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USAGE OF CRITICAL THINKING STRATEGIES IN THE CHEMISTRY COURSE FOR A FUTURE DOCTOR

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Abstract

The goal of general chemistry and biochemistry – teach students to use their knowledge about chemical structure of organism and molecular processes. To better understand explanations and to prognosticate processes students are given, information presented on other courses. As time dedicated for chemistry course for first year students of RSU is reduced, use of critical thinking strategies in starting period of study process increases probability of achieving positive results. By organizing study process at the beginning of semester, students are introduced to detailed plan thus giving an opportunity to organize their own time according to previous learning experience. Students are provided with thorough study material both in printed and electronic form thus allowing them to find more time for fact analysis, problem solving and relation finding. By stepping away from the traditional routine, the proportion between lectures and practical lessons was changed in favour of practical lessons. Gained experience allows concluding that intensive work with small groups, by introducing students to different approaches to information analysis, graphical systematization of information, development of dialog skills and other methods is effective and worth developing.
Key words: *critical thinking, study process modification, study planning.*

Introduction

This millennium brought changes in all areas of life whether we were ready or not. Schools are at the edge of great democratic possibilities and educators must play a major part in the reinvention of a fairer more inclusive society. If so it will be a time for true inspirational leadership not compliance management (Hammonds, 2002).

We have to take these changes both less and more seriously at the same time. Less seriously, because most change is superficial and more seriously because it is important to work through these changes until we get shared meaning and improvement. The best defence against the relentless pace of change, Fullan believes, is to build professional learning communities that are good at sorting out the useful from the unuseful and to look for support and healing when ill conceived or random changes takes its toll (Hammonds 2002). Productive change in education is full of paradoxes and seemingly incompatible components, e.g. support and self-dependence, equality and excellence, self-motivation and external stimulation. K.Popper, when describing modern education, emphasizes that the tendency to reform must not lower the quality of education. Traditional pedagogy is such: *unseaked answers and unanswered questions* (Listeners comply). That is our pedagogy (Popper, 2005).

An ideal case in university would be work with well-informed, motivated, active and experienced students to whom studies are fulfilment of their goals of life. In such case reduction of study time would not create an issue and the study material would be mastered anyway. However, the situation in real life is that first-year students have reduced time for adapting to

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new learning style and environment thus preventing productive work. This situation demanded changing the way lecturers work as well as accelerated the introductory period for students.

The goal of the described research is theoretically justified methodical solution for providing high learning quality in reduced study time in medical chemistry course by using approach of developing critical thinking. Basis of this methodical solution are systemic and activity-oriented approach which allows practical testing, assessment and, if necessary, correction.

As much as possible must be done to aid students during the beginning of their studies while helping to gain skills in organizing their own study process. The most effective and efficient methods and approaches for this are methods for developing critical thinking, which are modified according to student experience and response.

In order to complete medical chemistry course in shortened amount of time, it is necessary to have a very precise organisation of one's work as well as in-depth information about study course. In the beginning of semester, students are informed about the study plan for the whole semester and even the whole year in relation with medical chemistry, biology and consecutive courses.

In medical chemistry course an emphasis is placed on practical work in small groups. In this way all students can participate. From all of the time intended for medical chemistry course, 80% are intended for practical work and 20% for lectures. In lectures, students gain information about general regularities which are concretized in practical and laboratory work. Intensive practical work is possible thanks to freely available study materials thus allowing students to learn theory self-dependently. Students are provided with printed and electronic study materials which include:

- Medicine oriented study books and lectures which include logically justified examples of ineffectiveness of unambiguous evaluation;
- Specially prepared tasks with solution examples where students need to evaluate genuineness and precision or errors and inconsistencies of given facts;
- Descriptions of laboratory assignments which are intended for learning core principles of science (theory proposal, repeated practical examination, statistics processing, result analysis and conclusion drawing).
- Examples of information gaining and analysis, e.g. illustrative materials, graphical organisers of information etc.

Experience gained over a period of two years, allows concluding that intensive work in small groups, after students are introduced to different approaches to information analysis, graphical information systematization and dialogue skill development methods, and is an effective approach and it is necessary to be used and developed further. Experience in organizing one's own study process is of equal importance, e.g. weekly tasks can be best planned when the whole plan of semester is known. Weekly tests allow students to analyze effectiveness of their own work thus signalling them to devote more time for harder to learn topics. At the same time, freely available sources of information allow comparing given examples, looking at facts from different perspectives and create their personal notes.

Gradually, students must reach a conclusion that they are responsible for their own grades and that students need to use lecturer's potential rather than the other way around. At the end of every definite time period (week, month, semester, year) students must look back and analyse whether a consistency of achievements can be seen. If results are not pleasing, it is necessary to find out causes – distractions, lack of planning. Thus students will gain practical skills and experience in studying.

First Year Student Study Skill Development Methods Based on Critical Thinking Strategies

At the beginning of study process, students have an opportunity to choose the most appropriate study method. Lecturer's responsibility is to create situations for students to be able to realize their own development potential and to gain universal studying skills. One of such skills is critical thinking. R. Paul defines critical thinking as general quality of thinking process and a tool for self-realization of one's personality. R. Paul states that critical thinking is associated with development of general thinking principles which can be used in different fields (Paul, Elder, 2001).

Contributors from the area of philosophy (such as Richard Paul) remind us that critical thinking is a process of thinking to a standard. Simply being involved in the process of critical thinking is not enough; it must be done well and should guide the establishment of our beliefs and impact our behaviour or action Contributors from the area of behavioural psychology help to establish the operational definitions associated with critical thinking. They work to define the subtasks associated with final outcomes and the methodologies teachers can use to shape initial behaviours towards the final outcomes. Psychologists analysing critical thinking demonstrate that lecturers can provide necessary conditions for behaviour modification (Huitt, 2006).

By analyzing different methods for developing critical thinking (both universal and specific), active forms of work (practical work, seminars, dialogs, and presentations) were emphasised.

Complex didactic method cannot be viewed as sum of its separate parts as it is the binding of these parts which determines the complete value of the method. Development of critical thinking during study process can be made more effective by pedagogic processes which are dynamic and flexible individually and remaining effective when combined.

During work with first-year students, deviations from traditional university methods are necessary since there is a transition period. Different levels of qualification and the need to adjust accordingly increases significance of subjective conditions. It is impossible to demand instant analysis – one of the most significant components of critical thinking – of new information from all students.

Qualification and motivation for learning chemistry between RSU first year students varies radically both between students of the same group as well as of all groups combined. First step - diagnostics – an opportunity for the lecturer to choose: to solve problems using an established algorithm or using a creative approach. Strategy and methods are chosen based on results (level).

These are didactic methods which can be used for development of critical thinking:

- Development of reflection by encouraging students to engage in dialogues (analysis of questions and answers, listening tasks);
- Information analysis and visualization (graphic information organizers);
- Creation and solution of problem-situations by comparing one's own proof with that of others;
- Analysis of one's own qualification level at the beginning of studies and at the end of course;
- Development of individual study strategy;
- Variation of proportion between reproductive and research methods during studies.

Student cognition process is organized step by step – by moving from simple to complex and diving deeper in analysis of given situations or problems, gradually comprising the general picture.

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Students are unable to evaluate whether one method derives from another, is it an advancement of already known or is it an illustration or contradiction. During reading, facts which derive one from another are not spotted. Technical terms are not connected with real life analogies.

In order to solve this problem, it is useful to create special study situations and problems and to adapt them for developing critical thinking in practical lessons. Complexity should be determined by proportion of already known and new information within study material as well as level to which students are able to integrate knowledge gained in other courses. The more complex the problem, the higher the level critical thinking technique to be learned.

General concept of critical thinking can be gained by increasing student attention and analyzing examples (in a particular scope), traditionally by reproducing facts.

Unaccented critical thinking techniques can be gained by traditional study process with example analysis (different but related scopes) – highlighting priorities and analysing facts.

Accented critical thinking techniques – by information evaluation, critical approach to facts and study situation analysis (analogies/contrasts), promotion of hypothesis, choice of solution process, practical (or theoretical) examination, evaluation of experiments (or problem solution), results and statistical processing.

Choice of means depends on topic and student capabilities. Offered layout of study material anticipates high student qualification since physician must operate with universal knowledge as well. For less qualified students, it is characteristic to consider universal knowledge as unnecessary when facing difficulties in study process as well as to strictly outlining boundaries of one's competence. In such situations, lecturer is constrained to step back from traditional work method by choosing high school didactic methods (changing the proportion between student self-dependent work and explanatory work in lessons). More capable students in such situations do not always gain, but it is inadmissible to have students stop asking questions and sink deeper in hopelessness to understand study material.

Special Study Texts Customized to Promote Critical Thinking Development in Three-Phase Practical Exercise Model: Suggestion, Perception, and Reflection

Special texts were developed in chemistry course by customising existing texts in order to make them suitable for three-phase practical exercise model: suggestion, perception and reflection. During suggestion (determining individual goals) phase, students actualize existing knowledge regarding given subject, determines missing information and sets individual goals in order to solve the problem.

During perception (realization of individual goals) phase, students evaluate new material, establish a personal view and assess arguments and justifications necessary for discussing the topic.

During reflection (development of personal position) phase, students completely understand the given subject and are able to analyze their own thinking, causes and effects, as well as draw conclusions regarding what they have done and analyze mistakes and personal contribution.

Reading, for example, is a macro skill which coordinates several micro skills. Title is the first thing to consider, then comes introduction, then problems or goals of the book. Unclear sentences and interpretations of concepts are considered afterwards. At the same time it is possible to find examples based on personal experience thus validating opinions of the author. These separate steps are joined together in order to create understanding of information read (Paul, Elder, 2001).

E.g. students can learn fundamental thermodynamic regularities by successively moving from general regularities towards specific examples and vice versa - from specific examples

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towards generalities. As a result, they get theoretical justification of their own experience since prospective doctors do not need to call upon trivial „calorie burning" though it is necessary to understand that every process in organism takes place on molecular level involving energy consumption or production.

Critical reading is text analysis by evaluating expressed ideas, proposed assumptions and consequences while gathering logical contradictions. Critical reading also involves proficient ability to ask questions. The ability to capture ideas for further processing and discussing both in schools and universities is underrated. Notes by students are often made without purpose to be used again in the future. Very often good notes made by others are photocopied while one's own are placed aside.

Perception of reading and writing as instruments for development of critical thinking in university is judged very contradictory. E. Volokov criticizes this method and objects to the use of high school methods in university (Volkov, 2009).

Opinion of pedagogues and psychologists which value reflection of writing as an important condition for developing critical thinking skills, for example, theory of *Lev Vigotsky* about relationship between thoughts and language and inner speech, can be mentioned as a counterargument. Written text gives an opportunity to read it again in case of failing to understand it; however it lacks dialogic bond with reader meaning that process of understanding cannot be corrected by changing direction of dialogue and explaining the unclear (Vigotsky, 1982).

Development of Reflexion by Encouraging Students to Engage in a Dialogue

Equally important is oral reflexion which allows following one's own study progress and encourages students to engage in a dialogue – by asking questions, performing listening tasks and analysing answers afterwards. Ability to engage in a constructive dialogue between colleagues and discussions with lecturers must be developed thus improving speaking and listening skills.

Lecturer can stimulate self-dependent thinking and encourage students to participate in discussions and active listening and thinking by:

- avoiding excessive instructing or controlling, however, if necessary inconspicuously guiding discussion by questions or explanations;
- using vocabulary understandable to students and emphasizing if the topic of discussion is already known to students - just in a different context;
- pointing to evident contradictions or rephrasing what has been said in order to stimulate students to give alternative answers and explanations;
- spontaneously reacting to unplanned incidents and using them as illustrations and reinforcements;
- adjusting discussion speed in order to involve all students in discussion;
- using questions of different types to get answers of different levels - fact reproduction, analysis, synthesis and generalization.

The aim of questions must be to encourage students to follow comprehension of obtained information by dividing information in fragments which can be used further in the context.

By reading texts, students train to record facts and learn to evaluate whether new information is a development of already known, an illustration or a contradiction.

Best methods for text analysis are SQ3R (Huitt, 1997; Halpern, 2000) and SQ4R (Huitt,

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1997). These methods are based on cognitive psychology and they explain how to receive the largest amount of information from books and extramural courses. SQ4R:

1. Survey - Read chapter outlines, chapter headings, recaps, objectives, etc.
2. Question - Formulate questions you believe will be addressed in reading
3. Read - Read material quickly, carefully, actively; try to answer previously formulated questions
4. Reflect - Write in journal, make notes, or simply consider the material
5. Recite - Explain aloud to yourself or another person what you have read; use study guide; answer questions at end of chapter
6. Review - Go back over what you have learned; use study guide; reread recaps, reviews, or end of chapter summaries

Both free and question guided exchange of thoughts by sustaining a dialogue activates cognition and thinking process. The best way to understand information in seminaries is to explain it to others. During seminaries students engage in dialogues by correcting and adding to what their colleagues have said, thus developing skills necessary to justify, analyse and correct their opinions. Working in groups and generating new ideas for solving a problem allows developing individual capabilities of students as well as gathered information about resources of others which all can be used to find a solution for a common problem.

Graphic Information Organizers

A more complex level of analysis is graphic organizers. Creation of organizers offers higher level of reflection than text analysis. By having to work within reduced timelines, these organizers become key in organizing self-oriented study process.

The use of graphic organizers helps to visualize already known and to add new information as well as to raise argumentation levels. Thought guiding questions in order to focus thinking process:

1. What is my position regarding the subject and which facts, arguments and processes must be understood?
2. Which layout will help to organize material and to show its meaning?
3. What type of graphic organizer will represent the way of understanding the material?
4. Which problems must be emphasized in order to promote thinking process of students (Clarke, 1991).

Graphic organizers analyzed by John H. Clarke are intended for two main purposes. Organization of information which helps students reach conclusion by inductive thinking (graphics "from bottom to top"). Forming hypotheses, making decisions and solving problems using deductive thinking (graphics "from top to bottom") (Clarke, 1990).

Until now it was evident that students like using predefined techniques, however from now on, emphasis must be placed on self-dependant creation of techniques and mutual comparison between them during practical exercises.

However, there are students for whom this proves to be difficult due to lack of knowledge in chemistry. It can be compared with reading a book without knowing the alphabet. These students pick descriptive information variants.

Creating Problem Situations and Solving Problem Exercises

Intensification of student thinking process is done gradually by guiding their cognitions toward contradictions. It can be realized by creating problem situations and problem solving

exercises. Creating problem situations is effective only in cases when there is a logical connection with already known. If contradictions between the new and already known cause amazement then there is will to find out more.

J. Dewey highlights „sense of burden" and psychological experience when coming across a problem. In order to solve the problem, J. Dewey suggests a procedure consisting of five steps:

1. Problem description and analysis: "What is the nature of the problem facing the group?"
2. Generation and elaboration of possible solutions: "What might be done to solve the problem we've described?"
3. Evaluation of possible solutions: "What are the probable benefits and possible negative consequences of each proposed solution?"
4. Consensus decision: "What seems to be the best possible solution we can all support?"
5. Implementation of the solution chosen: "How will we put our decision into effect?" (Dewey, 1997).

Given tasks included problems which students often solved incorrectly or about which categorical and unproductive conclusions were drawn (conclusions which involve different incompatible solutions). Problem exercises were developed by incorporating already known information which gained different meaning through different points of view. By solving problem exercises students must learn basic principles: statements, consequences, conclusions, problem investigation, evidence an argument presentation, contradiction and imperfection identification. By thinking critically these are not performed as separate operations but rather as one complex operation. Exercise solutions allow evaluating student level of critical thinking.

Evaluation of Study Results and Method Effectiveness

Students participating in this experiment were first year students with different preliminary chemistry knowledge from faculty of Medicine. No comparison was made between experimental and control groups since grades of previous study years with larger amount of contact-hours were chosen as reference points. Critical thinking levels were recorded at the beginning of the semester by results of problem solving exercises. Exam results show student level of chemistry knowledge but critical thinking level was determined by questionnaire and results of problem solving exercises.

The initial level of critical thinking – poor information evaluation, inability to justify own opinion. Intermediate level of critical thinking – ability to operate on level of elementary reasoning, insufficient experience in justifying or denying evidence, self-evaluation and incomprehension of criticism as thinking operation. High level of critical thinking – persistent thinking skills, ability to see drawbacks of others and themselves, ability to find mistakes, logically justify evaluation and self-evaluation, skilfully chosen arguments, tolerance towards justified criticism. Methodical solution options are chosen or corrected if necessary based on initial evaluation and intermediary evaluation. Final evaluation of students show both – mastered study material as well as ability to work critically. Final evaluation was based on *Peter A. Facione, Noreen C. Facione,* criteria (Facione, Facione, 2009).

By surveying students a conclusion was made – methodical solution for learning medical chemistry over reduced time period by using critical thinking development methods was successful since students have completely or partially gained these skills:

- To develop information seeking skills in study literature and other sources;

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- To avoid planning tasks for excessively long period of time but e.g. from colloquium to colloquium;
- To formulate tasks briefly and concretely, without trying to comprising incomprehensible but what corresponds to ones level of qualification;
- To draw conclusions regarding experience this far and to predict which methods will be most effective;
- To control distractions and to have a precise work plan;
- To continuously create one's own study material by using provided materials and other sources;
- To critically evaluate and conclude, which information in addition to one provided is necessary, is it clear why some questions are not understood and is it necessary to hear an opinion of authority regarding these questions;
- To summarize – what was done right and what could have been done better, were action consequent, were achievements made;
- To transfer responsibility from lecturer to student – students must use the lecturer's potential.

Final exam results differ between the last two years differ insignificantly. Results displayed in first image are obtained from study process within its previous model – with larger amount of contact hours. It serves as a point of reference for comparing methodical solutions in RSU Human Physiology and Biochemistry department. Both succeeding images display results obtained from study process using the model described in this paper.

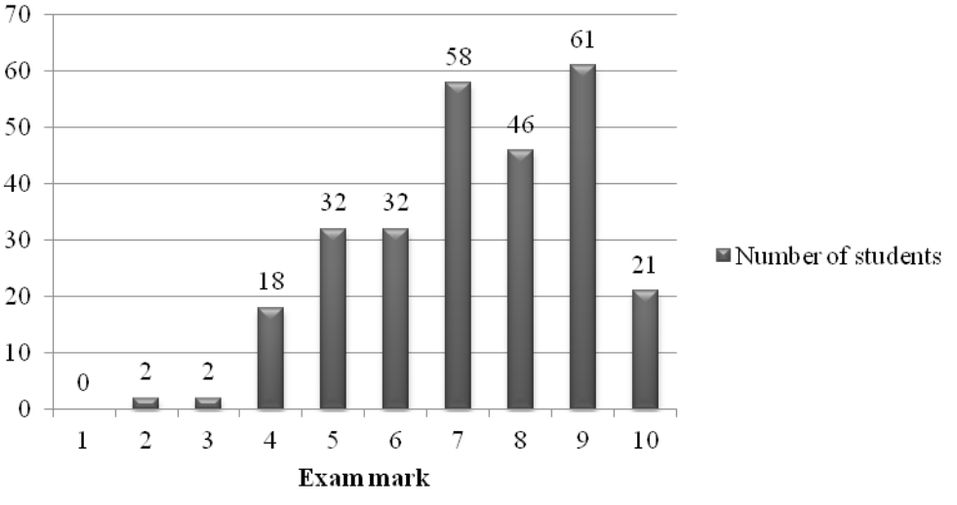

Figure 1: Exam Results in General chemistry in 2009/2010 year.

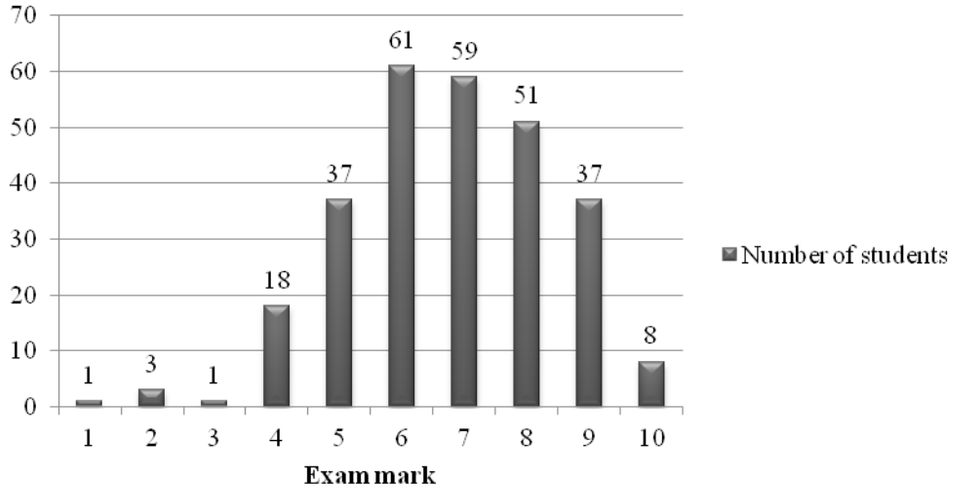

Figure 2: Exam Results in Medical chemistry in 2010/2011 year.

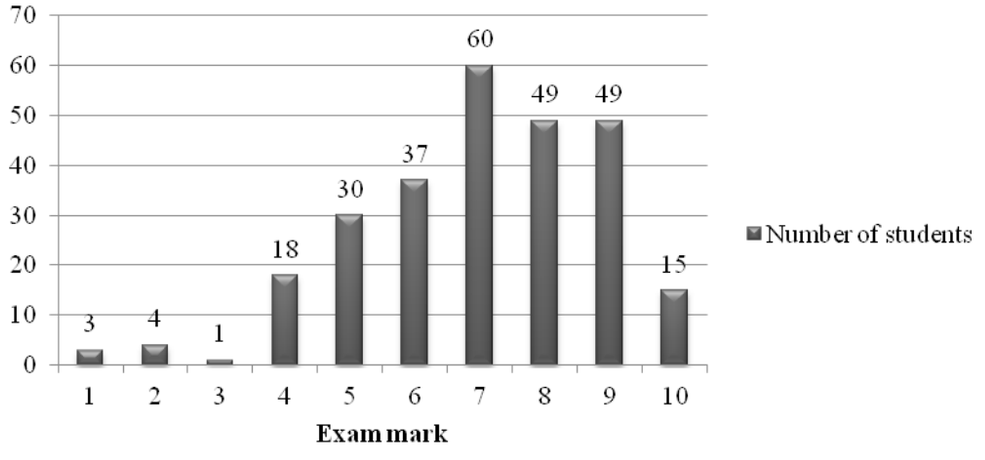

Figure 3: Exam Results in Medical chemistry in 2011/2012 year.

It is evident that departure from traditional distribution of study time by considerably reducing amount of lectures and increasing practical and self-dependent work is sufficiently effective since students have managed tasks of first semester in medical chemistry. Chosen solution proved itself to be successful, however it can be still be optimised for further use.

Conclusions

Learning medicinal chemistry is more effective when using critical thinking skills since students learn how to relate theory with practice (at the beginning of studies to see the connection between study subjects). Student performance is organized so that to master the study material it is necessary to use increasingly thorough fact and situation analysis, systemisation and result prediction. Students are provided with problems, solutions for which require analysing facts, finding, evaluating and eliminating contradictions and errors since facts included in theoretical material not only logically derive one from another but also present contradictions which must be justified and interpreted according to ones experience. Clear evaluation criteria must be present in order to guide students towards self-evaluation (reflection).

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