EDUCATIONAL CYBERNETICS OR DIDACTICS APPROACH TO “ECONOMY” OF HUMAN THINKING

Martin Bílek, Pavel Cyrus, Ivana Šimonová
University of Hradec Králové, Hradec Králové, Czech Republic
E-mail: martin.bilek@uhk.cz, pavel.cyrus@uhk.cz, ivana.simonova@uhk.cz

Abstract

The paper describes starting point of so called ”Educational Informatics“ as one of the Educational Cybernetics approaches, and example of research results of theory called as „human thinking economy“ application in the field of science and technical education is provided.
Educational informatics is based on so-called educational theory of signs (educational semiotics) developed by M. Lansky which provides great support to the process setting the basis of branch didactics in learner’s cognitive capacity. This approach contents the psycho-structural model of processing information explaining the route of information which is to be processed. It starts with registering it by sense organs (sensory perception), followed by aware perception (apperception) and operating it, i.e. the entire processing the information including storing it in the memory. Within this process various functions are activated, both when the memory stores (associates) the information and effectors (performing organs) are activated. This psycho-structural model synthesizes both behavioural approach (stimulus - “black box” - reaction) and the humanistic psychology approach based on the introspective analysis. A similar model was provided for the chemistry didactics by Johnstone, too. This psycho-structural model also distinguishes certain cornerstones (i.e. model of operations) of human perception and learning, i.e. stimuli – perception filter – working space within the memory (operational memory) – long-term memory which influences the accommodator (adaptor, i.e. the apparatus for directing attention or reduction the apperception). It differs from cybernetic pedagogy as it does not apply the “hard“ quantitative approach to expressing the content of single parts of the psycho-structural model (in bits) but divides the learning content into several mastered parts (operations) called “pieces“ which the learner must run in the operational memory. This method is called “chunking“, i.e. composing, stratifying, layering information in the memory) and was applying in our research their selected results are presented in the second part of the paper.
The research project results were based on analyse of teacher’s predictive evaluation of items in didactic test. Results of a comparative study of reception of pictures in the test items by so called experts (having a certain level of knowledge of the presented subject matter, i.e. teachers) and so called non-specialists (who have minimum knowledge in the area learned, i.e. learners) are added. In concerned research were analyzed the prognosis of chemistry teaching students (experts) in learners succeeding in the didactic test items with or without picture parts. Results show that future teachers overestimate the role of picture materials on positive responses of learners in didactics test.
Key words: *educational informatics, cybernetic approach in branch didactics, science and technical education, teacher’s predictive task evaluation*.

Introduction

The branch didactics or subject methodologies are understood as disciplines dealing with the process of delivering and intermediating results and methods of certain branches (learning subjects) into the social awareness (adapted according to Fenclová (1982). These approaches include a wide spectrum of scientific views, from the idiographic paradigms to those of

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nomothetic sciences, from so called substantive paradigms to those of informatics sciences (Frank, 1996) etc. One of the approaches deals with using the basis of the so called educational informatics which is defined as the intersection of educational sciences and cybernetics. In the second half of the 20th century several disciplines on the basis of educational cybernetics were outlined, the widely known are the cybernetic pedagogy by H. Frank, educational informatics by M. Lansky, systemic didactics by H. Riedel and information didactics by K. Weltner (in Frank, 1996). In this paper we would like to discuss the contribution the educational cybernetics to the field of chemistry (science and technical) didactics with the use of the theory of signs (semiotics) and models of human perception and information processing.

On the "Economy" of Human Thinking

"Efforts towards quantification of the learning content result in the introduction of the term ´subjective information of text´. It is grounded on the information of super-signs which are created by clusters of elementary characters. The basic idea of the dynamic approach is that the super-signs in the text multiply the basic alphabet signs, which consequently decreases the frequency of elements, and thus it increases the information led by them in general. This process is partly compensated by the decrease of information as the result of increase in the frequency of super-signs, i.e. the total (subjective) information never increases but it rather decreases. Thus the human mind saves efforts by constructing the super-signs." This is the core characteristics of the so called educational theory of signs (educational semiotics) by M. Lansky (2000) which provides great support to the process setting the basis of branch didactics in learner's cognitive capacity.

The "human beings´ activities" as the psychological term expresses the subject of specific characteristics to be the originator, aiming at a certain objective, making volitional efforts and being influenced by social context (Průcha, Walterová & Mareš, 1995). If we discus the degree of human activity in the decision-making process and searching for solution within the running and learning a certain activity, two utmost approaches are distinguished (Holý, 1993):

a) the production process, when new programmes of activities are formed and relations between A and B are independent, i.e. the B may but need not follow the A,
b) the algorithmic activity which is characterized by strict keeping the rules of moving from A to B.

The Pedagogical dictionary (Průcha, Walterová & Mareš, 1995) defines the learning activity as a type of individual and/or social activity which is the core (heart) of learning. The learning activity is based on the cognitive process but it also includes elements of motivation, performance and correction. The different learning activities aim at forming knowledge, attitudes, abilities, standards, values etc.

The term activity closely relates to perception. The sensory perception does not mean the passive process accepting something which is objectively defined but it consists in the re-construction of information about the reality created on the results of analysis, synthesis, memory and generalizing. The sensory-motoric functional processes which are formed within learning are of selective character and are able to assimilate new elements of behaviour (Holý, 1993).

The psycho-structural model of processing information by Weber and Frank (in Bílek, 1996) is applied in educational cybernetics. According to Weber (1984) the route of information which is to be processed starts with registering it by sense organs (sensory perception), followed by aware perception (apperception) and operating it, i.e. the entire processing the information including storing it in the memory. Within this process various functions are activated, both when the memory stores (associates) the information and effectors (performing organs) are activated. This psycho-structural model synthesizes both behavioural approach (stimulus -

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"black box" - reaction) and the humanistic psychology approach based on the introspective analysis.

The main memory functions (Weber provides them in the form of software description, i.e. he considers their information content) are as follows (Weber, 1984):

1. Learning – connecting the impulse and reaction to the change in behavior,
2. Reacting – connecting the impulse and reaction without any change in behavior,
3. Remembering – storing the impulses or reflections,
4. Reflecting – the brain and mental operation,
5. Acting – spontaneous reactions directed by inner information or reflected cognition.

The memory is understood as the unity of active and passive functions meaning the German "Gedächtnis", i.e. the ability to remember, the memory in the passive meaning as the storage of information corresponds to German term "Speicher". In the patterns of so called "information ways" following characteristics should be taken into consideration:

- Learning processes are always divergent, e.g. The process of learning and forgetting are running at the same time,
- Various processes in the memory require a different time period, energy or efforts to run successfully,
- Conscious (intentional) and subconscious (unintentional) functions are activated at the same time,
- Various fields of the central nervous system are activated at the same time (e.g. within the inner reflection and direct reaction),
- The knowledge of basic functions enables us to deduce and explain both the partial and complex functions, etc.

The detailed explanations from the point of information psychology and theory of information processing (including the physiology of brain activity) can be found in works of Frank, Weber, Lánský, Lehrl, Riedel and others (e.g. Frank, 1995, Weber, 1984, Weiss, Lehrl, & Frank, 1986, etc.).

Johnstone (1985, 1997) provides similar model for the chemistry didactics. This psycho-structural model also distinguishes certain cornerstones (i.e. model of operations) of human perception and learning, i.e. stimuli – perception filter – working space within the memory (operational memory) – long-term memory which influences the accommodator (adaptor, i.e. the apparatus for directing attention or reduction the apperception). It differs from cybernetic pedagogy by Frank as it does not apply the "hard" quantitative approach to expressing the content of single parts of the psycho-structural model (in bits) but divides the learning content into several mastered parts (operations) called "pieces" which the learner must run in the operational memory. This method is called "chunking", i.e. composing, stratifying, layering information in the memory). Thus the more complex elements of learning than the above mentioned super-signs of Lansky are considered.

Johnstone (1997), while running experiments within the higher secondary learners in the field of chemical equilibrium, empirically discovered six – seven mastered operations ("chunks") which the learners can make in their operational memory, i.e. he defined the capacity of the operational memory. After reaching the top capacity, the number of successful task solutions decreases rapidly. This conclusion can be illustrated by the single experiment: Remember letters in 10 seconds. The results show that:

- It is easy to remember six letters (AVPSNQ),
- It is more difficult to remember twelve letters (LCVOEAMKZNSP),
- It is possible to remember twelve letters which are the combination of four Czech words (MOCVLKNESZAP = MOC-VLK-NES-ZAP); The procedure is called spearing by forming complexes (of words), which results in a lower number of "pieces" to be remembered. Another example is the information reduction, i.e. supering by forming "classes" (of shared common characteristics).

According to this structure the process of forming complexes (i.e. "pieces", "chunks") can be run in two ways:

a) supering (based on German "Superierung" – i.e. stratifying (composing) single signs into more complex ones (i.e. letters into words, words into expressions, expressions into statements etc.);
b) "chunking" – i.e. stratifying (decomposing) more complex parts into single ones (the learning content into topics, topics into subtopics, statements, expressions, words etc.).

These processes can be illustrated by the difference in remembering the structural and rational formula (e.g. CH_3 - CH_2 - COO - CH_3) where the process of "supering" and "chunking", i.e. forming signs, was applied.

Within the process of instruction the teaching system should consider how difficult the task for the learner is. This criterion is often omitted, as Johnstone proves on the example of secondary level topic on equilibrium where the difference between expected and real results is presented.

Let us provide another example of "pieces" application from the learner's and a teacher's point of view: What is the volume of the HCl solution of the c = 1 Mol/l concentration stoichiometrically reacting with 10 grammes of limestone?

I. Possible "pieces" from the teacher's point of view:

1. 10 g of limestone = 1/10 mol of $CaCO_3$.
2. It corresponds to 1/5 mol of HCl in the chemical equation.
3. I need 1/5 mol of HCl, c = 1 mol/l.
4. 200 ml HCl of c = 1 mol/l concentration.

II. Possible "pieces" from the learner's point of view:

1. Limestone = calcium carbonate.
2. Calcium carbonate = $CaCO_3$.
3. Molecular weight = 100 g/mol.
4. 10 g = 1/10 mol.
5. Notation of the chemical equation.
6. Quantification of the chemical equation.
7. Realizing the relation in the equation.
8. 1/10 mol of $CaCO_3$ = 1/5 mol of HCl.
9. Notation c = 1 mol/l means 1 mol HCl in 1 L.
10. 1/5 mol of HCl is 200 ml of HCl of concentration c = 1 mol/l.

The example clearly proves teachers underestimated the cognitive demands of the task for learners. The number of operations from the learner's point of view was more than twice higher than teachers expected, which influenced the solvers´ successfulness. That was the reason we dealt with the predictive evaluation of the tasks with pre-graduate students – chemistry teachers.

Example of Research Results Based on "Thinking Economy" Oriented to "Teacher's Predictive Tasks Evaluation"

The research project, based on previous ideas, realised at Department of Chemistry, Faculty of Science, University of Hradec Králové (Bílek & Slabý, 2004), was focused on the comparative study of reception of pictures by so called experts (having certain level of knowledge of the presented subject matter, i.e. teachers) and so called non-specialists (who have minimum knowledge in the area learned, i.e. learners). Analogically to the verbal learning the important role of teaching from the picture material is based on previous knowledge. In our opinion this fact plays important role in the educational process in the teacher's (expert) to the learner's (non-specialist) selection of the adequate subject matter presentation (self learning systems). Consequently attention was paid to this aspect in relation to the chemistry didactic tests for the lower secondary school level (learners of age 12 – 14 years). The prognosis of chemistry teaching students in learners succeeding in the didactic tests was analysed. The students expressed their opinions on differences in results on scale points 4 - 0: will the average result be significantly better in the test with pictures - scale point 4 or better in the test item of the variant with pictures - scale point 3 or the same for both variants – scale point 2 or better at picture variant - scale point 1 or substantially better at picture variant – scale point 0 (expert assessment at the scale 4 – 0; value 2 represents insignificant influence of the form of item in the didactic test). The collected data resulted in some interesting conclusions, which may serve as the starting point for further research in the mentioned area. The most important findings were as follows:

- In 13 test items (out of 20) students expected the positive influence of the picture elements on the test results of 12 - 14 – year – old learners.
- In 9 test items (out of 20) students provided correct answer when estimating the positive, weak or negative influence of picture elements.
- Students substantially overestimated the positive influence of the symbolic description of the situation in comparison to the verbal description (e.g. the symbolic versus verbal definition of substance amount – significantly better results were achieved in the verbal form, record of proton number as part of the symbol of the chemical element - only a tiny difference was discovered in both test versions.
- Students substantially underestimated auxiliary information obtained from graphs in comparison to tables (properties of halogens).
- Students substantially overestimated the influence of the drawing of chemical apparatus to the task solving (in the task concerning selection of distillation apparatus - the task included either drawing or description of the position of the hydrometer in the cylinder to set the density of given liquid).

Conclusions

The above described example proves that each learner deals with processing all provided information. Their nervous systems conduct wide reduction of information while sensing and processing it. The sensory perception volume is very large as well as the possibilities of information processing in the operational memory (fewer than 10^{-7} of the perceived content can be processed at the same time (Weber, 1984). That is why any filter mechanism is required to provide necessary selection. The process of selecting the individually substantial part (content) is called motivation. If the learner is motivated (i.e. ready to accept and process information), different processes were detected in the brain than if the information is rejected. Motivation is analyzed in numerous pedagogical and psychological publications. The inner and outer motives are considered within the preparation and running the instruction, when different level of complexity and abstraction of teaching aids should be taken into account; younger learners require a wide variability of media presentation so that the sensory and motoric centres were connected to associations and the atmosphere (climate) of safety, love and understanding was kept. Later in older school age the more complex processes should be initiated which require more fantasy, creativity and productive thinking (Bílek & Slabý, 2004, Weber, 1997).

The educational informatics paradigm and theory of super-signs by M. Lansky, which are understood as the educational cybernetics approaches to the field of education, aim at re-vitalizing branch didactics, mainly in science and technical subjects in the Czech Republic and abroad (Bílek, 2001, 2003, 2005, Lánský, 1995). Their following development is going to be the subject of research projects in several institutions focusing on e-learning etc.

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Advised by Eleonora Melnik, Karelian State Pedagogical Academy, Republic of Karelia, Russia

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Martin Bílek	Professor, Head of Section for Chemistry Didactics, Department of Chemistry, Faculty of Science, University of Hradec Králové, Rokitanského 62, 500 03 Hradec Králové, Czech Republic. E-mail: martin.bilek@uhk.cz Website: http://lide.uhk.cu/bilekma1
Pavel Cyrus	Professor, Department of Technical Subjects, Faculty of Education, University of Hradec Králové, Rokitanského 62, 500 03 Hradec Králové, Czech Republic. E-mail: pavel.cyrus@uhk.cz Website: http://www.uhk.cz/pdf
Ivana Šimonová	Assistant Professor, Department of Applied Linguistics, Faculty of Informatics and Management, University of Hradec Králové, Rokitanského 62, 500 03 Hradec Králové, Czech Republic. E-mail: ivana.simonova@uhk.cz Website: http://www.uhk.cz/fim