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PROBLEMS WITH TEACHING PHYSICS AND CHEMISTRY AT ACADEMIC LEVEL - THE CASE OF MARITIME UNIVERSITY OF SZCZECIN

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Abstract: The education reform being implemented stirs a lot of emotions both among teachers as well as pupils and their parents. However, a close consideration of the present upper secondary school graduates and their abilities of assimilating the material obligatory at higher education level lead to a conclusion that the current core curriculum at the third and the fourth level of education urgently needs to be changed. Furthermore, changes of the number of hours allocated at present to sciences ought to be reconsidered. The changes are necessary, because the number of hours allocated at present to teaching sciences does not match the amount of information and skills that a future student of a technical university ought to possess. Education at the third and fourth level of education has a very strong impact on the possibility of educating young people at higher education institutions. This paper presents young people's educational problems by examining the case of the Maritime University in Szczecin.

Keywords: education reform, problems with teaching physics and chemistry, core curriculum of physics and chemistry.

Introduction

Currently, new core curricula are being developed for all subjects at post lower secondary schools and for newly created primary schools. It is a matter of extreme importance from the standpoint of teaching sciences at academic level. Upon closer examination of the present core curriculum and the material that a student of the first year of the Maritime University must assimilate it is easy to see why students find it very hard to understand the issues discussed during computational and laboratory classes in physics and chemistry. At present, a first-year student of the Maritime University needs to master the issues that will enable them to assimilate information and acquire skills of, e.g.: calculating vessel displacement or stability, which are useful in the subsequent years of study. Determining the above-mentioned physical values is impossible without a previous analysis of the forces acting on a given body in liquid. Information on buoyant force is currently taught at lower secondary school level and the issue is no longer continued at upper secondary school level – if a pupil does not previously select an advanced physics programme. Virtual lack of physics classes (the legislator provided for one physics class in the first grade) at the fourth education stage, i.e. at post lower secondary school level, results in the inability of solving problems of physical or chemical nature during technical studies. Students face huge problems with planning and conducting experiments at physics laboratory classes, despite the fact that there is laboratory instruction at their disposal, devised especially with a particular experiment in mind. The greatest problems are observed in analysing measurement errors and formulating conclusions. Students report that they experience difficulties analysing popular-science texts. They are unable to interpret information from research papers. That problem is related to the gaps that emerge in previous years of physics education.

Problems with teaching physics

Students are unable to recall the material taught at lower secondary school. Additionally, the knowledge acquired at lower secondary school is neither reinforced nor advanced at upper secondary school – unless a pupil has chosen advanced physics programme. At the fourth level of education mainly new issues of nuclear physics and radioactive disintegration are discussed. Frequently, solving computational problems or problems requiring a greater degree of deduction, defining cause and effect relations of a given physical phenomenon are not required at lower secondary school level. On account of the above, first-year students of technical universities find it problematic to apply basic concepts of physics and physical quantities in order to describe the phenomena in their surrounding reality. Ignorance of the laws of physics and physical relations entails inability to solve physics problems. Moreover, students are unable to overcome the barrier of constructing physical models to describe observed phenomena. A mathematical description of an experiment or illustration of the laws of physics and physical relations occurring in a given physical phenomenon pose tremendous difficulty to students. Upon closer examination of the core curriculum currently in force at the third and fourth level of education, one can clearly see why students encounter such huge problems in learning science subjects. At the third stage of education a lower secondary school pupil is expected to learn fundamental concepts regarding rectilinear motion, the issues related to mechanical energy and heat. Moreover, pupils study the built and properties of matter (including the concept of density and pressure). Apart from that, lower secondary school pupils learn the basics of electricity, magnetism, elements of oscillating motion and selected issues of electromagnetic waves and optics. One needs to bear in mind that at this stage of education emphasis is placed on identifying a given phenomenon, and not on its deeper analysis, which ought to be carried out at the subsequent stage of education. However, at the fourth stage of education (upper secondary school) the core curriculum for basic programme of physics makes virtually little reference to the issues discussed earlier. The current education framework at the fourth stage of education comprises the problems regarding gravitation and selected elements of astronomy. The present core curriculum includes the concepts of uniform circular motion, centripetal force, the impact of gravitational force of the Sun on the motion of planets and planet gravitational force exerted on their moons along with gravitational force as the cause of bodies falling to the Earth's surface. The teaching content also features the issues related to circular velocity. Furthermore, the matters concerning the phases of the Moon and lunar eclipses, methods of calculating Earth's distance from the Moon are brought up at physics classes. At the fourth stage of education pupils learn the principle of approximate determination of the age of the Solar System. They learn the structure of the Galaxy and the Big Bang theory. The two remaining chapters discussed during physics classes at upper secondary school level in the basic programme refer to atomic and nuclear physics [1]. The teaching contents proposed at the moment are extremely valuable from the point of view of developing the awareness of modern energy sources. Such orientation of the material will enable a wider use of new energy sources in the future – and will most likely reduce the fear of using the achievements of nuclear physics in everyday life. At the same time, significant lack of the problems of mechanics, dynamics, kinetics or thermodynamics is glaringly obvious. The aforementioned fields of physics constitute the foundations for teaching physics in the course of technical studies. These branches are obviously covered within the scope of advanced programme of physics at the fourth stage of education. Nevertheless, one needs to bear in mind that lower secondary school leavers are the least keen to choose mathematical and physical profile, and upon their graduation from upper secondary school they frequently decide to undertake technical studies. With the upper secondary school core curriculum of the basic level of sciences devised in such a way, their decision is not entirely well though-out. Consequently students face substantial difficulties in assimilating the material of a given field of technical studies. At times it results in a decision to resign from a technical course of study. The current situation will most likely improve, since the draft of a new Polish core curriculum, which will enter into force from the school year of 2019/2020, provides for expanding the teaching contents included in the present core curriculum. Apart from gravitation and elements of astronomy, the new basic programme of physics already includes elements of mechanics, electrostatics, electric current, magnetism, the problems of elasticity and vibrations [2]. The new curriculum also features the issues concerning thermodynamics as well as waves and optics. In the draft of a new core curriculum under discussion the questions referring to atomic and nuclear physics have been included. The branch of physics that has been completely excluded from the basic programme is the mechanics of a rigid body – these issues have only been featured in the advanced programme. Such construction of the core curriculum enables expanding the knowledge acquired at primary school level and at the same time it will make a shift from upper secondary school to tertiary education of engineering profile easier, even if a secondary school leaver did not complete an advanced programme of sciences.

Problems with teaching chemistry

The situation of chemistry teaching at higher education institution presents a similar picture. First-year students of the Maritime University in Szczecin are obligated to participate in classes of "Basic chemistry" or "Technical chemistry". Furthermore, in the third year of study at the Faculty of Marine Engineering laboratory classes on "Chemistry of water, fuels and lubricants" are administered during which basic physical and chemical parameters of water, fuels and lubricants are determined. Observation of students' reactions leads to a conclusion that a substantial proportion of them cannot recollect basic concepts of chemistry taught at lower secondary school level. Moreover, the inability of writing chemical equations is easily noticeable. It is most probably caused by a gap in chemistry education at the level of the second and third grade of upper secondary school. It results in the students' inability to foresee possible products of a chemical reaction. It may be a contributing factor to work accidents later in life. If a student fails to predict that in the course of performing certain activities (e.g. cargo hold cleaning) explosive gas may be released, and if they work in an environment in which open flame may be present, then an explosion may follow. What is more, at lower and upper secondary schools chemical experiments are typically not performed, the result of which is students' inability to use laboratory equipment and glassware. Students do not know how to handle chemical agents safely. They are not aware how to behave when utilising hazardous substances. They often do not realize that chemical substances may be harmful both to human health and the health of animals or plants. They do not associate the fact of using certain chemical substances with lesions appearing even several years later. At times highly reckless students' behaviour can be observed when they handle hazardous chemical substances. They explain such carelessness by the fact that they have worked on-board a vessel before using a given substance and they observed nothing irregular when using it. Students of extramural studies who already have gained some work experience do not see that some ship's operators sometimes do not pay attention to OHS, while incompetent handling of chemical substances may lead to tragic consequences both for the entire crew and for the environment. They do not care to put on suitable clothing and ensure proper protection of the work they perform. Students are also largely unable to translate theoretical knowledge to a situation in practice. It is most likely caused by students' inability to draw conclusions from a conducted chemical experiment or the acquired theoretical knowledge. They should have acquired such a skill at earlier stages of education. The aforementioned problems are rooted in the core curriculum of previous stages of education. At those stages insufficient emphasis is placed on the proper behaviour while handling chemical substances. Studies show that a significant proportion of pupil population finishes education without conducting a single chemical experiment. According to teachers the reasons for such a state of affairs is lack of time caused by a mismatch of the number of teaching hours to the scope of mandatory material as well as poorly equipped chemical laboratories. The core curriculum of chemistry at lower secondary school comprises the problems regarding mass, volume and density – however, at later stages of education these concepts are not reinforced. The effect of that is that first-year students may experience problems with converting units of density. According to the core curriculum a first-grade pupil of a lower secondary school should be able to assign a given substance to a proper group of elements or chemical compounds or mixtures. In the case of mixtures a pupil should be able to indicate a difference between a homogeneous and non- homogeneous mixture as well as describe methods of mixture separation. Section two of the core curriculum [3] for the third stage of education is dedicated to internal structure of matter, where a pupil is expected to learn the structure of an atom, isotopes, ions, the mechanism and type of chemical bonds, to determine an empirical and structural formula of simple binary chemical compounds. Other subjects included in the core curriculum refer to chemical reactions and differentiating them from physical phenomena. Furthermore, a pupil is expected to learn how to write simple reactions of synthesis, analysis and exchange reactions. Pupils need to be able to differentiate between an exoenergic and endoenergic reaction. A lower secondary school pupil at that stage ought to know and apply the law of definite proportions and the law of conservation of mass. Other subjects that a young person needs to tackle refer to air – its composition, the development of an ozone hole, oxygen cycle in nature and problems related to rust formation. Similar situation applies to water. A pupil needs to determine the solubility of a given substance in water, calculate percentage concentration of a given substance in water, to define the type of solution created. Subsequent branches of chemistry concern acids, hydroxides and salts. Pupils need to learn how to write chemical equations of reactions in which the aforementioned compounds are created and at the same time pupils ought to, in line with the core curriculum, provide examples of application of the above-listed compounds. The last items of the core curriculum at the third stage of education provide for studying the basics of organic chemistry, i.e. division of hydrocarbons and their properties along with hydrocarbon derivatives and their biological significance. At present, a majority of previously described issues is no longer advanced at stage four of education in the basic programme. If one notices that a definite majority of students have not completed advanced programme of chemistry, the knowledge of chemistry after the fourth stage of education of an upper secondary school leaver comes down to simple issues regarding the chemistry of cleaning products, soil chemistry, elements of human nutrition and processes of food preservation, the use of medication and substances as well as chemistry of packaging and clothing. Furthermore, at the fourth stage of education some simple problems referring to fuels as well as materials and materials of natural origin are raised. The teaching material that is currently taught at the first grade of post lower secondary school largely comprises the content that enables learning the application of chemistry and the importance of chemistry in basic spheres of life – which is of great significance, however, on these grounds it is very difficult to introduce specialised issues regarding e.g. fuels used in maritime navigation. Students are unable to remember the difference between the phenomenon of viscosity and density, which are discussed in the first grade of lower secondary school. Frequently these two concepts are treated as being synonymous. A two-year gap in chemistry education and very general matters discussed in the first grade of upper secondary school cause substantial problems not only in learning chemistry at academic level, but also in communicating and applying the right terminology. At present it is hard to predict what will be taught at the fourth stage of education, since a draft of teaching contents and learning objectives are not yet available – they will be published in the near future (at the end of August 2017). On 26 of May 2017 preliminary consultations on the core curriculum for individual subjects in the framework curriculum for public post-primary schools have been concluded – including also for chemistry. In the school year of 2017/2018 the core curriculum for chemistry in the 7th and 8th grade of primary schools is not very different from the old core curriculum for lower secondary school

[4]. Nevertheless, a greater emphasis was placed on obtaining, processing and creating information from various sources, the application of the acquired knowledge to solve problems, including calculation of chemical laws. A fact of great significance is that at this stage of education pupils are expected to use simple laboratory equipment and selected chemical agents, what is more, pupils are to design simple chemical experiments, present observations and formulate conclusions. One can only hope that the subject matter discussed at upper secondary school level will be extended – as has been done in the case of physics.
The number of teaching hours allocated to technical subjects has a significant impact on the current state of knowledge and skills of general and technical upper secondary school leavers. Currently a lower secondary school pupil does four hours of physics in the course of three years, divided into 1+1+2 classes per week, and then one hour per week in the entire post-lower secondary school cycle, unless a pupil selects an advanced programme of physics. The situation is the same in the case of chemistry. Students of the Maritime University who completed advanced programme of physics or chemistry at upper secondary school constitute approx. 5% of all students of the Maritime University in Szczecin. Such a percentage share of students who completed an advanced programme of sciences suggests that a substantial number of individuals studying at the Maritime University of Szczecin encounter immense problems in assimilating the issues discussed at laboratory classes, computational classes and lectures in physics. The situation is further exemplified by the number of people who succeed in examinations and obtaining credits in subjects such as physics or chemistry in the first year of study. Only a small percentage of students are capable of successfully passing an examination or obtaining a credit at their first attempt. The situation will probably change once new framework curricula have been implemented at public schools and once the numbers of teaching hours have been assigned to particular subjects. In line with the Ordinance of the Minister of Education dated 28 March 2017 on framework teaching plans for public schools the following has been implemented [5]:
- an eight-year primary school, where four hours have been allocated for physics and four hours for chemistry classes to be realized in the seventh and eighth grade (two hours of physics and two hours of chemistry for each of the aforementioned grades);
- a four-year secondary school, where one hour of physics and chemistry per week were allocated in the first grade, one hour of physics and two hours of chemistry per week in the second grade, and two hours of physics and one hour of chemistry per week in the third grade, provided that a pupil does not realize advanced material in either of the subjects. If a pupil does realize an advanced programme, in the four-year system of secondary education the school provides for six hours for each of the subjects per week (on top of the number of hours designated for the basic programme);
- a five-year technical secondary school, in which physics and chemistry are taught four times per week in the five-year period of education. The subjects can be taught in the first, second, third and fourth grade;
- a three-year vocational school of the 1st degree, which provides one hour of physics and chemistry in the first grade during a three-year cycle. In the subsequent grades these subjects are no longer continued;
- a two-tear vocational school of the 2nd degree, where no classes of chemistry or physics are featured in the curriculum;
- a two-year vocational school of the 2nd degree (intended for graduates of present lower secondary schools) where no classes of chemistry or physics are featured in the curriculum.
Comparing the total number of hours assigned to science subjects at lower and upper secondary schools in their present form with the number of hours proposed in the new education reform (from 2019/2020) – the change seems to be beneficial. At present, an upper secondary school graduate had the benefit of 4 hours of physics at the stage of a 3-year lower secondary school + 1 hour of physics at the upper secondary level (in the case of the basic programme), while in line with the newly implemented act, a pupil has 4 hours of physics at primary school + 4 hours at secondary level. The same applies to chemistry. In the case of an advanced programme, additional 6 hours play a significant role. Such a change in the number of hours will most certainly facilitate holistic perception of the variety and complexity of the phenomena of the surrounding world. It will develop the ability of understanding physical and chemical processes and phenomena. A change of the previous construction of the framework teaching curriculum at the secondary level should translate into the quality of students' education, since thoroughly assimilated basics of physics and chemistry provide a solid foundation for continuing education at technical university studies.

Conclusions

Students lack an established ability of identifying physical phenomena or chemical transformations. It is an effect of a low number of hours dedicated to sciences at every stage of education, as well as a mismatch of the core curriculum in sciences to the requirements posed by higher education institutions. In the case of students of engineering fields a particular emphasis needs to be placed on developing the abilities of creative problem solving. What is more, the skill of building cause and effect relations needs to be developed at every stage of education. A realistic evaluation of experimental results is also a significant aspect, which is further linked with a critical approach to information provided in every-day life. At the stage of higher education it is vital to take into account the fact that a student needs to learn qualitative and quantitative estimation as well as efficient calculation. The latter aspect does not receive sufficient emphasis at lower stages of education. It is understandable, as the teaching of sciences at early stages is chiefly aimed at inspiring curiosity about the world, facilitating its description and stirring imagination. Only when we are able to identify the phenomena occurring in nature and specify the laws governing it, can we talk of quantitative description, and consequently of a creative use of physical and chemical phenomena in science, professional work and technology. In order to improve the situation in which students find themselves, the Maritime University conducts compensatory courses in sciences. Thanks to that approach young people find it a little easier to achieve their own goal – completing an interesting course of study, even if to a large degree it is an engineering field of study. Furthermore, a closer cooperation between academic teachers and teachers of secondary schools is of great value. It will help in understanding mutual expectations of both groups of teachers, it will ensure the continuity of teaching, and most importantly, it will improve the situation of general or technical secondary school leavers at a time when they undertake the hardship of studying at a technical higher education institution.

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