STRATEGIES OF FORMING STUDENTS' CRITICAL THINKING IN THE FACE OF NEW TECHNOLOGIES DURING BIOLOGY LESSONS

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ABSTRACT
In the research the presentation of possibilities of forming students' critical thinking about complex subject issues during ICT- aided genetics lessons at high school level was attempted. This paper reports research which was carried out during the last two years. It is a part of more extensive research connected with application of new technologies, especially information and communication technologies at biology lessons. However, it is also concerned with the influence of new technologies on the development of science and its educational implications.
The theoretical part of research focused on the models of teaching and learning biology and strategies of forming students' point of view and attitudes in the field of new technology. The practical part of research was connected with the organization of biology teaching and learning environment with ICT tools use and application of the selected teaching strategies support students' questions, their new ideas and arguments. 240 students of experimental and control classes participated in the research (lessons, questionnaires, cards of activity, tests). The data are interpreted in view of the new concepts of teaching and learning and point to the fact, that the development of computer techniques creates a possibility to shape views and evaluate the consequences of various activities owing to e.g. the application of simulation methods; it also enables acquisition of knowledge unavailable when using traditional methods. The ability to quickly search for information that is necessary in everyday life and awareness of free choice popularize ICT tools. However, it is critical knowledge and creative attitude of people that are the basic condition for their fulfillment in the contemporary world. Among other things, what arises is a need for educating students as future users of Cyberspace. The conclusions are discussed on the basis of literature.

KEYWORDS
new technologies, strategies of teaching, students'critical thinking

INTRODUCTION

At secondary school level teaching usually is performed by the teacher. The teacher gives lectures and the students watch and listen. This way of teaching has been found to be less effective than active learning, in which students solve problems, answer questions, formulate their own questions (Potyrala & Wolek, 2003), or brainstorm during clase, and cooperative learning, in which students work in teams on problems and projects (Potyrala & Walosik, 2006) under conditions that offer them positive interdependence and individual accountability. It happens no matter if we aim at short-term or long-term retention, or depth of understanding the material, critical thinking or creative problem solving skills.

Critical thinking is a rather diverse class of concepts and techniques to help students think better about complex subjects matters, make better decisions, and just learn in a more active way.

It is suggested that while thinking in a critical way students should consider the following check list[1]:

- **C**laim: What claim is being made?
- **R**ole of the claimant: Who is making the claim and why?
- **I**nformation backing the claim: What is it?
- **T**est: How can the claim be tested?
- **I**ndependent testing: Has the claim been tested by others?
- **C**ause: What explanation, if any, is being proposed?

A particulary important role is attributed to the way in which the questions are asked (Felder, 1994). The questions which are important in the course of critical thinking include among others[2]:

- ✓ **What** are the central concepts and relationships?
- ✓ **What** are the main arguments being advanced?
- ✓ **Why** are the arguments being made?
- ✓ **What** evidence exists for doubting the arguments?
- ✓ **Which** of these possible conclusions should be accepted and **why**?
- ✓ **What** other knowledge is needed to make a sound judgment?
- ✓ **What** are the probable consequences of the accepted conclusion?
- ✓ **How** the other position should be considered?

Kimber & Wyatt-Smith (2006) point to the educators' need to understand the way of students' learning in digital environments. In their opinion it promotes the development of effective digital learning through the construction of 'students-as-designers'where teachers and students strive to use and create knowledge. Their point of view focuses among others on challenges facing school in order to provide the professional development and material resources necessary for teachers to develop the types of activities and practices with IT tools, which extend student capacity for critical engagement and knowledge building.

Selected strategies (recommend by Kimber & Wyatt-Smith, 2006 after Gibbs, 1992) with computer use (for example: explicit reflection by students on their learning, problem-based learning, project work) have been applid in research on forming students' attitudes towards new technologies (Potyrala & Walosik, 2006). In conclusion, one may state that the civilization challenge for education is technology understood in a number of ways, which can be an effective tool among others in preventing extreme polarization of views and attitudes through showing the role of information in knowledge building.

Ge & Er (2005) propose a cognitive model for contextualizing learning scenarios to support real-world problem solving, which has implications for designing e-learning. The creation of learning objects should address issues such as sequence and scope, instructional scenarios, learning environments, instructional strategies and learning activities to facilitate knowledge acquisition and transfer. The learning environment should provide learning scenarios to engage learners in authentic problem solving activities among others through modelling (Hannafin, Land & Oliver, 1999).

Research (Potyrala & Wolek, 2003, 2005) confirmed these findings. Yet they also revealed that students have numerous problems with question forming also in the situations of being confronted with information made available to them due to IT tools. It revealed the need for elaborating the strategies supporting students in question forming and critical thinking in a better way.
Educational activity means performing various changes in students in emotional and cognitive aspects. In genetic education there have appeared a number of new contents which revealed the necessity for research connected with checking motivational achievements of students regarding their interest in

[1] CRITIC, a simple guide to critical thinking. Produced by Wayne R. Bartz, adapted from Skeptical Inquirer Sept/Oct 2002, p. 42-44
2 (http://fp.bio.utk.edu/evo-eco/resources-general/CT_questions.pdf)

genetics issues and connected with students' attitudes to genetics (Sternicka, 1996). Attempts are undertaken at finding the answer to the questions: to what extent can one influence the ways of students' argumentation? Can argumentation skills regarding bioethical issues connected with moral dilemmas be shaped? Are such skills transferred into other contexts concerning everyday life? Can instructions facilitating presenting arguments be included in traditional teaching of biological contents? (Zohar & Nemet, 1998).

All the strategies suggested in this paper are related to learning through experiment, to which Kolb (1984) attributed four stages, i.e. 1/ specific experiment, 2/observation and reflection, 3/ concluding and generalization, 4/ checking – testing the assumed solutions. Education based on hermeneutic (Kolb & Fry, 1975) is close to constructive learning and teaching, which in turn is close to problem teaching. In relation to situated learning theory cognition is understood as projection activity, and not representing the world with help of symbols, any knowledge is contextually situated and it is largely dependent on the situation in which it is acquired (Lave & Wenger, 1991). Learning is thus a function of activity and situational context, under which knowledge is acquired.

In accordance with those assumptions a model of teaching and learning with use of information technology (IT) tools that assumes application of forms of active planning, discussion, divergent, critical thinking and learning in cooperation with others was adopted in the paper.

RESEARCH DESIGN AND METHODOLOGY

The main research objective has been specified: studying aspects related to functioning of the cybernetic model of teaching as an instrument for students' critical thinking during biology lessons.

Research on the strategies supporting the process of students' critical and questioning approach to new technologies has been combined with the research on students' attitudes concerning both research methods and tools offered by new technologies.
While planning the research conclusions and reflections published in the numerous articles written by K. Potyrala & A. Walosik have been used. They regarded students' competence against the background of European standards, tendencies in biology education in the light of contemporary social and cultural changes, role and tasks of education in the process of European integration.
The project's only author is K. Potyrala and her experiment is part of the to-date unpublished research concerning the influence of IT tools on students' metacognitive competence.

In this part of research the following hypothesis was assumed: Application of the selected strategies of biology teaching/learning with IT tools use has a possitive influence on students'critical thinking. It appears in asking questions by students, formulating by student proposals of answers to the questions asked, building concepts and theories by students, formulating arguments by students and accepting by students' counterarguments in discussion.

Research methods: observation (64 genetics lessons) and pedagogical experiment.
Research tools: hospitation chart, observation guide, questionnaire.

The research was focused around genetics teaching contents mainly. The participants of the project were high school students 120 students in experimental classes and 120 students in control classes as well as 4 teachers. In experimental classes the following methods of work were proposed in connection with the assumed strategies: method of projects, panel discussion, discussion, seminar, modeling and the method of didactic games. Strategies of education enabling students to acquire knowledge on their own through solving theoretical and practical problems including manual and intellectual activities and developing emotional processes: learning through action (situated learning), learning through communication (problem learning) and learning through experiencing (simulation games, techniques of creative and critical thinking) were considered the most suitable ones.

During experiment the authors' project connected with combining strategies was used, experimental didactic concept was subjected to the author's model of biology teaching and learning based on ICT tools (Table 1). In control classes the strategy of traditional transfer of ready knowledge to students by teacher was used.

The perceptible effects of the applied model were registering by students the results of observation of the occurring events, recognizing the processes connected with these events, their evaluation and undertaking activities reinforcing or correcting the course of these events in accordance with the accepted system of values.

Table 1. IT tools and strategies of teaching in experimental classes

INFORMATION PROCESSING TOOLS	STAGES OF LEARNING & STRATEGIES	COMMUNICATING TOOLS
Interactive tasks constructed by author	METALEARNING Situated teaching; Problem-solving teaching; Simulation games; Techniques of creative thinking	Interactive tasks constructed by author
	DEVELOPING METACOGNITIVE STRATEGIES (synectics, simulation, mnemotechnique) Situated teaching; Problem-solving teaching; Simulation games	
Internet info Pack 1. creating data base 2. sorting records 3. filtering 4. preliminary research 5. reports	INFORMATION ORGANIZATION Situated teaching; Problem-solving teaching	Net Meeting as a presentation projector
	RECOGNIZING DIFFERENTIATED NATURE OF SITUATION OR PROBLEM Situated teaching; Problem-solving teaching	
Educational programs Dictionaries Encyclopedies Educational Portals	INFORMATION COLLECTION Situated teaching	Multimedial presentation (MP): 1. project template 2. hyperlink 3. animations 4. display 5. simulation

In the research the form of computer application during lessons described as partnership model was assumed as the basic and organizational one (after G. Pfligersdorffer , H. Weiglhofer 1997, modified). Assuming the existence of feedback within the model, the adopted biology teaching/learning organizational form refers to the cybernetic model of computer-aided teaching (according to Tadeusiewicz, 2002). Organizational forms of computer use during experimental research were presented in scheme 1.

Symbols: T – teacher, S – student, three kinds of feedback:Teacher – Student , Student – Student , Teacher – Computer and Student – Computer „„ small frame" functions at the assumption of work in small student groups.

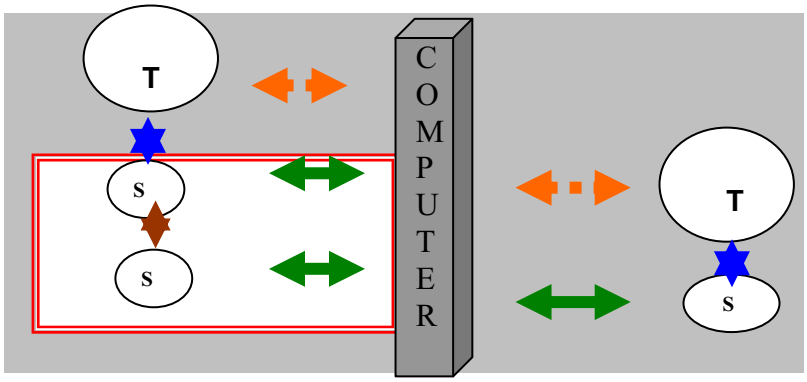

Figure 1. Organizational forms of computer application at experimental classes.

RESULTS

On the basis of lesson observation protocol in control (C) and experimental (E) classes (Table 2), organization schemes regarding the activities leading to forming opinion, discussion, expressing and creating bioethical views by students have been developed. It has been noted that in control classes too many difficulties connected with problem solving arise above all due to the fact that the student cannot adapt it to the specific situation quickly. While collecting information on the way to problem solving in experimental classes the condition of cooperation was fulfilled (cooperative learning). While cooperating, students applied situational strategies. The strategies revealed that students in classes E have many knowledge schemes contradicting the knowledge provided by the teacher in control classes and with the new information.

E class students were confronted with new information, more or less consistent with their pre - knowledge based on cognitive schemes. The way of transferring information due to IT tools determined which schemes activated the student to explain new experiences. One may believe, however, that pre - knowledge directed students' attention to certain information, while another could be ignored. Cooperative learning and problem solving gave possibility of analysis of alternative solutions and discussing on quite different concepts. Finally, the students of E classes accepted the concepts which were more close to the new experiences.

Analysis of lesson visitation sheets allowed qualitative comparison of cases of appearance of such students' activities as: experiment, observation and reflection, formulating opinions, judgments, concepts, testing ideas, exchange of views, change of concepts, application of rules (chart 1) and comparison of the number of lessons conducted in accordance with the methodical assumptions of four teaching strategies: A, P, O, E (chart 2).

Table 2. Organization scheme regarding the activities leading to forming opinions, discussion and creating bioethical views in control (C) and experimental (E) classes. Strategy A – strategy of traditional transmission by the teacher of ready knowledge the students are to absorb

C CLASSES		E CLASSES		
Problem teaching		**Problem teaching**	**Project /modeling**	**Situated teaching**
STRATEGY A	Formulsting problems Posing hypotheses	Formulating problems Hypothesis posing	Precise specifying of project/model purpose, way of solving problems and sources	Contextualization of knowledge
or				
Verifying hypotheses-exercises, experiments	experiences,	Verifying hypotheses-exercises, experiences, experiments	Evaluation of information Collecting and analysis of data and comparing them with theoretical model	Perceiving relations between knowledge and activity
				Communicating
Problem solving		Problem solving	Drawing conclusions e.g. regarding the essence of the studied phenomenon	Analyzing consequences of action

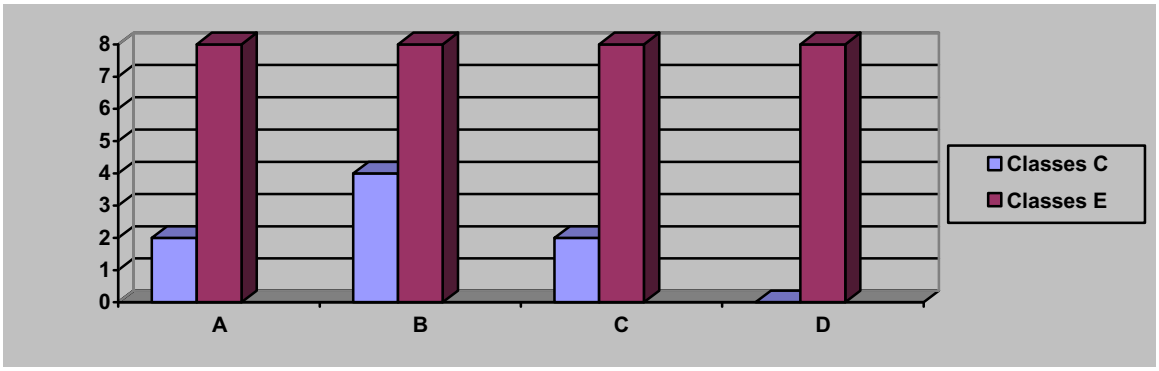

Chart 1.Comparison of cases of appearance of such students' activities as: A- experiment, B- observation and reflection, C- formulating opinions, judgments, concepts, D- testing ideas, exchange of views, change of concepts, application of rules

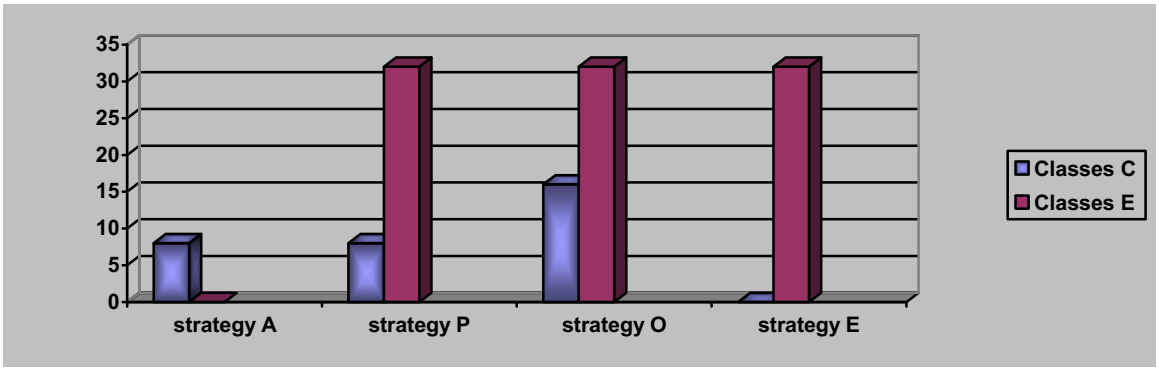

Chart 2. Comparison of strategies applied in experimental and control classes. Strategy A – traditional transmission by the teacher of ready knowledge the students are to absorb; Strategy P – the teacher organizes conditions and situations enabling students independent knowledge acquisition through solving theoretical and practical problems; Strategy O – directed at the organization of students' action regarding both manual and intellectual activities; Strategy E – aims to develop emotional processes.

While collecting information those situations were helpful when the responsibility for obtaining information and understanding remained with the student. Students in classes E in optimum way worked on only that information about which they clearly inquired. Independent question posing by students improved their understanding of genetics issues available through IT tools.

The students' activities (Chart 1) were registered according to the following sequence:
1. Inspiring questions – students formulated problems according to the scheme: Why? What? How?
2. Recognizing situation – students gathered components of new knowledge, reorganized it
3. Metathinking – students arranged metacomponents: planning, decision making, evaluating
4. Performance – students created ideas, solved problems
5. Correction/Evaluation – students critically evaluated their action and slogans and opinions which were the effect of creative process.

In connection with the teaching strategies applied in the control and experimental classes (Chart 2) the following has been noted:

- The tasks solved by the students checked such skills as searching for information, formulating problems and creating plans of their solutions. It turns out that in spite of the possessed rudiments of genetic knowledge the students in the control classes cannot name the difficulties, formulate a problem or appropriate slogan (or question). They have problems with posing hypotheses as in spite of more and more common use of the Internet, students have problems with reaching the necessary information. About 48 % students did not cope with the task requesting them to enter a suitable word in the Internet browser and finding associations between consecutive slogans.
- In classes E, during strategies 'O', 'P', 'E', the teacher required students to ask such questions to which the answer could be found through observation alone (IT tools' use). It led to enhancing cognitive activities in students. Initiating cognitive activity and registering the observation results of the occurring events, recognizing processes related to those events, their evaluation undertaking action reinforcing or correcting the course of the processes, building concepts and theories by students were also found to be measurable effects of the applied model of teaching. Due to IT tools students in experimental classes had also the opportunity of reaching all kinds of information which helped them in it. Construction and reconstruction of knowledge by students and its reorganization and graphic representation in the form of notion maps, due to the framework created by the model of teaching & learning and organizing the activities in 'work charts' occurred efficiently. In control classes

the mentioned phenomena were not found and all the students' actions were initiated by the teacher.

Following the above observations and general didactic regularities of applying specific strategies and teaching methods, one may state that within the proposed model of IT tools aided genetics teaching and learning, students acquired competences which helped them process knowledge, creating ideas and critical thinking on the topics included in the experiment. It was proved, to a much bigger extent than in control classes by:

- asking questions by students – altogether there were 3440 questions asked by students of experimental classes, which on average amounts to 4 questions asked by a student at every lesson; in control classes there were altogether 16 questions asked by students during the stages connected with problem arising,

- formulating by student proposals of answers to the questions asked – altogether there were 1720 proposals of students in the experimental classes, which on average means 2 correct answers per student (or attempts at giving the correct answer) to the posed issues; in control classes the stages of solving the posed problems had the form of group work, usually only one version of the answer was taken, and the whole class agreed to it,

- building concepts and theories by students; students in experimental classes due to IT tools had the possibility to reach diversified information which helped them; construction and reconstruction of knowledge by students and its reorganizing, due to the framework created by the learning model and organizing activities in „work cards" were efficient; in control classes no such phenomena occurred,

- searching forms of individual and group activity by students,

- formulating opinions by students with consideration of „for" and „against" arguments. „Work cards" contained decision scheme („decision tree"), which enabled the students in experimental classes critical analysis of all the information; students in control classes had such an opportunity at few lessons (altogether 4 lessons in all the control classes) regarding the latest achievements in genetics,

- Accepting by students' counterarguments in discussion and readiness to change the view in the situation of being unable to overthrow it or to maintain the view contrary to the group's opinion. In case of bioethical issues students in control classes were largely impartial, they tried to provide proofs and verify expressed opinions with the help of available sources of information.

DISCUSSION & CONCLUSIONS

Solving problems and critical thinking, from Piaget's point of view are more likely in the environment where exploration and autonomous construction are valued, where openness exists, and autonomy is a universal way of functioning. Passive methods of education, including too extensive contents are not conducive to them; having cognitive knowledge itself is not enough if there is no autonomy and willingness (cognitive aspects) (Wadsworth, 1998). Yet even ways of solution proposed by students on the basis of the acquired information, should not be treated as definitive, in particular in matters arousing any ethical objections. The teacher may not allow students to be satisfied with premature conclusions (Aebli, H. 1959).

In the course of learning the students' system of values in connection with citizen's, social-political, family and professional roles develops. The need for presenting teaching contents in the context of the world of values that exceeds the individual and their clarification (Denek, 2005). In order to move towards the model of generative education and critical – creative doctrine, there is a tendency to create

and popularize the models of reflective education, oriented towards shaping and development of values. In biology education there is talk about shaping attitudes which are connected with the values, norms and patterns of conduct.
Information, which is a way of human communication; of one man going out towards another man, yet which is not built on substantial foundations of impartial truth, becomes a way of manipulating man (Śnieżyński, 2005). In information flowing from social groups to particular individuals there are contents of norms and principles of behavior, impulses to apply them or even warnings regarding all kinds of sanctions in case of disobeying them (Muszyński, 1975).

In the situation of the model of information processing on the basis of IT tools applied in the research, it seems obvious that the attitudes accompanying learning genetics contents in this environment should be studied. Information technology tools are often a carrier of feature film schemes, commercially oriented film and publishing production, hence in order to release in students consideration of scientific issues, there should be created a situation blocking their influence (Kałuszyński, 2002). Independent reaching conclusions by students due to accessible materials and source texts to which students were referred by IT tools was significant for creation of bioethical views during experimental lessons.

The areas of influence resulting from the computerized genetics teaching and learning environment may be associated to the attitudes (their forming) if we believe them to be specific dynamic schemes, i.e. consolidated systems of action or its result and reality images undergoing changes under the influence of new information on reality. If we take natural relations to other people to be a significant point of reference, we may assume that students' answers may be based on socially approved schemes.

However, while comparing opinions, questions, answer variants and students' attitudes one must admit that application of the model connected with transformation of information accessible due to IT tools significantly influenced students' creative activity visible in expressing and creating bioethical views as well as in undertaking reflection related to the topics that come up at lessons. In literature creative attitude is rendered in terms of personality norm and has features of active attitude of the individual towards information (Siemieniecka-Gogolin, 2005).

Creative attitude should be additionally characterized by criticism towards the media. It was revealed in questions asked by the students ('What? Why? How?') and was also expressed in notion (conceptual) maps created by students. The view that critical attitude towards the media may be formed only in the situation of open access to many sources of information, justified by the need for comparing information and seeking its reliable sources is in agreement with the authors intent and may account for high students' activity at experimental lessons in displaying their assessment and concepts and communicating them. Impartiality function, module function and transgression function of computers enumerated among other functions that should be played by computer to stimulate students in their creative development (Siemieniecki, 1998) seem particularly important from the point of view of shaping bioethical views in students and their critical thinking.

Real inclusion of these computer functions in the experiment and interpretation of the obtained results in connection with the hypothesis of the influence of IT tools used in accordance with the proposed model on students' critical thinking encountered many obstacles. The encountered difficulties confirmed the opinion that to-date verbalism and schematism in teaching increases the distance from ethical values and teachers find it difficult to reject their habits and dogmas (Siemieniecki, 2003). The collected material connected with the application of the proposed learning model at genetics lessons allowed verification of the posed research hypothesis may, however, constitute the starting point for and the basis of further research related to the implementation of information technology tools in teaching and learning various subjects.

In view of numerous ethical and moral issues regarding the safety and security of applying biology achievements in various areas of knowledge and life, attention is drawn to the necessity of extensive discussion; not only among professionals (genetic engineers or physicians), but also among specialists

in other areas of knowledge, e.g. philosophy, law, sociology, psychology and theology. There also is a view that fast pace of development of science and technology as well as accompanying it civilization changes causes the necessity of moving away from traditional ethics and building the foundations of a new one, capable of facing difficult challenges of the contemporary world (Szóstek, 1998). It makes biology education confront opinions, views and interests of various social and professional groups. It requires from teachers use of strategies leading to rebuilding the earlier structure of students' knowledge, creating different structures in connection with new students' concepts in response to new information.

One can come up with a conclusion that there is a need to extend the research on individual competence which Lyle and Signe Spencer illustrated by means of an iceberg (Spencer & Spencer, 1993). Values are difficult to teach, yet they have unquestionable importance for efficiency and effectiveness of learning. Motives, labour ethics, enthusiasm and own image (the bottom of the iceberg) is not enough to acquire metacognitive skills, and the sole knowledge and abilities (surface and the top of the iceberg) shall not ensure a high level of efficiency of learning. Competence must be characterised by interactivity, which means its constant updating, appropriately to new contexts.

In education it is important to shape axiological attitude – the ability to make a selection of values as the axis crystallizing personality. An important issue is also the existence, due to media, of broad public opinion regarding the basic issues of the contemporary world. In biology education the issues of the protection of the natural environment, application of achievements in genetics and medicine, human right protection occur at all the education levels. Presence of these issues in media and communication interactivity resulting from the access to hypermedial techniques, enforce promoting specific ethical strategies in biology teaching and learning aided with information technology tools. In this context it seems that the old concept of problem-focused teaching has to be revised in the situation when particular stages of this strategy are at present implemented "in different time and place."

Coexistence of formal, informal and incidental education in the permanent education of the knowledge society is the reason why solving school biological problems may be only a proposition of possible ways and tools in search of answers to questions. Existence of "ready-made biological problems" and "ready-made ways of solving those problems" and even "ready-made solutions" does not go well with preparing students for a real confrontation with problems of the information society. It is some proposition to combine problem-focused teaching and situation-focused teaching, accepting many possible ways of students' thinking and supporting them by means of differentiated methods, means and forms of teaching. First and foremost, school has to give up the mission of teaching and focus on showing how one can learn.

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