organizing and reorganizing of their knowledge fund, and of belonging to the theoretical systems and subsystems of knowledge.

At the beginning of mathematics teaching in primary school, as well as in theoretical conceptions of concept development presented in mathematics teaching methodology textbooks, the presence of traditional empirical conception of concept development and development of thinking operations in teaching can be observed. As a consequence of theoretical conception that mathematics teaching concept is based on, it is discussed in mathematics teaching methodology (Cvetković, 1981) that the origin and genesis of the concept of "number" contents and its internal objective base were not explored and dis-

covered. By withholding students at this level of familiarizing with the characteristics of number at the beginning of mathematics learning prevents them from getting a chance to get to know the essence of mathematical objects, from the starting point of approaching the world of mathematics. This kind of essence may be more recognizable by the properly chosen teaching contents, compared to knowing objects in other school subjects.

On the basis of previously examined standpoints, it may be concluded that one of the key aims of mathematics teaching should be represented by forming the *system of mathematics knowledge and concepts*. Davydov was of the opinion that constitution of mathematics teaching, as a complete teaching subject, is a very complex aim which requires common efforts not only of mathematicians, but of experts in other scientific disciplines, such as psychologists, pedagogues and logicians. The important point of these common efforts should be finished by the separation of some mathematics concepts in the process of conceptualizing and designing of teaching program. It is needed to start teaching mathematics using these concepts in the lower grades of primary school. Basic scientific concepts, each in the framework of the belonging areas, according to El'konin and Davydov (1966), make up the basis for organizing each school subject's program, and these mathematics scientific concepts are fundamental for mathematics teaching. Scientific source concepts in mathematics teaching affect general orientation in mathematics reality, which can essentially influence further progress in this field of knowledge attainment. The general orientation in the framework of some teaching subject is made just by the source concepts from a referent field, and is an important factor of forming knowledge system in the knowledge attainment field in teaching.

*Knowledge interconnectedness in biology teaching*. Apart from influence in the process of developing general culture with students, it can be seen that biology teaching has great importance in primary school for enabling students to form interconnected knowledge and concepts about living world, its essential values and ways of its protection and improving. Teaching contents in biology as a school subject should enable students to form the *system of biological knowledge and concepts* that will represent, besides general educational values for students, a stable basis for further education in secondary school, not only in the field of biology teaching.

Also, one of the important aims of biology teaching is personified in enabling student *to develop biological thinking*, ways of thinking which should be closer to the theoretical-scientific thinking in biology as a science, the kind of thinking which exists in the system of biological knowledge and concepts. This represents one of the key demands which is put into biology teaching, considering educational importance and role which biological thinking has for each person. Biological thinking can be developed in the way to enable students in the teaching process to discover internal characteristics of living beings, how they function as living organisms, and to discover the network of causal relations which exist in the living world. In other words, if teaching contents make it possible for students, independently or with teacher's help, to discover and attain theoretical-scientific biological concepts, in such situation the development of theoretical-scientific thinking and also the development of theoretical-scientific approach to the living world will be enabled.

Through considerations of essential differences which can be observed between contents of empirical and theoretical-scientific knowledge, it is emphasized that only theoretical-scientific knowledge becomes a constituent part of broader or narrower knowledge system. Also, when the same topic of biological concepts is discussed, the same rule can be applied: one biological concept represents in itself a knowledge system if its contents

are made by theoretical-scientific elements. From these assumptions, it can be concluded that *empirical knowledge about living beings and their mutual connections and relations cannot be a part of a complete and logically consistent knowledge system* across several concepts or in some knowledge area.

The process of connecting previously acquired knowledge to newly attained knowledge could play an important role in the process of forming the system of biological knowledge and concepts. This could be possible to a high degree if students can be enabled to form logically consistent knowledge system in teaching. In that case, biological knowledge and concepts are immediately involved into the stable base of knowledge. The contents of students' knowledge system can be developed only by the genuine theoretical-scientific concepts in the field of biology, and at the same time students can possess *operations of theoretical-scientific thinking* in regard to *biological way of thinking*. Each of these facts is based upon the system of scientific biological concepts, as a part of biology teaching contents.

*The model of knowledge interconnecting process in teaching*. There are some immediate opportunities to improve knowledge attainment process in mathematics and biology teaching. It is possible to improve knowledge attainment process by introducing into teaching contents such kind of basic concepts that enables students to connect their knowledge and concepts into the entire system. For this purpose, some crucial concepts in mathematics and biological science are of essential importance for initializing and advancing such kind of conceptual system. It is necessary, in order to make teaching process more efficient in general, through enabling students to achieve better and deeper understanding of internal properties, connections and relations to which contents of the basic concepts refer.

In the field of mathematics, the concept of "number" should be introduced properly, as the fundamental mathematical concept, important for understanding all basic mathematical concepts and existent system of concepts that appears in mathematics teaching. In order to form and to advance the sourcing system of mathematical concepts in students in the beginning grades of primary school, it is important to enable students to *discover genuine nature and real subject basis* of this concept. In traditional mathematics teaching this concept has been taught in one inductive way, by choosing of several examples which immediately illustrate the obvious value of used things. For instance, "number five" is illustrated by the set of five balls, five dices, five apples, etc. However, this method doesn't enable students to discover internal essence of number, which is represented by *relation between sizes*. Enabling students in the first grade of primary school mathematics to discover this internal abstract relation can be achieved by choosing proper mathematics contents, through which the central role has to be devoted to students activities targeted to discovering the internal essence of the subject matter.

In the field of biology, one of the basic scientific concepts is the concept of "cell". The importance of this concept in biological science is indisputable and it may be a real epistemological point of forming and advancing the system of biological concepts in biology teaching. Some crucial characteristics of cell are taught and learned in biology teaching. The concept of "cell" is taught in the biology teaching program for the fifth grade in the Serbian primary school, and also the concept of "human cell" is taught in the eighth grade. One of the shortcomings in the process of the concept of "cell" formation is represented by the fact that crucial elements, functions and characteristics of cell are not discovered through the system of their mutual interconnectedness. Cell is a kind of a

complex system itself, with numerous connections and relations inside and in relation to the surroundings of cell, regarding different kinds of other cells and tissues. Upon these reasons, the scientific biological concept of "cell" represents an appropriate opportunity for creating specific polygon for initializing and advancing the broader system of biological concepts, mutually interconnected, in the biology teaching program.

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These are some essential characteristics of the level and the quality of knowledge interconnectedness, which could be observed in the contents of teaching and in the process of knowledge attainment in teaching. As we could see, one of the crucial, internal characteristics of organized and logically consistent knowledge system is represented by *knowledge interconnectedness* which refers to the existence of definite connections and relations between the elements of personal knowledge.

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## KARAKTERISTIKE POVEZANOSTI ZNANJA U NASTAVI

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*Temu rada predstavlja utvrđivanje osnovnih karakteristika, oblika i nivoa povezanosti znanja u nastavi, posebno u nastavi matematike i biologije. Analiza je sprovedena razmatranjem teorijskih stanovišta u ovoj oblasti, kao i utvrđivanjem svojstava i nivoa povezanosti znanja u oblasti nastavnog programa, udžbenika i nastavnog procesa, kao i svojstava povezanosti znanja kod učenika. Određeni teorijski stavovi zasnovani su na analizi teorijskih stanovišta o problemu povezanosti znanja u nastavi. Utvrđeno je da je u udžbenicima didaktike i metodika posebnih nastavnih predmeta uglavnom zastupljena tradicionalna, empiristička koncepcija procesa saznavanja, povezivanja i sistematizacije znanja u nastavi. U okviru teorije razvijajuće nastave, čiji rodonačelnik je ruski psiholog Davidov sa sledbenicima, javlja se pojam "sistemnost znanja", kao jedan od ključnih pojmova koji pripada koncepciji nastavne delatnosti.*

Ključne reči: *sadržaj nastave, proces saznavanja, povezanost znanja, sistem znanja*