

Education of Chemistry at the 1st Independent High School in Bratislava, Slovakia from General Education to Key Competencies

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Abstract

Education of Chemistry at the 1st Independent High School differs from the ones at other schools in Slovakia. Several equal bases support the education generally. The first one is the pedagogical and psychological art of the teacher who has the freedom to create the curriculum of the subject and choose the method of teaching. The second is connection of education with real life. Then there is the definition of the basic content and need of complex view when studying a phenomenon. The last but not the least is the specialization of the study. It is important to see and train the cognitive abilities of the student while choosing method in education process. All the abilities are categorized as key competencies and as shown many of them are suitable for training in chemistry classes. They can be used as motivation. There are several methods for the key competencies training e.g. to learn from experience, to contextualize the facts, to solve the problem and the student should learn as well to be responsible for own learning.

1. Introduction

Europe is changing and so is our society. It goes through some deep and wide changes that are accompanied with drop of trade increase, economic and politics crises and changes in the labor market. New technology is getting old in short time. Every sixth employee change his job during a year and each eighth even a field of his job in average [1]. Keeping the same job for whole life is a rarity. To learn how to learn and learn for the real life gets more important than pass along the knowledge that grow old very fast. Accentuate the acquirement of factual knowledge got useless also because of development of information-communication technologies (ICT) speeded up the communication and information are easier accessible. It is important to move the accent in education on the personal possibilities of students, their approaches and allover cognitive abilities "facilities". It should be moved to their personal and social competencies. We build up our model of education on this base. The main problems we solve in our school projects:

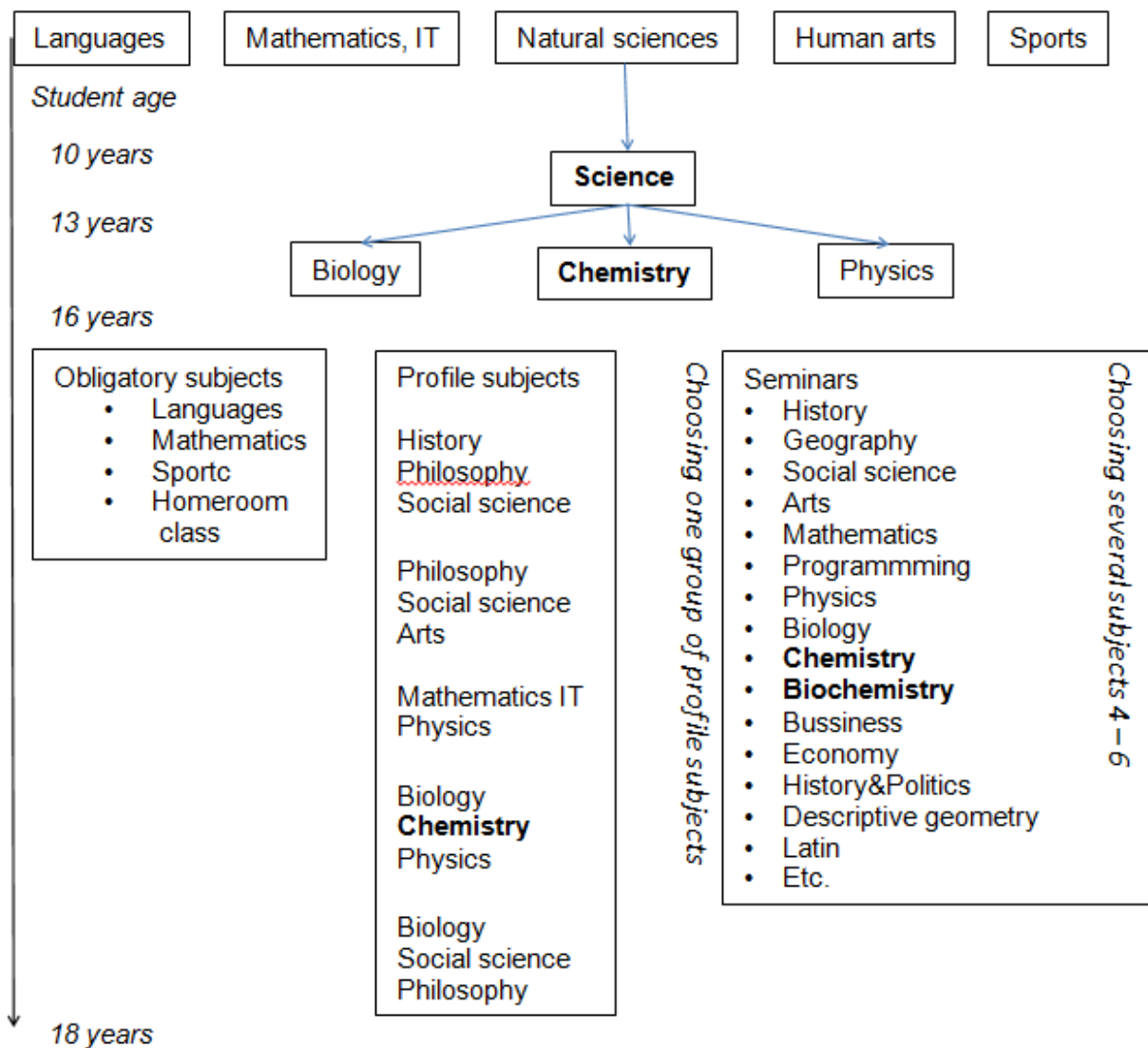
- The creation of the subject curriculum with the teacher
We used the newest world trends studies as a valuable information source. [2, 3, 4, 5] The teacher is the most important agent in forming the content and form of the educational process and so he is the creator of the subject curriculum. Our ideas of the content and form of the chemistry education aroused from this point.
- The connection of the real life and education
The subjects are understood as science disciplines in classic education system in Slovakia. There is the intention to advise students with the whole range of their content. According to the intense boom of science and technologies is education even more apart from the real life. Students live their life of cognizance outside of school. They obtain there decreasingly less knowledge and skills useful in the real world. This we tried to change in our school program aiming the natural sciences content not to copy the subjects as the science disciplines.
- The need of complex view during study of natural phenomena
Natural phenomena should be study in the complex view; therefore it means integration of knowledge, skills and attitudes obtained from the view of physics, chemistry, biology geography as well as social sciences. Methods and methodologies (Integrated Thematic Education – ITE,



experience learning, Socrates dialogue, team work, etc.) aimed in this direction are used mostly in the classes.

- No need to teach everyone everything

Nobody will probably doubt the fact that high school with general education (ISCED 3) should prepare students mostly for the study at university or other higher education institution (ISCED 6). The field range of higher education is so wide in this era, that it is impossible to prepare the student for all types of higher schools in the whole range and depth. The preparation has to be sooner or later specialized. Today education makes it more difficult for the student in the state schools in Slovakia. The student is forced to be dedicated to all the subjects' thorough whole study and there is lack of time for specialization. General education does not mean that the graduate should be polymath, who masters all the sciences. The training of key competences on the basic knowledge of the subject, the ability to understand some of the life situations, to sense their complexion, is considered to be the general education bases. Therefore, we support selection of subjects according to student's choice of higher education in the last two years of high school education at our school.



- Student cognitive abilities training

It is important to train, so help student in ability to learn more effectively.

- I. The subject: "To learn how to learn" was added to our education program in 2004. We work with Raven Feuerstein instruments there. [6, 7, 8] We train two and three dimensional imagination before the atomic or molecular orbital image creation.

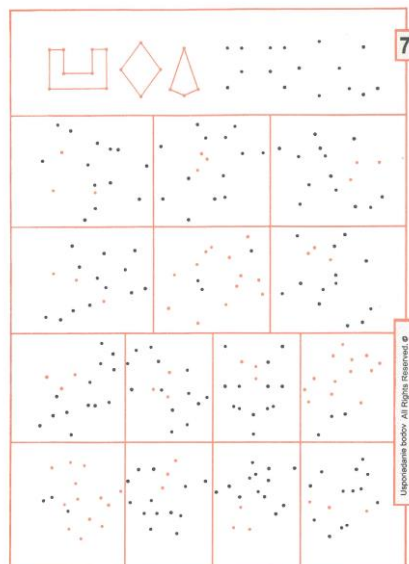


Fig. 2. Feuerstein instrument for 2D vision training

- II. Students are thought to observe, register natural phenomena, conclude, verify and generalize the conclusion in the subject Science for 10 to 13 years old students with 4 classes of the laboratory work and 1 theoretical class per week.
- III. Mutual themes of natural science subjects such as electrolysis, basic image of quantum physics and chemistry, physical consequences of chemical bonds are thought in classes with two teachers of both subjects.

2. Education program for Chemistry and natural sciences of the 1st independent high school

We have education program based on: identification of the basic knowledge of chemistry, solution of the phenomena through the integration of natural sciences subjects, training of the key competencies.

2.1. Basic knowledge

Basic knowledge should be identified in such range that even student with minimal amount of information and experiences is able to work adequately with wide range of phenomena and manage to master even deeper content of the field by self-education. The basic knowledge should be the material, what all the key competencies are trained on. The basic knowledge of chemistry is presented in our school program as written below.

The study of chemistry begins practically in the level ISCED 1 in the subjects called: Discovering the world and Science. Students observe the natural phenomena. They learn to talk about them independently, describe them and induct them into the relations. The content integrates several natural and social sciences fields.



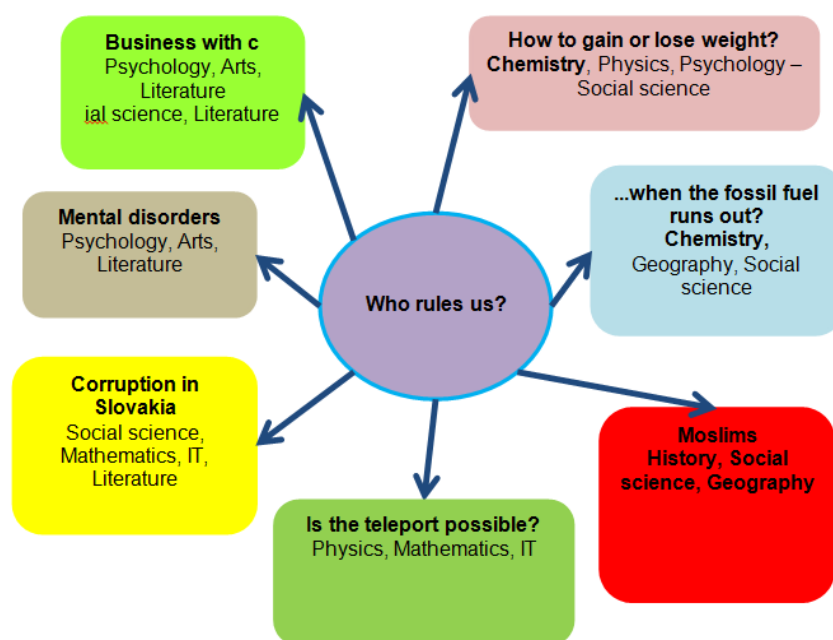
Second step continues in the level ISCED 2 in the subject Science in 4 classes' laboratory work and 1 theoretical class per week. Students receive the possibility to research the phenomena being in progress daily in their nearest surrounding and to experiment and search for answers to coming out questions. Formulating the questions and search for answers is crucial in these lessons. The main theme for further study of chemistry is the chapter: Substance structure. Student **creates image** of particles contained in the substance. Formation of the particles during Big Bang is represented by experiment of observed crystallization nuclei. Electron is presented as an electron cloud – shapeable balloon with special properties. Mutual force interaction between one nucleus and electrons of another atom is presented as a deformation of electron cloud and a creation of the chemical bond possibly expressed by change of newly obtained substance properties. Based on the chemical bond theory we later talk about physical and chemical properties of the gases, liquids and solid substances.

Further these created images lead to the subject chemistry in the last year of the level ISCED 2 and in the level ISCED 3 with 2 theoretical and one laboratory lesson per week. More detailed information about the atomic electron shell; atomic electronegativity and type of created bonds are the basic knowledge on this level. Very important themes are creation of the molecule geometry of simple inorganic and organic compounds. Supporting programs for molecule image creation can be found as freeware in internet in example ETC Educhem. Discussions about possible electron shell changes induced by another particle interaction are background for the chemical reaction image. It is the time to learn and accept the chemical language (formulas and names of compounds, description of chemical reactions by equations) in this state of knowledge, not sooner. The last chapter of the basic knowledge content is chemical reaction inception condition, so thermodynamics, kinetics and thermic of chemical reactions. Chemical reactions are explained and described according to the knowledge of chemical bonds. Explanation comes out of the exchange of particles between reactants, the possibility of chemical bond change etc.

At last there is the application the chapters of substance structure, atomic structure, chemical bond creation, chemical reaction inception conditions and chemical reaction progress, which are the tasks of inorganic and organic daily chemistry as well as interesting facts in biochemistry.

2.2. Integration

Integration of natural sciences subjects could be explained on the Socrates' dialogue on the theme of Mpemb's phenomenon and or ITE themes [9].



2.3. Training of the key competencies

We try to motivate student to effectively obtain the knowledge about nature and natural processes by training of the key competencies [10, 11, 12], such as using the logical operation to

- analyze whole entity and synthesize into the whole entity e.g. theme periodic system of elements
- understand of information serried text in chemical formulas and equations themes
- understand the process described by algorithm and describe the process by algorithm (preparation of experiment)
- recognize of causal inaccuracy and error, e.g. by distractors in the test exercise:
Chemical properties of the elements are determined by:
 - a) *Position of the element in the periodic table*
 - b) *Valence sphere of the element and its electronegativity*
 - c) *Position of the element in the period of the Periodic table*
 - d) *Number of electrons in the atom*
- express the thought precisely e.g.:
“Physical properties of metals are consequence of
 - a) *Chemical bond between atoms*
 - b) *Crystal lattice between atoms”*
- Think divergently – offering the choice e.g.: “Consider the possibilities for oxidation-reduction reaction products creation.”
- structure the researched field
- organize data set, assort it and hierarchize e.g. atomic structure, Mendelejev discover of periodic system
- capture the process by sign system, table e.g. chemical formulas and equations
- manipulate with idealized and abstract concept e.g. the shape of electron orbital of concrete atom
- think critically, to recognize original thoughts e.g. to suggest a method for sorting compounds out of composition
- improve the 2D and 3D vision e.g. molecule geometry
- search for solving strategies e.g. to create the molecule geometry
- transfer ideas from situation to another one e.g. to describe the type of chemical reaction for different elements from one group
- overcome standard procedures by innovative ones e.g. to prepare different compounds
- construct logic maps of the whole
- guess the result before proceeding the calculation
- find limits of the solution
- find analogies of the problem
- describe the solution qualitatively as well as quantitatively
- argue own opinion and find counterarguments
- make a complex chain from partial intellectual activities e.g. to derive atomic and molecular characteristics from partial experiments or information
- work in the team

3. Methods of key competencies training

3.1 To be able to learn from experience e.g. experiments in laboratory classes

This competence is used lifelong. It is often misunderstood and replaced by the term “having praxis”. Having the praxis does not mean effective learning, the praxis alone does not guarantee flexible learning employee for the employer. Learning from experience contains four steps forming the cycle.

The first step is actual experience, the second step is reflexing the experience, the third step is creating new concept of the problem and the fourth step is planning of the active experiment and again step one: actual experience (from the experiment etc).



The first step: Actual experience can be realistic or substitution of the reality. We create the actual experience by observing the chemical process, work with the case study, role playing, and simulation games in the process of education.

The second step: Reflexing the experience means systematic evaluation of the actual experience, evaluation of own achievement and preparation for it. An advantage can be writing the work (laboratory) diary, where the facts about work are captured as well as own feelings and evaluation of procedures. It has the character of dialogue

The third step: New concept of the problem represents contextualization the experience with the theory. It answers the questions: Why the success was a success? Why the failure was a failure? How could the failure be prevented?

The fourth step: There is summed up and applied knowledge from previous steps in planning new experiment. The plan of next activities is prepared in this step.

Positive side of this method is the fact that mistakes and failures are considered as instruments of learning.

3.2 To contextualize real facts and organize knowledge of different types and field

Knowledge of person is non-transferable. Only information is transferable. Knowledge is created in the mind of learner as an individual construction. The construction creation depends on most common learning abilities of the person (according to the Bloom taxonomy). Offering space and time for this process leads to the skill of working with the knowledge and recognizing original approaches and ideas. Standard procedures may be overcome by inventive ones if the learner is able to:

- Structuralize researched field
- Apply assorting and hierarchy of phenomena, concepts, experiences etc.
- Apply ideas obtained from one situation to another
- Describe a process by algorithm
- Transform the symbols and algorithms of other people into the own ideas of reality
- Search for solution strategies

3.3 To organize information of different types

Learning is an active process. The base of success is:

- Sufficient motivation
Being able to motivate students is the pedagogical and psychological art of the teacher. It is successful only in cooperation with whole society mostly with the student's family. The motivation in chemistry is derived from the possibility of experiments. Therefore we prefer experimentation to theorizing.
- Clearly set goals
Training of this competence is easier by teacher stating following information in the beginning of the class or course. Needed information is: actual object specification in the course, standards (either for content and student's achievement), theme schedule, and the most importantly key competencies trained during the course in actual themes. (Common and legitimate student's questions are: "What is this for? Where will I use this information? Why do I need it?") Training the key competence may be used as adequate motivation agent
- Adequate activity planning and time management
To master in preparing own work plan is essential competence for whole life. To date the tasks, informing of the exams and evaluations dates, expectation of agreed tools, and the clear plan of each class is helping to learn this. Evaluation dates are helping as well. Teachers actually are not supposed to catch a student in the act of ignorance; they are supposed to give him a possibility to show what he knows and is able to do.
- Self-evaluation of the learning process:
Student should have time to obtain information about his own learning from teachers as well as from his peers. The theme: Learn how to learn should be essential in planning the content of homeroom classes (e.g. in Slovakia homeroom classes are once per week for each student with his classmates)



usually used for organizational information). All the learning evaluation data should be mainly in the center of student's attention and secondly of the parents' attention. Adequate evaluation is therefore also verbalizing the evaluation, not only grade the knowledge.

- The next new goal
Evaluation is meaningful only in further changes. The change should reflex previous mistakes and search the way to achieve the goal

3.4. Ability to solve problems

A task becomes a problem if the solution is not based on memory or automatic repetition of learned steps and procedures or mechanic usage of experience. A problem is a problem if the answer is not known and the path to the answer is not known as well. This situation needs a very learning.

The first step is definition of the problem. It needs:

- Precisely know the information content in words, pictures, used situations.
Adequate training is the skill of comprehensive reading of scientific, artistic or technical texts, understanding the rules of communication, dialogue, discussion, task analysis, signs reading information transfer from symbol into the own constructions, process describe by algorithm understanding, ability to create such an algorithm, ability to organize and hierarchize the data set
- Precisely set the question.
Adequate training is the creation of quiz questions for peers, evaluation of test questions by students, case study, recognition of causative inaccuracy in the information, encourage students in question asking during the class as well as out of the class.

The second step is giving the time to think. Student should learn the way of his thinking and the type of his intelligence. To understand what on level is his realization of logical operation. Does he make intuitive conclusions or he thinks in structures more? Is he able to analyze and/or synthesize? It is adequate to train the result guess, to know own solution strategies, to overcome standard procedures, to find solution limits, to find solutions for analogical problems, to be able to describe the problem qualitatively and quantitatively as well.

The third step is critical thinking. There is a pre-requisite in ability of evaluation, assumption according to criteria, searching for concepts, structure creation, e.g. categorization and argumentation of own opinion, active, precise and deep in problem thinking without stereotypes.

The last step is to have the courage to decide. We train it e.g. in formative tests with the choosing from possibilities answer, if none of the possibilities is absolutely right, but it is possible to choose the best one according to the known criteria. Student has to have limited time for decision, work independently and assert himself. Teacher has to make space for quiet and submissive students as well.

3.5 To be responsible for own learning

Responsibility is the competence required nearly in each job offer. Individualization is a considerable trend of postmodern era. Parents allow their children the process of deciding for themselves in very early age. Unfortunately, the reason for this allowance is a resignation for upbringing their own children many times. The possibility of deciding must go hand in hand with taking the responsibility and stand the consequences, because freedom without responsibility is anarchy. The training of the responsibility for own learning begins in motivation. There has to be clear goal in being in high school. The help with search for this goal is the task for the class teacher e.g. in homeroom classes, discussion clubs etc. as well as other teacher in actual classes. Importantly, student has to become familiar with possible professions (with the help of parents) and types higher education possibilities in the required field as soon as possible. Later on, there comes the possibility to create personal learning project in high school by defining obligatory and satisfactory conditions for successful accomplishment of study. Being responsible for own learning needs clear aiming demand, standards and evaluation of achieving them. This information must be known by student in advance. Teacher can help student in organizing own learning process in choosing subject and specializations (e.g. see Fig.1.). We do not take the process of learning chemistry as an isolated issue of usage student's

competencies, but as well as a procedure and training of the student's key competencies for whole and professional life.

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