Appendix 4
of Regulation No 2 of the Government
of the Republic of 6 January 2011
National Curriculum for Upper Secondary Schools

Last amendment 29 August 2014

Subject Field: Natural Science

1. General principles

1.1. Subject Field Competence

The objective of teaching natural sciences at upper secondary school is to develop the student's natural sciences competencies, which means scientific and technological literacy, which covers the capability to utilise observations and explanations of phenomena taking place in the natural, artificial and social environment (hereinafter *environment*); to analyse the environment as an integrated whole, notice different problems occurring in it and make justified decisions; to utilise scientific methods and use knowledge about biological, physio-chemical and technological systems to solve problems; to value science as a part of culture and to follow a sustainable lifestyle.

Teaching natural sciences is aimed at the upper secondary school graduate having developed the capability to:

1) interpret phenomena at the micro, macro and mega levels, and appreciate the role of models in describing natural phenomena;
2) use sources of scientific and technological information in Estonian and English, presented at the verbal, numerical or symbolic level and critically evaluate such information;
3) determine and analyse environmental problems, differentiate between the scientific and social components of these problems; use scientific method to gather information, frame research questions or hypotheses, check variables through observations or experimentation, analyse and interpret results and make evidence based conclusions;
4) use systematic information obtained from studying biology, chemistry, physics and geography for solving everyday problems and making justified decisions;
5) understand the interlinking and particularities of natural sciences and the place of emerging interdisciplinary scientific subjects in this overall system;
6) appreciate science as a process of obtaining scientific information in its historical and modern context, the role of creativity in scientific discoveries and the limitations of science;
7) evaluate and predict the effects of technological achievements to the environment on the basis of scientific, social, economic, political, ethical and moral standpoints;
8) value the environment as a whole and follow the principles of sustainability and healthy lifestyles;
9) be interested in local and global phenomena taking place in the environment and society, as well as in new developments in science and technology, make career decisions and be motivated towards lifelong learning.

1.2. Subjects of the Subject Field and number of courses

The subjects in this field are biology, geography (physical geography), physics and chemistry. The subjects are divided into compulsory and optional courses. The compulsory courses by subject are the following:

1) Biology 4 courses: ‘Cells’, ‘Organisms’, ‘Inheritance’, ‘Evolution and Ecology’
2) Geography 3 courses: 2 courses of physical geography ‘System Earth’, ‘Natural resources and their management’ and 1 course of human geography ‘Population and Economy’ included in the subject field of social subjects,
3) Chemistry 3 courses: ‘Foundations of Chemistry’, ‘Inorganic Compounds’, ‘Organic Compounds’
4) Physics 5 courses: ‘Introduction to Physics. Kinematics of Translational Motion’, ‘Mechanics’, ‘Electromagnetism’, ‘Energy’, ‘The Physics of the Micro and Mega Worlds’.

Eight optional courses have been described in the natural sciences subject field: ‘Applied Biology’, ‘Geoinformatics’,‘Principals of Chemical Processes’,‘Chemistry of Elements’, ‘Chemistry of Life’, ‘Physics and Engineering’,‘Another Kinds of Physics’

Six interdisciplinary optional courses have been described in the field of natural sciences: ‘Natural Science, Technology and Society’, ‘Mechatronics and Robotics’, ‘3D Modelling’, ‘Technical Drawing’, ‘Using Computers for Inquiry’, ‘Basics of Programming and Development of Software Applications’.

1.3. Description of the Subject Field and integration within the subject field

The subjects in this domain should develop scientific and technological literacy through:

1) acquiring empirical knowledge about biological and physio-chemical definitions, laws and theories defining the substance of the specific subject and corresponding to modern scientific achievements;
2) using scientific methods that forms the common basis of all science subjects;
3) taking into consideration scientific, economic, political, environmental, social, ethical and moral aspects when solving problems and making decisions;
4) developing creativity, communication and cooperation skills, acknowledging risks, developing attitudes and career awareness.

The internal integration of the subjects in the subject field of Natural Science supports the development of a system of scientific knowledge. Natural sciences help to understand the applications of technology. An overview of the main laws, theories, practical applications, future directions and the related applications and professions based on natural sciences supports the students in their everyday lives and in choosing a career.

The aim of studying **biology** is to gain a comprehensive overview of the diversity of life, the structures and functions of organisms, heredity, evolution and ecology, as well as the main principles of environmental protection and applied biology. Based on the main theories, general laws and their applications, the students gain a wider scientific world view, improve their skills of solving biological problems in everyday life and coping in the natural and social environment.

Geography is considered to be both within the subject fields of Natural Science and Social Science. Studying geography develops the students’ concept of the Earth as a system, gives them an understanding of different processes in nature and society, their spatial distribution and interdependence. The focus is on promoting sustainable ways of life, natural and cultural diversity, attitudes valuing active participation in civil society as a responsible citizen and the use of modern technology. Studying **human geography** the students acquire an understanding of the phenomena and processes in the nature and society, their spatial distribution and interdependence. Also the students’ problem solving and research skills are improved

In **chemistry** lessons, the aim is to broaden the students' knowledge of chemistry and their scientific world view. The students gain an overview of the main laws of chemical processes, associations between phenomena and laws, the future developments in chemistry and the related applications and professions.

In **physics** lessons, the students learn the laws, on which modern technology is based, learn to explain phenomena in a scientific way, using also mathematical methods. Studying physics broadens the student's scientific world view, the student will understand the role of physics in the modern society.

1.4. Options for forming general competencies

The subject field enables developing all general competencies in everyday learning activities both through theory and practical work. The teacher plays the central role in connecting the four differentiated and interrelated components – knowledge, skills, values and behaviour – of competencies and the values and self-establishment skills of the teacher create a suitable learning environment and affect the students' values and behaviour.

Cultural and value competence. In studying science subjects, the student's attitude towards science is shaped, their interest towards sciences is developed, their sustainable attitudes towards the environment, including all living organisms, is enhanced and sustainable, responsible and healthy lifestyles is valued.

Social and citizenship competence. When solving dilemmas and making justified decisions scientific arguments and aspects of human society – such as legal, economic, environmental, ethical and moral arguments – are considered. Active learning methods support the achievement of social competence.

Self-awareness competence. The development of the student's ability of self-analysis and the ability to evaluate one's weaknesses and strengths is supported. By learning about the particularities of the human organism and its place in the environment, the students learn to solve problems related to their mental and physical health and everyday life.

Learning to learn competence. Through scientific problem solving and using exploratory learning methods the students acquire capabilities enabling them to seek and evaluate scientific information, define scientific problems and research questions, plan and carry out experiments or observations, analyse, and present the results. The development of learning competencies is supported by using ICT-based learning environments and new technological tools.

Communication competence. Correct use of scientific language and the ability to understandably present scientific information is developed through written and oral communication, solving dilemmas and socio-scientific problems, and gathering and interpreting scientific information.

Mathematics, natural sciences and technology competence. Studying sciences develops the skill of recognising scientific questions, understanding scientific phenomena, the importance of the development of science and technology and its impact on the society and making evidence based decisions. Mathematic skills are implemented when analysing and generalising the measurement results in all natural science subjects and the student's acquire the skills for using new technological solutions in their studies and everyday lives.

Entrepreneurial competence. Studying natural sciences develops the student's creativity, ability to set goals and cooperate for achieving the goals. The students learn to choose suitable and innovative methods for carrying out their ideas, to take responsibility and complete activities. Problem-oriented learning and recognising the importance of scientific knowledge and skills gives a strong basis for entrepreneurship attitudes. Supporting the students' initiative helps them become persons able to think and take initiative, who approach life's challenges creatively and flexibly.

1.5. Options for integrating subjects with other subject fields

Language and literature, incl. foreign languages. By learning natural sciences and working with texts natural sciences, the skills of understanding and analysing texts are developed in students. By generating various texts (e.g. summaries, presentations, etc.) they develop the ability to clearly express themselves both in oral and in written form. The students use appropriate language tools, subject-related vocabulary and rich expressive language, and respect the rules on the correct use of language. The students develop the ability to acquire information from various sources and evaluate it critically. The students are instructed to format their papers correctly, make references and protect intellectual property rights. Natural science terms originating from foreign languages are explained and foreign language skills are further developed by having the students search for and comprehend additional literature.

Mathematics. The development of mathematics competence is supported by natural sciences through research and problem study which develops creative and critical thinking. An important part of research study is data analysis and interpretation as well as presentation of results in the form of tables, graphs and diagrams. Mathematical models are applied in studying the connections between natural phenomena.

Social studies. Learning natural sciences helps to understand the functioning of individuals and the community, develops the ability to perceive the connections between the developments in the community and the environment and the ability to make conscious choices, and act as a moral and responsible community member and person.

Art subjects. The development of arts competence are supported by the formalisation of research results, making of presentations, visiting of exhibitions, appreciating the beauty of nature during educational outings, etc.

Physical education. The learning of natural sciences supports the appreciation of physical activity and healthy lifestyles.

1.6. Options for implementing cross curricular topics

Lifelong learning and career planning. Different learning activities direct the students to understand and value lifelong learning as a lifestyle and to consider career planning as a continuous process of making decisions. Learning activities enable direct contact with the working world, e.g. visits to companies, students being introduced to occupations professions and further learning possibilities related to the subject field. The learning activities enable the students to deepen their knowledge of the associations between education and the working world. The student's ability to learn independently and their responsibility and skills of independently finding and analysing information about educational options based on their development needs and to prepare a career plan is developed. Different learning activities, including the independent work of the students, enable the student to associate their interests and capabilities with their subject knowledge and skills and to understand that hobbies and interests keep life and career in balance. A general positive attitude towards natural sciences and learning them, interest in continuing to study natural sciences is achieved by taking into consideration the interests and individuality of the student and by applying problem and investigation based studies. Learning activities enable the student to broaden their understanding of the specialities in the field of natural sciences and the modern work of scientist.

Environment and sustainable development. At the upper secondary school level, the students develop their skills of making justified decisions and evaluation, taking into consideration the potential and limitations of modern scientific and technological developments, as well as legislative documents. This supports their readiness to become involved at the personal, social and global levels in environmental protection issues as citizens with critical minds, and to apply sustainable and economic practices in their private and business lives.

Civil initiative and entrepreneurship. Natural sciences value cooperation based on democracy and free will, develop cooperation skills and promote initiative. Awareness of civil rights and obligations is related to all matters of human and environmental development both on the local and global levels.

Cultural identity. Appreciation of the living environment of Estonia, the cultural heritage, the naturalists related to Estonia and their contribution to the development of science. Developing tolerance towards different ethnic nationalities and cultures.

Information environment. Information environment. By learning natural sciences, information is collected from various sources and assessed critically.

Technology and innovation. New scientific achievements, materials and technologies are introduced to value the role of science in improving quality of life of humans and environmental preservation. Novel teaching methods are applied to support initiative, creativity and critical thinking abilities in students, and to enable them to evaluate the advantages and risks associated with new scientific achievements.

Health and safety. Through experimental work students learn safe ways of working to avoid risks and correct behaviour in the case of accidents. In studying science subjects the students gain, in the form of information and values, an understanding of healthy lifestyles.

Values and morality. The scientific knowledge and skills are the basis for developing values necessary for preserving life and the living environment.

1.7. Planning and Organizing Study Activities

In planning and organising curricular activities:

1) the starting point is basic values, general competences, subject competencies, educational goals and the expected learning outcomess of the curriculum, while also supporting integration with other subjects, generic competencies and cross-curricular topics;
2) the aim is to achieve a moderate learning load (including homework) which is divided evenly during the whole school year and leaves the students enough time for rest and recreational activities;
3) the students are given the opportunity to take part in individual and group learning (individual, paired and group work, educational excursions, practical work, work in computer-based learning environments and with materials from the Internet and other sources of information) to support their development as active and independent learners;

4) differentiated study assignments are used, the essence and level of difficulty of which should support an individualised approach and increase students' motivation to study;
5) learning environments as well as learning materials and equipment based on ICT are used;
6) the educational environment is broadened: computer classes, the school yard, natural environments, museums, exhibitions, enterprises, etc.;
7) the learning process is supported by a wide range of active learning approaches: role play, discussions, debates, project learning, compiling learning folders and research papers, practical work and students` investigations etc.

In addressing the course content, specialist teachers make their choices with a view to achieving the described learning outcomes and the general and subject field competences.

1.8. Assessment

Assessment of learning results is based on the stipulations in the general part of the Upper Secondary School National Curriculum and other legislation concerning assessment. Knowledge and skills are assessed on the basis of students' oral answers (presentations), written and practical activities, and considering the correspondence of students' knowledge and skills to the aims set in the curriculum. Assessment is given as a verbal grade and as a numerical grade. In grading written papers and tests, the subject learning of the work is primary; all spelling mistakes are corrected, but are not taken into account in grading. The forms of assessing learning are varied and correspond to the learning outcomes put forward. The students must know what will be assessed and when, how the learning is measured and what criteria are used.

In upper secondary school biology, the learning outcomes are divided into two main fields: developing (1) mental abilities in the context of biology; and (2) experimental problem solving and decision-making skills. These fields are presumed to comprise 70% and 30% of the grade respectively. The ratio of lower and higher order mental processes in determining the grade of learning is approximately 40/60. The general stages of problem-solving that are evaluated are the following: (1) identifying the problem, (2) planning the investigation, (3) finding solutions, (4) applying a strategy and (5) evaluating the results. In the case of issues with several equally good solutions (such as dilemmas), decision-making is added to the stages. In evaluating the solutions provided for dilemmas, the level at which the different arguments are considered is taken into account.

1.9. Physical learning environment

The school shall organise:

1. for practical work, the school shall organise study in groups, if needed;
2. practical work in a classroom, where there is hot and cold water, skinks, electrical sockets, work desks with a special cover, at least one mobile data collection set with the main device and different sensor per four students, and ICT demonstration tools for the teacher;
3. in the Chemistry classroom, where there is a fume cupboard for demonstrative experiments;
4. in the Geography classroom where there is a necessary set of World atlases and Estonian atlases (atlas for each student)
5. in the Biology classroom, where there is a microscope connectable to the microscope camera and a binocular;
6. in the Physics classroom, where there is at least one computer per four students for group work and analysis and the option of darkening the room for optics experiments.

The school shall enable:
1. The school shall supply the equipment and materials as well as presentation tools needed for practical work listed in the curriculum.
2. The school shall create an environment suitable for collecting and storing the materials needed to carry out practical work and presentations.
3. The school shall provide students with lessons outside of the school territory (in the natural environment, museums and/or laboratories) at least twice per school year.
4. The school shall enable curricular activities in computer classes where the students can carry out the tasks listed in the curriculum.

2. Syllabuses

2.1. Biology

2.1.1. Learning and Educational Objectives

Biology lessons at the upper secondary school level are designed for students to:
1) develop their scientific and technological literacy, as well as creativity and a systematic way of thinking;
2) exhibit interest in biology and other sciences, value the importance of sciences in everyday life and become motivated for lifelong learning;
3) gain a systematic overview of nature and its major processes and be able to use biological vocabulary in communicating to the scientific community and the general public;
4) exhibit a responsible attitude towards their immediate environment in tackling socio-scientific issues and illustrate values, acquired through studies in biology, are commiserate with the importance of biological diversity and sustainable and responsible ways of life;
5) determine and use different sources, including electronic sources, to obtain biological information, and critically assess this information;
6) utilise appropriate scientific methods in solving problems related to biology;
7) make competent socio-scientific decisions related to their everyday lives on the basis of scientific, economic, political, ethical and moral perspectives, , and forecast the consequences of their decisions; and
8) relate the importance of biology to careers and use their knowledge and skills of biology in appreciating career opportunities in the field of science and technology.

2.1.2. Description of the Subject

The biology taught in upper secondary school is based on developing competencies in the use of knowledge, skills, attitudes and values acquired from basic school; it is linked to chemistry, geography, physics, mathematics and other subjects taught in upper secondary school. The use of knowledge, skills, attitudes and values gained from biology lessons at this level, when integrated with the use made of knowledge, skills, attitudes and values gained from other subjects, form the basis for internally motivated lifelong learning.

Through problem-solving, the biology taught in upper secondary schools gives students a comprehensive overview of the diversity of life, the structure and functioning of organisms, heredity, evolution and ecology, as well as the basics of environmental protection and applied biology. Students gain knowledge of laws, theories and trends in biology, as well as of their applications and professions connected to biology, thus helping them make career decisions.
The knowledge and skills of biology are learned predominantly through exploratory tasks based on scientific methods. Through these tasks the students learn the skills of problem-setting, framing hypotheses, planning experiments and observations, carrying them out, and analysing and

interpreting the results. Another important aspect is oral and written presentations of research results, involving appropriate verbal and visual forms of presentation. At the same time, skills in solving the biological problems occurring in everyday life and making competent socio-scientific decisions are developed, improving the students' ability to survive in natural and social environments.

The learning process is problem-based and student-centred, guided by the personality and age traits of the students as individuals, and their different talents. TStudies are based on active learning principles with a focus on exploratory discourse based on scientific methods, and solving biological problems integrating the natural, technological and social environments, through which the students develop their higher mental processes.

Technological instruments and ICT are used during all stages of the learning process. At the same time, skills in using various (including electronic) sources of information and evaluating the truthfulness of the information obtained from these sources are also developed. In upper secondary school biology, one focal point is developing the intrinsic learning motivation of the students, and to achieve this aim, various active learning methods – problem learning and exploratory learning, project learning, role plays, discussions, brainstorming, compiling definition cards, outdoor learning, educational visits et al. – are used.

Through all of this, students acquire biological knowledge and skills, thus enabling them to understand, explain and forecast various natural phenomena and processes. At the same time, a positive attitude towards biology as a science and as a cultural phenomenon is developed, also taking into consideration the scientific, economic, social, political, ethical and moral aspects of socio-scientific decision making.

2.1.3. Learning Outcomes in Upper Secondary School

Biology lessons in upper secondary school level are designed for students to gain competiencies so as to be capable to:

1) value their knowledge of, skills in and attitudes towards biology as important components of scientific and technological literacy and to be internally motivated for lifelong learning;
2) acknowledge the interrelations of nature, technology and society and understand their influence on the environment and society;
3) gain a systematic overview of the main objects and processes making up the organic world, the relationships between organisms and their interaction with the inorganic world;
4) show a responsible attitude towards the environment they live in and value biological diversity and a sustainable and responsible lifestyle;
5) apply the scientific method to solving biological problems, plan, carry out and analyse observations and experiments and present the results obtained in the correct verbal and visual form;
6) make competent socio-scientific decisions about the natural and social environment and predict the consequences of these decisions;
7) use various (including electronic) sources to find information about issues of biology, to be able to analyse and critically evaluate the information obtained from these sources and apply it effectively in explaining objects and processes in the organic world as well as solving problems associated with the organic world;
8) reasonably use technological means, including ICT possibilities, in studying biology and carrying out research.

2.1.4. Learning Outcomes and Learning Content of the Courses

2.1.4.1. 1st course 'Cells'
The field of biology

Learning outcomes

By the end of the course, students can:

1) compare the characteristics of organic and inorganic nature of substances and recognise aspects characteristic of the organic nature only;
2) connect the organisational levels of the organic world with the characteristics of life and describe the fields and professions of biology studying these levels of organisation;
3) give reasons for the necessity of using scientific methods in solving scientific and everyday problems;
4) plan and carry out inquiry-based experimentation
5) analyse texts about problems associated with applying scientific methods, giving reasoned opinions about these texts; and
6) using scientific methods arrive at sound conclusions.

Learning content

Characteristics of life and comparison of organic and inorganic nature; organisational levels of the organic world and branches of biology investigating them and corresponding professions; characteristics of life typical to organic nature at the molecular, cellular, individual, population and ecosystem level of organisation; planning and carrying out scientific experiments and analysing and presenting the results; applying the scientific method in solving biological and everyday problems.

Practical work and use of ICT

Carrying out a small-scale biology investigation project to gain an overview of the scientific method.

Composition of organisms

Learning outcomes

By the end of the course, students can:

1) compare the chemical compositions of organic and inorganic matter in nature;
2) associate the properties of water with the functioning of organisms;
3) explain the importance of cations and anions in the structure and functioning of organisms;
4) associate the structure of carbohydrates, lipids and proteins with their functions;
5) compare the structure and functions of DNA and RNA; and
6) appreciate the role of water, minerals and biomolecules in healthy nutrition.

Learning content

Comparison of chemical composition of organic and inorganic nature; the connection between the properties of water and life processes of living organisms; general structure and functions of biomolecules; structural and functional relationships between the most important biomolecules – carbohydrates, lipids, proteins and nucleic acids; structure of DNA and RNA and comparison of their functions; the role of water, minerals and biomolecules in healthy nutrition.

Practical work and use of ICT

1. Comparison of the chemical composition of different organisms using data from the Internet as the source of information
2. Investigate the effect of temperature on enzyme reactions
3. Practical work: isolating DNA and investigating its properties

Cells

Learning outcomes

By the end of the course, students can:

1) explain the unity of organic nature of matter according to the main principles of cell theory;
2) associate the structure of human epithelium, muscle, connective and nervous cells with their functions and identify these tissues on slides, microscope images and drawings;
3) explain the role of the cell nucleus and chromosomes in the functioning of cells;
4) compare active and passive movement through the cell membrane;
5) associate the components of animal cells (the cell membrane, cell nucleus, ribosomes, mitochondria, lysosomes, Golgi apparatus, endoplasmic reticulum and cytoskeleton) with their functions;
6) identify the main parts of an animal cell on microscope images and drawings; and
7) compile and analyse sketch drawings and definition cards for the functional relationships between cell components.

Learning content

Main principles of cell theory and its importance in understanding the unity of the organic world; the correspondence between cell structure and its functioning (using mainly human tissues as an example); the relationship between the structure of an eukaryotic cell and its biological processes (using an animal cell as an example); the cell nucleus and the role of its chromosomes; the main functions of the cell membrane and passive and active movement through this membrane; the role of ribosomes, lysosomes, Golgi apparatus and mitochondria in biological processes; the functions of the endoplasmic reticulum and cytoskeleton; the integration of cell structure and functioning and the team work of organelles.

Practical work and use of ICT

1. Using computer models, or practical work to explore structural and functional relationships between the parts of an animal cell.
2. Identifying epithelium, muscle, connective and nervous cells under a microscope and describing their main structural elements.
3. Investigate the effects of environmental factors on the functions of the cell membrane.

Cell diversity

Learning outcomes

By the end of the course, students are expected to have the capacity to:

1) describe the main techniques for performing a microscopic examination;
2) analyse the roles of plastids, vacuoles and the cell membrane in the life of plants;
3) compare the structure of animal, plant and fungal cells and identify these cells on slides, microscope images and drawings;
4) compare bacterial cells with eukaryotic cells;
5) identify bacterial, fungal, plant and animal cells on microscope images and drawings;
6) by giving examples, identify the use of fungi and bacteria in applied fields of biology;
7) associate the most common human fungal infections with the preventive measures used against them and value healthy lifestyles; and
8) describe the significant role of fungi and bacteria in nature and appreciate them as an important part of the organic world.

Learning content

Relationships between plastids, vacuoles, the cell membrane and the life processes of plants; the main distinctions of fungal cells compared to other eukaryotic cells; the role of fungi in nature and for humans and their importance in applied biology; human fungal infections and their prevention; the structure and functioning of the prokaryotic cell and its main distinctions compared to the eukaryotic cell; the life of bacteria and their effect on nature and human activities; human bacterial diseases and their prevention; the importance of bacteria in applied biology.

Practical work and use of ICT

1. Identifying animal, plant and fungal cells under a microscope and describing their main components.
2. Describing the diversity of plastids through observations made under a light microscope.
3. Using computer models, or practical work to explore the factors influencing the growth of fungi or bacteria.

2.1.4.2. 2st course 'Organisms'

Energy needs of organisms

Learning outcomes

By the end of the course, students are expected to have the capability to:

1) analyse the energy needs and energy-producing methods used by autotrophic and heterotrophic organisms;
2) explain the universality of ATP in energy storage and transfers;
3) explain the role of environmental factors during the stages of respiration and in energy storage;
4) by giving examples, indicate the value of fermentation from applied biology;
5) compare the cost/benefit ratio of aerobic and anaerobic respiration in human muscle;
6) analyse the tasks, results and importance of photosynthesis;
7) compile and analyse sketch drawings and definition cards describing the relationships between photosynthesis and the biosphere; and
8) describe the value of photosynthesis for plants, other organisms and the biosphere as a whole.

Learning content

Energetic needs of organisms and the methods of energy-producing used by autotrophic and heteroprophic organisms; general flow of substance and energy in organisms; ATP as the universal mediator for energy storage and transfers; respiration as a mechanism providing organisms with energy; preconditions for the stages of respiration and their results; aerobic and anaerobic respiration; fermentation as anaerobic respiration and its applications; the tasks and results of photosynthesis; an overview of light-dependent and light-independent reactions and the factors influencing them; the importance of photosynthesis for plants, other organisms and the biosphere.

Practical work and use of ICT

1. Using computer models or practical work to explore the cost/benefit ratio of breathing.
2. Using computer models or practical work to explore the factors controlling photosynthesis.

Development of organisms

Learning outcomes

By the end of the course, students are expected to have the capacity to:

1) by giving examples, recognise types of non-sexual reproduction in different types of organisms;
2) evaluate the results and importance of sexual and non-sexual reproduction;
3) use photos and drawings to explain the changes taking place during the stages of meiosis and mitosis;
4) compare spermatogenesis and oogenesis in humans and analyse the sources of differences;

5) analyse the mechanisms and effectiveness of different contraceptives and value family planning;
6) make decisions related to the dilemmas of the feasibility of pregnancy termination in problem situations and forecast the impact of such action;
7) appreciate healthy lifestyles in the context of gamete formation and foetal development; and
8) analyse the changes that take place in humans at the cell and organism level during aging and evaluate the influence of genetic and environmental factors on life span.

Learning content

Sexual and non-sexual reproduction in different organisms and the importance and results of these two types of reproduction; changes in cells during the stages of cell cycles; changes in the chromosome complex during mitosis and meiosis and their importance; comparison of the formation of male and female gametes and the factors influencing their formation; external and internal fertilisation in different animals; fertilisation of the human ovum in females; the mechanisms of different contraception methods and comparison of their effectiveness; transmission of sexually transmitted diseases and their prevention; human pre-natal development and birth; stages of post-embryonic development in vertebrates; factors influencing the life span of organisms; changes accompanying the aging of humans and death.

Practical work and use of ICT

1. Investigate the influence of environmental factors on the growth of yeast.
2. Observing the structure of a chicken's egg.

Regulatory mechanisms in humans

Learning outcomes

By the end of the course, students are expected to have the capacity to:

1) associate the parts of the human nervous system with their functions;
2) analyse the role of different factors on the formation of neural signals and their transmission;
3) associate the most common disabilities and diseases of the nervous system with their manifestations;
4) value the showing of a negative attitude towards the use of substances damaging the nervous system;
5) explain the importance of protective mechanisms and the immune system in the human body;
6) compile and analyse sketch drawings and definition cards describing the role of neural and humoral regulations in coordinating the functioning of the human body;
7) explain the mechanisms of guaranteeing stable blood composition and its importance; and
8) describe the thermoregulatory mechanisms in the human body and the relationships between these mechanisms.

Learning content

General structure of the human nervous system and its functioning; factors influencing the formation and transmission of signals in nerve cells; the structure of chemical synapses and transmission of neural signals; the reflex arc and transmission of signals to the muscles; the effect of neural signals on muscle tissue and its regulatory mechanisms; the functions of brain regions and areas; inborn reflexes and generated reflexes; the most common disabilities and diseases of the human nervous system and factors damaging the nervous system; neural and humoral regulation of organ systems; mechanisms of assuring a stable internal environment within the human body; an overview of protective mechanisms and the immune system and its most common disorders in the human body;

the role of digestive apparatus, the excretory system and the respiratory system in guaranteeing the stable composition of blood; energy needs of the human body and its thermoregulatory mechanisms.

Practical work and use of ICT

1. Using computer models to study the formation of neural signals and their transmission
2. Investigate the effect of external stimuli on reaction time.
3. Investigate the effect of physical effort on the energy needs of an organism (heart and lung functions).

2.1.4.3. 3st course 'Inheritance'

Principles of molecular biology

Learning outcomes

By the end of the course, students are expected to have the capacity to:

1) evaluate the role of genetic and environmental factors in the development of individual characteristics;
2) analyse the role of DNA, RNA and proteins in the expression of genetic information;
3) compare the processes and product of DNA and RNA synthesis;
4) evaluate the role of genetic regulation in different stages of human ontogenesis and appreciate the influence of the environment on genetic regulatory mechanisms;
5) compile an experiment to prove the universality of the principles of molecular biology;
6) undertake a search to find examples of human diseases associated with gene regulation disorders;
7) explain the properties of genetic code and its expression during protein synthesis; and
8) explain the synthesis of proteins.

Learning content

The factors influencing the formation of the characteristic features of organisms; the role of the main molecular processes (replication, transcription and translation) in realising genetic information; comparison of DNA and RNA synthesis; gene expression and its regulations and changes arising from disorders in genetic regulations (especially in human beings); the properties of genetic code; interpreting genetic code through protein synthesis; the roles of molecules participating in protein synthesis and the course of this process.

Practical work and use of ICT

1. Using computer models to study the main processes of molecular biology.
2. Using computer models to study the applications of genetic code.

Viruses and bacteria

Learning outcomes

By the end of the course, students are expected to have the capacity to:

1) explain the structure of viruses and give examples of viral diseases in humans;
2) analyse the characteristics of viruses that make them a connecting link between the living and non-living nature of matter;
3) compare the spreading and replication of viruses and bacteria;
4) associate AIDS with the workings of HIV in the human body;
5) compare viral and bacterial infections, their effects on organisms and their possible treatments and appreciate healthy lifestyles designed to avoid infections;
6) by giving examples, value uses of viruses and bacteria in genetic engineering;

7) solve dilemmas about genetic engineering applications considering their scientific, economic and ethical aspects as well as legislation; and
8) demonstrate a knowledge of the specialties and professions connected to genetics and genetic engineering.

Learning content
Structural and functional diversity of DNA and RNA viruses, examples and their role in nature; spreading and replication of viruses; the effect of HIV on the human body and AIDS as a disease; the most common viral infections in humans and their prophylactics; spreading and replication of bacteria; the possible uses of viruses and bacteria in genetic engineering; scientific, legislative, economic and ethical problems associated with genetic engineering; specialties and professions connected to genetics and genetic engineering.

Practical work and use of ICT
1. Undertaking an investigation on the diversity of bacteria.
2. Using practical work or computer models to investigate factors influencing the life processes of bacteria.

Heredity and mutation
Learning outcomes
By the end of the course, students are expected to have the capacity to:
1) by giving examples, investigate expressions of heredity and mutations in different types of organisms;
2) compare and contrast the origins and products of mutational and re-combinational genetic variations;
3) analyse diagrams of modificational mutations;
4) evaluate the effect of heredity and environmental factors on the development of individual characteristics in humans;
5) associate the phenotypal relationships of Mendel’s experiments with the re-combination of genotypes;
6) explain the genetic causes of the most common sex-linked disabilities in humans;
7) solve genetic exercises involving Mendel’s laws, the A-B-O and rhesus blood group systems and sex-linked inheritance; and
8) illustrate, with justification, actions expected of a responsible attitude towards the role of environmental factors in human disabilities and diseases.

Learning content
Heredity and mutation as characteristics of life; the role of hereditary mutations in shaping the characteristics of organisms; the role of mutational and re-combinational genetic variations in nature and for human activities; the mechanisms of non-hereditary mutations and their importance; the relationship between hereditary and non-hereditary mutations in humans; the laws of Mendel’s hybridisation experiments and their practical value; determining gender in humans and sex-linked inheritance; genetic exercises involving Mendel’s laws, the A-B-O and rhesus blood group systems and sex-linked inheritance; the effect of heredity and environmental factors on human health.

Practical work and use of ICT
1. Investigatingthe effect of environmental factors on the norms of biologically related reactions.
2. Using computer models to investigate the mechanisms and expression of hereditary mutation.

2.1.4.4. 4st course 'Evolution and Ecology'

Biological evolution

Learning outcomes

By the end of the course, students are expected to have the capacity to:

1) explain the evolutionary views of Darwin;
2) by giving examples of scientific research, present evidence of biological evolution;
3) analyse and evaluate theories on the origins of life on Earth;
4) compare types of natural selection, the conditions of their occurrence and their products;
5) analyse and evaluate the roles of different factors in the emergence of new species;
6) analyse the origins and manifestations of evolutionary diversification, improvement and extinction;
7) evaluate the roles of biological and social factors in the evolution of modern man; and
8) illustrate, through justified actions, how a critical attitude towards pseudo-scientific discourse on biological evolution is possible.

Learning content

Development of the idea of evolution paralleling developments in science; main principles of Darwin's theory of evolution; evidence for evolution obtained from scientific work; various approaches to the origin of life on Earth; the first stages of biological evolution and emergence of modern life; the struggle for existence and its forms of expression; natural selection and its types and products; adaptation and the emergence of different types of adaptation; the role of mutational variation, re-combinational variation, genetic drift and isolation in species formation; the origin and manifestations of macro-evolutional processes: evolutionary diversification, improvement and extinction; biological evolution and systematics; the separation of hominids and anthropoid apes and the emergence of new features; Hominidae and how they compare to apes; scientific views regarding the origin of modern man; factors influencing human, biological and social evolution; pseudo-scientific discourse on biological evolution; specialties and professions studying evolution.

Practical work and use of ICT

1. Using computer models to investigatee the human struggle for existence.
2. Investigate experimentally, in the local area, effects of natural selection

Ecology

Learning outcomes

By the end of the course, students are expected to have the capacity to:

1) Associate, with explanations, the effect of abiotic factors with the life processes of organisms;
2) analyse diagrams of the effects of abiotic and biotic factors and give practical examples;
3) associate,with explanations, the structure of an ecosystem with the food chain relationships within it;
4) compile and analyse sketch drawings and definition cards about the feeding relationships in an ecosystem;
5) explain the formation of self-regulation in an ecosystem and possible sources of danger;
6) evaluate the role of anthropogenic factors in changing the balance of an ecosystem and demonstrate a sustainable and responsible attitude towards the natural environment;
7) solve problems based on the rule of the ecological pyramid; and
8) compile and analyse sketch drawings depicting changes in energy flows through the biosphere.

Learning content

The role of abiotic ecological factors in the life processes of organisms; graphic description of the effect of ecological factors and its applications; the role of biotic factors in different forms of co-existence between organisms; the structure of ecosystems and mutual relationships in them; the relationships between the main links – producers, consumers and decomposers – in the food chain; the emergence of self-regulation in ecosystems and factors influencing it; the relationship between the number of populations, their size and changes in the ecological balance; using the rule of the ecological pyramid to solve problems; energy flow through the biosphere and the foundations for life on Earth.

Practical work and use of ICT

1. Exploring the effects of abiotic factors on the number of populations and their size.
2. Using computer models to explore self-regulation in ecosystems.

Environmental protection

Learning outcomes

By the end of the course, students are expected to have the capacity to:

1) analyse the role of human activities in species extinction and demonstrate responsibility in their activities in the natural environment;
2) explain the importance of the protection of biological diversity;
3) value biological diversity and acknowledge the responsibility of every human being in its protection;
4) identify the mutual relationships between nature, technology and society and give reasons for sustainable development at the personal, local, national and international levels;
5) explain the groups of protected natural objects listed in the Nature Protection Act of Estonia and give examples;
6) appreciate the protection of nature and the environment as a cultural phenomenon;
7) use local examples to solve environmental dilemmas considering scientific, economic and ethical perspectives as well as legislation;
8) subject basic trends in nature and environmental protection to critical analysis and determine a justified position.

Learning content

Anthropogenic factors of species extinction and options for species protection; the need to protect biological diversity and methods of protection; modern trends in nature and environmental protection in Estonia and on a global scale; state regulations and domestic measures shaping environmental policy in Estonia; applications of the sustainable development strategy at the personal, local, national and international levels; nature protection legislation and organisation in Estonia; considering scientific, economic, ethical and moral perspectives as well as legislation in solving environmental dilemmas and making decisions; trends and actions in nature and environmental protection based on grassroots movements.

Practical work and use of ICT

1. Investigating ways in which a sustainable development strategy has been applied at the local level.
2. Analysing personal everyday activities from the viewpoint of sustainable and responsible lifestyles.

2.2. Geography

2.2.1. Learning and educational objectives

Geography lessons at the upper secondary school level are designed for students to:

1) become interested in geography and other sciences and social sciences and understand their role in our everyday life and in the development of societies;
2) acquire a systemic overview of phenomena and processes of nature and societies, their spatial distribution, mutual relationships and developments;
4) 3) be aware of and distinguish between local, regional and global socio-economic and environmental problems and illustrate justified actions as a responsible citizen in determining solutions; solve usingscientific methods problems in geography;
5) explainthe possibilities for, and consequences of, human activities in various geographical settings, while valuing a multicultural environment and the need for sustainable development in their surroundings as well as other areas;
6) seek geographical information from sources of information in Estonian as well as other languages, evaluate the information critically and make reasoned conclusions and decisions;
7) obtain an overview of professions associated with geography, apply knowledge and skills of geography to everyday lives and consider this in making career decisions; and
8) enhance scientific and technological literacy, including being creative and motivated for lifelong learning.

2.2.2. Description of the subject

Geography is an integrated subject considered to be both a science and a social science subject. The geography in upper secondary school is based on the knowledge, skills and attitudes acquired during basic education; it is intertwined with the curricula of physics, chemistry, biology, mathematics, history, civic studies and economics. The knowledge, skills and attitudes learned in geography lessons support motivated lifelong learning.

Studying geography develops the students' concept of the Earth as an integrated whole and their understanding of different processes in nature and society, as well as the spatial distribution and interdependence of these processes. The focus is on learning the interaction between the environment and human activities and on supporting sustainable behaviour. The environment is understood in its broadest sense, encompassing the natural, economic, social and cultural environments.

Geography plays an important role in shaping the values and attitudes of the students. Integrated discussion of natural, population and cultural geography forms the basis for understanding cultures and a tolerant attitude towards the cultures and traditions of other countries and peoples. Understanding the integrated evolution of nature and society forms the basis for understanding modern problems of development and for planning future developments. In order to cope in a globalising world, people must be better informed about its different regions and their economies, cultures and traditions. Studying geography helps students define themselves as active citizens of Estonia, Europe and the world.

In studying geography, the students acquire skills in reading maps and using the numerous possibilities of information technology – skills that are becoming more and more important in our mobile society. Another important feature of geography is Geographical Information Systems (GIS), which are becoming more and more important in many professions and fields of human activity.

The material of the subject is presented as problem-based wherever possible, with examples given from everyday life. Studies are based on the individuality of the students and the multi-faceted development of their abilities. A lot of attention is paid to developing motivation in the students for learning. To achieve this aim, various active learning methods – problem learning and exploratory learning, project learning, discussions, brainstorming, role plays, educational visits, etc. – are applied. Modern technological equipment and ICT are used.

Exploratory learning gives the students skills in proposing scientific problems, framing hypotheses, planning research work, collecting data, and processing, interpreting and presenting the results. Another important aspect is developing the ability to use sources of information, including the Internet, and the ability to assess these sources critically.

2.2.3. Learning outcomes in upper secondary school

Academic achievement describing the satisfactory level of achievements for a student in upper secondary school in put forward as learning outcomes.
By the end of the course, students are expected to have the capability to:

1) show interest in local and global phenomena occurring in nature and society, in researching these phenomena, and in fields of life associated with science;
2) explain the principles of spatial distribution of natural and social phenomena, their dynamics and the relationships between them;
3) analyse the possibilities and consequences of human activities in various geographical conditions, valuing a multicultural environment and natural diversity in their surroundings as well as other areas;
4) analyse the mutual influences of nature and society at the local, regional and global level, can give examples and appreciate the sustainable development;
5) use information sources (including web-based) for finding information about Geography, critically evaluate the information found in them and express it in correct and expressive language;
6) use scientific methods to solve scientific problems stemming from socio-scientific issues in the environment and everyday life; and
7) appreciate and use knowledge of Geography in new situations to solve scientific and technological problems, and make reasoned socio-scientific decisions, including career planning decisions.
8) use modern technological tools for gathering, processing and communicating information about Geography.

2.2.4. Learning Outcomes and Learning Content of the Courses

2.2.4.1. 1st course 'Population and Economy'
History and methods of geography

Learning outcomes

By the end of the course, students are expected to have the capacity to:

1) relate the history of geography to the current situation, discuss connections between geography and other sciences and recognise the position of geography in the sphere of modern science;
2) by giving examples of modern methods used in geography, carry out observations and surveys, use questionnaires and employ databases to obtain the necessary information;

3) find, evaluate and use sources of information (including maps) to obtain information, analyse correlations and make generalisations and conclusions; and
4) analyse natural conditions and the populations, economies and possible consequences of human activities in a given area using various sources of information, including maps.

Learning content
History of geography, its main fields of study; modern techniques used in geography.
Keywords: human geography and physical geography, remote monitoring, GIS, base map of Estonia.
Practical work and use of ICT: solving problem tasks using the geoportal of the Land Board and other interactive maps.

Development of societies and globalisation

Learning outcomes
By the end of the course, students are expected to have the capacity to:
1) justify indicators of development and how countries are grouped according to them;
2) characterise agrarian, industrial and information societies;
3) explain different aspects of globalisation and give examples of its effects on developed and developing countries;
4) use evaluated sources of information to compare and analyse the degree of development and its variation within one country; and
5) present a justified position of the current political map of the world.

Learning content
Classification of states by their development and contribution to world economy; measuring the degree of development; states by their degree of development; population, economy and spatial organisation of agrarian, industrial and information societies; globalisation and the emergence of the world economy.
Keywords: agrarian, industrial and information societies, developing and developed countries, globalisation, GDP, Human Development Index.
Practical work and use of ICT: Seeking and using information sources to analyse the degree of development comparing countries and their development by their development index.

Population

Learning outcomes
By the end of the course, students are expected to have the capability to:
1) analyse the location and density of the global population or the population of a given region or country using sources of information;
2) analyse population dynamics on a global scale or in a given region or country according to demographic transition theory and associate population dynamics with the development of the area analysed;
3) analyse age and gender structure as shown on a population pyramid together with its consequences for economic development;
4) compare birth and death rates in developed and developing countries and explain the main reasons for differences;
5) by giving examples, discuss population politics and why they are necessary;
6) identify types of migration and the main routes of international immigration, analyse the migration of a given area and associate this migration with major push and pull factors;
7) analyse positive and negative consequences migration has on source and target countries together with its effect on people changing their country of residence;

8) find, evaluate and use sources of information to analyse the population (demographic situation) and demographic processes of a given country together with the effect on the economy of this country, and
9) put forward justificated positions related to cultural diversity, including aspects of tolerance of the customs, traditions and religion of other peoples.

Learning content
Distribution and density of population and factors influencing it; global population and changes in it; demographic transition; population structure and its effect on the development of nations; factors influencing the birth and death rates; population politics; causes of migration and its classification; main global routes of migration; consequences of migration; problems with refugees around the world.
Keywords: demography, demographic transition, traditional population structure, modern population structure, population explosion, population aging, birth rate, death rate, natural increase, age and gender structure of population, migration, immigration, emigration, push and pull factors influencing migration, employment structure, population politics.
Practical work and use of ICT:
Using evaluated sources of information to compose an overview of the demographic situation of a given country.

Settlements
Learning outcomes
By the end of the course, students are expected to have the capability to:
1) compare cities, towns in developed and developing countries;
2) analyse the process of urbanisation by comparing developed and developing countries;
3) analyse the internal structure of urban settlements and its transformations on the basis of given information;
4) by giving examples of city planning in developed and developing countries, analyse social and environmental problems accompanying cities;
5) find, evaluate and use maps and other sources of information to analyse the settlements in a given country or region; and
6) justify the extent, size and location of the world's urban areas and compare and contrast the world's largest cities and urban conglomerates on a map.

Learning content
History of settlements and the factors determining the locations of settlements in different periods of history; the history of global urbanisation in developed and developing countries; internal structure of urban settlements and its transformations; problems accompanying urbanisation in developed and developing countries; the urban environment and urban planning.
Keywords: urbanisation, emergence of suburbia, counterurbanisation, reurbanisation, over-urbanisation, conurbation, megalopolis, slum, internal structure of urban settlement.
Practical work and use of ICT: preparing an overview of the demographic situation of one chosen country on the basis of information sources.

Changes in the global economy
Learning outcomes
By the end of the course, students are expected to have the capacity to:
1) use evaluated sources of information to analyse the economic structure and the employment and dynamics of a given country;

2) analyse the shift in production locations using car manufacturing and light industry as an example;
3) by giving examples, analyse the effect of technology and product development on the development of the economy;
4) use evaluated sources of information to analyse the tourism sector of a country, the prerequisites for its development, its connections to other sectors of the economy, its role in the world economy and its effect on the environment;
5) use evaluated sources of information to analyse the position in transport geography and the role of transport in the economy of a country; and

Learning content

Changes in the structure of the economy and in employment; Factors influencing production and changes in the location of production using car manufacturing and light industry as an example. Role of international companies in the economy. The role of tourism in the economy of the country and its impact on the environment. The role of tourism in national economies, environmental effects of tourism; development of transport and its influence on the world economy.

Keywords: structure of the economy, primary, secondary, tertiary sectors of the economy, capital, network economy, high-tech production, science park, fordism, toyotism, geographical division of labour, position in transport geography, international corporation.

Practical work and use of ICT: analysis of the position in transport geography or tourism economy of one chosen country on the basis of information sources.

2.2.4.2. 2nd course 'System Earth'

Introduction

Learning outcomes

By the end of the course, students are expected to have the capacity to:

1) characterise, with justification, the Earth as a system and give examples of relationships between them;
2) analyse the relations between natural environment the natural environment and human activities; and
3) describe the general evolution of Earth on the basis of the geological time scale.

Learning content

Earth as a system; formation and evolution of Earth; geological time scale.

Keywords: system, open and closed system, geological time scale.

Lithosphere

Learning outcomes

By the end of the course, students are expected to have the capacity to:

1) justifiably identify limestone, sandstone, granite, basalt, marble and gneiss in nature and pictures, seek evaluated information on their main properties and give examples of their uses;
2) classify rocks and explain the rock cycle;
3) describe the internal structure of the Earth and compare and contrast the continental and oceanic crust;
4) describe geological processes in the periphery areas of plate and hotspots;
5) use evaluated sources of information to characterise the geological processes of a given area and associate these with plate movements;

6) use evaluated sources of information to characterise and compare volcanoes, associate their locations with plate tectonics and their shapes and types of eruption with magma properties;
7) know regions where earthquakes occur, explain their causes and how their force is measured;
8) by giving examples, justify phenomena accompanying earthquakes and volcanism, as well as their effects on the environment and economy.

Learning content
The structure of earth's core. Composition of the lithosphere. Classification of rocks on the basis of their emergence. Plate tectonics, movement of plates and processes associated with it; volcanic activity; earthquakes.
Keywords: lithosphere, asthenosphere, mantle, inner and outer core, minerals, rocks, sedimentary, igneous and metamorphic rocs, rock cycle, ores, mid-ocean ridges, oceanic trench, folded mountains, volcanic islands, hotspots, continental rift, magma, lava, stratovolcano and shield volcano, fault, focus of an earthquake, epicentre, seismic waves, Richter magnitude scale, tsunami.
Practical work and use of ICT
Using evaluated sources of information to compile an overview of the functioning of a volcano, tectonic area or geologic structure in a particular place.

The atmosphere

Learning outcomes
By the end of the course, students are expected to have the capacity to:
1) evaluate of the composition of the atmosphere and the structure of the atmosphere with the help of figures;
2) explain the Earth's radiation balance and the Greenhouse Effect;
3) explain how climate is shaped by different factors, including the development of seasons;
4) explain air circulation and its effect on a specific, local climate;
5) analyse the effect of the climate on other components of nature and on human activities;
6) justifiably forecast the climate of a given location using weather maps
7) analyse the climate of a given location using maps on topic and climate charts and associate it with the factors shaping the climate; and
8) analyse, on the basis of figures, the short and long term changes in climate and explain the role of different factors, including astronomical, in climate change.

Learning content
The role of the atmosphere and its composition and structure; Distribution of solar radiation on Earth radiation balance; the Greenhouse Effect and its importance; factors shaping the climate; distribution of solar radiation; air circulation; local differences in temperatures and precipitation; masses of air and warm and cold fronts; climate changes.
Keywords: atmosphere, troposphere, stratosphere, ozone layer, radiation balance, greenhouse gases, Greenhouse Effect, astronomical factors shaping the climate, polar circles and tropics, air circulation, Coriolis force, cyclone, anticyclone, warm and cold front, monsoon, trade winds, western winds, tropical cyclones.

Practical work and use of ICT
1. Locating and evaluating the appropriateness of weather maps on the Internet and using them to describe the weather in a given location.
2. Using climate charts and maps from a given location hypothesise as to a likely description of the climate, based on the factors shaping the climate.

The hydrosphere

Learning outcomes

By the end of the course, students are expected to have the capacity to:

1) analyse the distribution of water on Earth and the water cycle and its components in different regions;
2) analyse regional differences in the temperature and salinity of ocean water using maps and figures;
3) explain the appearance of currents, the laws of their movement and their role in shaping the climate;
4) explain the tides and their importance;
5) explain the eroding and aggregating activities of waves on sheer and sloping coastlines and give examples of their effect of human activities in coastal areas;
6) know the distribution of glaciers, explain their formation, distribution and importance.

Learning content

Distribution of water on Earth and the water cycle; the importance of oceans; the role of oceans in shaping the climate; temperature and salinity of water in oceans; currents; tides. Coastal processes; different types of coastlines. Glaciers and their formation, distribution and importance.

Keywords: hydrosphere, oceans, components of the water cycle, warm and cold ocean currents, tides, continental shelf, coast, bank, eroding and aggregating activities of waves, beach ridge, spit, continental glaciers and mountain glaciers.

Practical work and use of ICT: using evaluated sources of information to compile a comprehensive survey of features of a coastline.

The biosphere

Learning outcomes

By the end of the course, students are expected to have the capacity to:

1) compare and contrast chemical and physical weathering and describe the role of weathering;
2) explain the constituents of soil, and paedogenesis;
3) analyse soil profiles using figures and explain the processes taking place in soils;
4) identify and distinguish podsol, chernozem, oxisol, and gleizated soil depicted in figures;
5) know the zonal distribution of biomes;
6) analyse the associations between natural components on the example of one biome.

Learning content

The climate and relationships between vegetation and soil; weathering of rocks Composition and structure of soil; soil characteristics. The factors of pedogenesis and soil processes, biomes.

Keywords: biome, ecosystem, physical and chemical weathering, parent rock, mineral constituents of soil, humus, humification, mineralisation, soil horizon, soil profile, podsolisation, sodding of soils, gleizated soil, podsol, chernozem, ferralitic soil.

Practical work and use of ICT: using evaluated sources of information to analyse the relationships between the climate, soil and vegetation of a given area

2.2.4.3. 3rd course "Natural resources and their management" (from the Domain of Natural Science')

Agriculture and the environmental problems

Learning outcomes

By the end of the course, students are expected to have the capacity to:

1) explain the reasons behind food problems in different parts of the world;

2) characterise self-consumption and commercial, and intensive and extensive agriculture on the example of different farm types;
3) analyse agriculture in countries with different natural circumstances and levels of development on the basis of sources of information;
4) have an overview of the main regions of cultivation of the most important crops;
5) explain the impact of agriculture to soil and groundwater;
6) bring examples about environmental problems caused by agriculture and aquaculture in developed and less developed countries.

Learning content
Global food problems; natural and economical factors influencing the development of agriculture. Forms of agricultural production; agricultural production in various natural conditions and in countries with different levels of development; the environmental effect of agriculture.
Keywords: growing season, specialisation in agriculture, subsistence crops and cash crops, extensive and intensive agriculture, organic or sustainable farming, irrigation farming, cone of depression, soil fertility, erosion of soils, salinisation and degradation, irrigation farming.
Practical work and use of ICT: using evaluated information sources to investigate the agriculture or irrigation farming in a selected country.

Forest management and forestry and environmental problems
Learning outcomes
By the end of the course, students are expected to have the capacity to:
1) explain the environmental problems associated with forestry and the timber industry;
2) analyse and justify the most forested areas and countries in the world and the major timber and timber product flows as illustrated by means of a map;
3) analyse rainforests as an ecosystem and explain the global importance of rainforests;
4) analyse the economic importance of rainforests and describe their management and environmental problems.

Learning content
Distribution of different types of forests. Destruction of forests and its reasons; equatorial rainforests and their management; temperate coniferous forests and their management. Forestry in developed and less developed countries. Sustainable management and protection of forests.
Keywords: forest types, biological diversity, area of woodlands, timber resources, timber increment, forestry, forestry cluster, sustainable development.
Practical work and use of ICT: preparing an overview of the forest management and forestry of one selected country or the comparison of the forest management of different countries.

Energy and environmental problems
Learning outcomes
By the end of the course, students are expected to have the capacity to:
1) analyse the causes of energy problems and possible solutions to them and appreciate sustainable uses of energy;
2) explain the political, economic and environmental problems accompanying the use of energy resources;
3) use evaluated information to analyse changes in world energy use;
4) analyse the use of fossil fuels for producing energy and the involved environmental problems, know the main mining/extraction regions;
5) analyse the socioeconomic and environmental problems involved in building a hydro-electric power stations on one example;

6) analyse the risks related to producing nuclear power on the example of specific examples;
7) analyse the possibilities for the use of renewable energy sources, as well as the problems accompanying them;
8) use evaluated sources of information to analyse energy resources and their uses.

Learning content
Problems with energy production around the world; energy resources and global energy management; modern technology in energy management; environmental problems accompanying production and use of energy.
Keywords: energy management, energy security, renewable and non-renewable energy sources, alternative energy production, fossil fuels, hydropower, nuclear, wind, solar, biological, tidal, wave and geothermal power, energy crisis, Kyoto Protocol, emissions quota.
Practical work and use of ICT
Using evaluated sources of information to analyse energy management in a given country.

2.3. Chemistry

2.3.1. Learning and educational objectives

Chemistry lessons at the upper secondary school level are designed for students to:

1) further develop their interested in chemistry and other sciences and understand the role of chemistry in the development of societies, in modern technology and in our everyday life, and become motivated for lifelong learning;
2) further develop their scientific and technological literacy, as well as creativity and a systematic way of thinking, and solve problems of chemistry using scientific methods;
3) identify, evaluate and use different sources to obtain information on chemistry and analyse and critically assesses this information;
4) develop, from studying chemistry and other science subjects, an integrated scientific worldview and obtain a systematic overview of the main definitions of chemistry and the rules governing the main chemical processes, and be able to use the vocabulary of chemistry in an appropriate manner;
5) carrying out chemistry investigations in a safe manner, and be able to use chemical reagents economically and safely in a laboratory, as well as in everyday life;
6) make competent decisions on the basis of scientific, economic, social, environmental, political, ethical and moral perspectives and predict the possible consequences of their decisions;
7) value a responsible attitude towards the environment and value healthy and sustainable ways of life; and
8) gain an overview of professions linked to chemistry and use their knowledge and skills from chemistry in planning their careers.

2.3.2. Description of the subject

Chemistry plays an important role in enhancing students' scientific and technological literacy. The chemistry taught in upper secondary school is based on the use of chemical knowledge, skills, attitudes and values acquired in basic school; it is linked to physics, biology, mathematics and other subjects taught in upper secondary school, while at the same time supporting the learning and teaching of other subjects. By studying chemistry, students develop several important competencies and achieve an enhanced positive attitude towards chemistry and other sciences, while also understanding the importance of the sciences in the economic, technological and cultural development of human societies. The students develop a responsible attitude towards their immediate environment and learn to value healthy and sustainable lifestyles. The knowledge, skills and attitudes gained from chemistry and other science lessons form the basis for internally motivated lifelong learning. The students develop scientific and technological literacy and an integrated scientific worldview corresponding to the upper secondary level and gain an overview of the main laws and theories associated with chemical processes, future trends in chemistry and professions linked to chemistry, thus helping them make career decisions.

Knowledge of chemistry is predominantly learned through exploratory tasks, where students learn skills of problem-setting, framing hypotheses, planning experiments and the determination of observations, carrying out the experimentation, analysing and interpreting the results. In solving chemical problems at the upper secondary level, the main focus is on understanding the problem discussed, analysing the results and arriving at conclusions, rather than learning by heart and routine training of mathematical algorithms of standard problems. Another important aspect is to develop skills in identifying various sources of information, including the Internet, and analysing and critically assessing the information obtained from these sources, as well as oral and written presentations of investigatory outcomes, involving appropriate forms of presentation. Technological equipment and ICT are used in all stages of the learning process.

In studying chemistry, the focus is on building links between this subject and other sciences, but also on processes taking place in nature (including humans) and relationships between humans and natural as well as artificial materials. Applying the knowledge and skills learned in solving everyday problems, making competent and ethical decisions and estimating the possible consequences of these decisions are all skills that are taught.

The curriculum is presented as problem-based and student-centred and linked to everyday life. The learning process is based on the individual traits of the students and their different talents, and attention is paid to developing intrinsic of the students. To achieve this, various types of active learning approaches – problem learning and exploratory learning, project learning, discussions, brainstorming, educational visits et al. – are used. Curricular activities using active learning principles help the students to develop their higher mental processes.

The chemistry taught in upper secondary school extends the knowledge, skills and expertise acquired in basic school. Compared with the basic school curriculum, the chemistry at upper secondary school considers the phenomena and processes of chemistry more profoundly, exactly and systematically, paying more attention to building connections. Inductive learning is complemented with deductive learning. Students learn to draw conclusions based on knowledge gained, find associations between different phenomena and apply their learning in new situations. The educational activities are directed towards fostering the intellect, skills and creativity of the students. Other important aspects are to develop the skill of working independently and the ability to use different sources of information and to distinguish between what is significant and what is insignificant. In studying chemistry, as with other science subjects, the development of the students' personality – independence, intellect and teamwork skills as well as responsibility and working habits – are important.

2.3.3. Learning outcomes in upper secondary school

Learning outcomes describe the satisfactory level of achievements for a student in upper secondary school.
Chemistry lessons at the upper secondary school level are designed for students to:

1) further develop interest in chemistry and other sciences, understand the role of chemistry in the economic, technological and cultural development of societies, and become motivated for lifelong learning;
2) apply scientific methods in solving chemistry problems, develop their ability to thinking logically and creatively, analyse and arrive at conclusions;
3) use various (including electronic) sources of information to obtain information on chemistry and be able to analyse and critically evaluate this information;
4) gain a systematic overview of the laws and theories in chemical processes and be able to use the vocabulary of chemistry in an appropriate manner;
5) apply skills of carrying out experiments to solve more complicated problems and use chemical reagents economically and safely in a laboratory and in everyday life;
6) make competent decisions related to everyday issues and evaluate the possible consequences of their actions;
7) understand the interrelations of nature, technology and society and their effect on the environment and sustainable development of society, value a responsible attitude towards the environment and healthy and sustainable ways of life; and
8) gain an overview of professions linked to chemistry and use their knowledge and skills in chemistry in planning their career.

2.3.4. Learning Outcomes and Learning Content of the Courses

2.3.4.1. 1st course

2.3.4.1. 1st course "Fundamentals of Chemistry"

Introduction

Learning outcomes

By the end of the course, students are expected to have the capacity to:

1) have an overview of the historical development of chemistry;
2) differentiate between qualitative and quantitative analysis and research methods in Physics and Chemistry;

Learning content

The development of chemistry as a science. Physical and chemical research methods in Chemistry. Chemistry-related career-choices.

Keywords: chemical analysis, qualitative analysis, quantitative analysis, chemical synthesis.

Practical work and use of ICT: study trip to a chemistry-related company, educational institution etc.

Subject structure

Learning outcomes

By the end of the course, students are expected to have the capacity to:

1) describe the placement of electrons in the outer electron layer of an atom (single electrons, electron pairs) depending on the placement of the element in the periodic table (in case of elements from group A);
2) explain changes in the properties of metals and non-metals in the periodic table (group A) in relation to the changes in the atomic structure;
3) determine the maximum and minimum oxidation levels of group A chemical elements according to the placement of the element in the periodic table and write the formulas for the model compounds of these elements;

4) on the basis of model examples, explain the nature of a covalent, ionic, metallic and hydrogen bond;
5) evaluate the polarity of a covalent bond on the basis of the placement of the elements forming the bond in the periodic table;
6) describe and evaluate the effect of the mutual impact of chemical bonds and molecules (also hydrogen bond) to the properties of substances.

Learning content
Modern understanding of the structure of an atom. Information in the periodic table and interpreting it. Types of chemical bonds. Hydrogen bond. Intermolecular forces. The relationship between the physical properties of a substance and the structure of a substance.
Keywords: atomic orbital, orbital, non-polar covalent bond, polar covalent bond, partial charge, hydrogen bond.
Practical work and use of ICT: investigating the structure of simpler molecules and comparing them with the use of molecule models or computer programmes.

Why and how do chemical reactions occur
Learning outcomes
By the end of the course, students are expected to have the capacity to:
1) associate a chemical reaction with particles crossing over to a more permanent state;
2) explain the thermal effects of chemical reactions on the basis of changes in energy occurring when chemical bonds are formed or disintegrated;
3) analyse the effects of factors affecting the speed of a chemical reactions and explain the changes in the speed of chemical processes in everyday life;
4) understand that in case of reversible reaction, there will be an equilibrium of opposite reactions, and bring relevant examples from everyday life and technology.

Learning content
Reaction activation, active collisions. Exothermic and endothermic reactions. The speed of a chemical reaction and influencing factors. Chemical equilibrium and it shifting (introduction of the Le Chatelier principle).
Keywords: reaction activation energy, reaction thermal effect, reaction speed, catalyser, catalysation, reversible reaction, irreversible reaction, chemical equilibrium.
Practical work and using ICT:
1) investigating the factors affecting the speed of a chemical reaction;
2) investigating the thermal effects of a chemical reaction;
3) explaining the operating principle of a car exhaust gas catalyser on the basis on online information;
4) studying the shifts in chemical equilibrium, including with the use of a computer model.

Dissolution process, chemical reactions in solutions
Learning outcomes
By the end of the course, students are expected to have the capacity to:
1) describe the creation of solutions (in case of ionic and covalent substances);
2) differentiate between electrolytes and non-electrolytes and strong and weak electrolytes;
3) explain the concepts of acid and base on the basis of proteolytical theory;
4) calculate molecular concentration;
5) create formula for interionic reactions (in molecular and ionic form);

6) evaluate and justify the environment created in the solution by dissolving different substances in water

Learning content
Dissolution process of substances. Electrolytes and non-electrolytes; strong and weak electrolytes. Proteolytical theory of acids and bases. Molecular concentration (introduction). Interionic reactions in solutions, the conditions of their course. pH. Environment in the solution of a hydrolysing salt.
Keywords: hydrating, electrolyte, non-electrolyte, strong electrolyte, weak electrolyte, acid, base, molecular concentration, salt hydrolysis.
Practical work and using ICT:
1) investigating the thermal effects of dissolution;
2) comparing the conductivity of different solutions (lightness of a light bulb or Vernier sensor); comparing the pH conductivity of weak and strong acids and bases;
3) investigating the reactions between ions;
4) investigating the environment of the water based solutions of different substances (pH of solutions)
5) specifying the concentration of a solution by titration (e.g. specifying the temporary water hardness, specifying the alkaline concentration in cleaning agents or specifying the acid concentration in battery acid etc.).

2.3.4.2. 2nd course „Inorganic substances“
Metals

Learning outcomes
By the end of the course, students are expected to have the capacity to:
1) associate the chemical properties of studied metals with the position of the element in the periodic table and their position in the period and compile corresponding reaction equations (metal reacting with a non-metal, water, diluted acid and salt solution);
2) describe the possible practical applications of the studied metals and their alloys;
3) know the most common natural metal compounds and their applications:
4) explain the principle of producing metals by reducing metal compounds and corrosion in the oxidation of metals;
5) explain the reversed energetic effect of corrosion and metal production, analyse the options for preventing corrosion;
6) analyse the general principles of redox processes (e.g. electrolysation, corrosion and in case of a chemical source of electrical current);
7) solve calculus tasks according to reaction equations, considering the yield and additions.

Learning content
Overview of the characteristic physical and chemical properties of metals. Comparison of the chemical activity of metals; reactivity series of metals. Metals and their compounds in everyday life and nature. Redox processes related to metals: producing metals from ore, electrolysis, corrosion, chemical electricity supply (without requiring reaction equations). Calculating yield and additions in molar calculations based on a reaction equation.
Keywords: alloy, ore, electrolysis, corrosion, chemical electricity supply, yield.
Practical work and use of ICT:
1) comparing the physical properties and chemical reactivity of metals;
2) investigating and comparing factors affecting the corrosion of metals and options for preventing corrosion;
3) investigating producing metals, electrolysis and chemical electricity supply with animations:
4) preparing an overview (report) on the production of one metal and producing/using its alloys.

Non-metals

Learning outcomes

By the end of the course, students are expected to have the capacity to:

1) associate the chemical properties of most common non-metals and their model compounds with the placement of the element in the periodic table;
2) write equations of characteristic reactions of the studied non-metals and their compounds;
3) describe the importance of the studied non-metals and their compounds in nature and/or the possibilities for applying them in practice.

Learning content

Overview of the physical and chemical properties of non-metals depending on the placement of the element in the periodic table. Comparison of the chemical reactivity of non-metals. Studying some non-metals and their compounds (chosen freely, on the example of natural and/or industrial processes).

Keywords: allotropy.

Practical work and use of ICT: producing non-metals and/or their common compounds, investigating and comparing their properties.

2.3.4.3. 3rd course Organic compounds

Hydrocarbons and their derivates

Learning outcomes

By the end of the course, students are expected to have the capacity to:

1) use different methods of depicting molecules (simplest structural formula, two-dimensional i.e. classical structural formula, graphic representation of molecules);
2) use the principles of systematic nomenclature on the example of alkanes; associate the prefixes or suffixes of systematic names with the studied chemical classes, determine the chemical class of based on the molecular structure or name;
3) evaluate the physical properties (solubility in different solvents and boiling temperature) on the basis of the molecular structure (capacity to form hydrogen bonds);
4) compare the chemical properties of saturated, unsaturated and aromatic hydrocarbons, write simpler reaction equations about the halogenation reactions of alkanes, alkenes and arenes an hydrogenation and catalytic hydration of alkenes (without reaction mechanisms);
5) describe the properties of more important hydrocarbons and their derivates, their applications in everyday life and dangers related to their use;
6) depict a section of a polymer produced from an alkene.

Learning content

Structure of carbon compounds and the ways of depicting it. Alkanes, nomenclature principles, isomers. Dependence of physical properties of substituted alkanes (halogen compounds, alcohols, primary amines) of their structure. Comparison of the chemical properties of unsaturated and aromatic hydrocarbons and alkanes. Chain polymerisation. Hydrocarbons and their derivates in nature and industry (introduction).

Keywords: isomerism, substituted hydrocarbon, alkane i.e. saturated hydrocarbon, unsaturated hydrocarbon, aromatic compound, chain polymerisation.

Practical work and use of ICT:

1) investigating the structure of the molecules hydrocarbons and their derivates and comparing them with the use of molecular models and/or computer programs:
2) investigating the intermolecular forces by comparing the enthalpy of vaporization;
3) mutual impact of hydrophilic and hydrophobic substances to water.

Organic substances around us

Learning outcomes

By the end of the course, students are expected to have the capacity to:

1) determine the chemical class of a substance on the basis of the molecular structure;
2) describe the properties of more important carboxyl acids and their importance in everyday life and nature;
3) explain the relationship between alcohols, aldehydes and carboxyl acids;
4) compare the chemical properties of carboxyl acids and inorganic acids and compile corresponding reaction equations;
5) describe the chemical processes in the body accompanying alcohol intoxication and the social problems associated with it;
6) compare the formation and hydrolysis reactions of esters and compile corresponding equations;
7) depict a section of a condensation polymer derived from source compounds;
8) explain in principle the structure of biomolecules (polysaccharides, proteins and fats).

Learning content

Aldehydes as the oxidation derivates of alcohols. Substituted carboxyl aids (amino acids, hydroxide acids) and functional derivates of carboxyl acids (esters, amides). Polycondensation. Organic compounds in living organisms: fats, saccharides, proteins).

Keywords: substituted carboxyl acid, functional derivates of carboxyl acids, hydrolysis, polycondensation.

Practical work and use of ICT:

1) investigating an comparing the level of oxidation of an alcohol and aldehyde;
2) investigating the strength of carboxyl acids and comparison to other acids;
3) producing and hydrolysis of esters;
4) investigating the hydrolysis of saccharides (e.g. starch) and its products;
5) investigating the behaviour of proteins (e.g. egg white water solution) with regard to acids, bases, salt solutions and heating;
6) investigating the behaviour of soap and synthetic washing products and comparing them in case of water of different acidity and added salts.

2.4. Physics

2.4.1. Learning and educational objectives

Physics lessons at the upper secondary school level are designed for students to:

1) develop their scientific and technological literacy, creativity and systematic way of thinking when describing and explaining natural phenomena;
2) be interested in physics and other natural science and be aware of the need for physics-related professions in the development of a sustainable society;
3) give value to physics as the most general science investigating the causal associations in nature and as an important cultural component;
4) understand the importance of models in studying natural objects, the development of models and their inevitable constraints;
5) collect and process information, distinguishing reliable information from noise and scientific information from unscientific information;
6) be able to solve essential qualitative and quantitative physics tasks and implement natural science methods when solving problem tasks;
7) understand the relationship between physics and technology;
8) use the knowledge and skills acquired in physics when solving natural science, technology and everyday problems and making justified decisions.

2.4.2. Description of the subject

Physics is among natural sciences, while being closely intertwined with mathematics. Physics forms the basis for understanding machines and technology and helps to value professions linked to technology. In the curriculum of physics, the importance of vertical and horizontal integration of natural science subjects is taken into account. In case of vertical integration, the universal topics are scientific methods, hierarchic structure of nature, interaction, motion (change and transformation), energy, scientific and technological literacy, technology, living environment and society. Vertical integration is supported by the horizontal integration of the subjects.

The aim of upper secondary school physics is to give necessary knowledge in physics to future citizens, to develop their attitudes directed at preserving the environment and the society and at sustainable development. At upper secondary school, physical phenomena are discussed systematically and holistically, developing a complete understanding of nature and putting emphasis on the essential relations between the parts of the complete image. Compared with the basic school curriculum, the upper secondary school curriculum more profoundly discusses various interactions and the types of motion caused by them and looks for associations between different forms of motion.

For developing the critical and systematic thinking of the students, problems and issues from various fields and subjects of life are solved by physics, experiments are planned and carried out using natural science methods. When solving quantitative tasks, it is not necessary to know the formulae by heart, but skills are developed to understand the physical content of the formulae and implement formulae in the correct context. The studies develop values, which determine the attitude of the students towards physics as a cultural phenomenon, open the role of physics in machines, technology and the environment as well as the sustainable development of the society. The physics in upper secondary school together with other subjects is aimed at developing a modern and complete worldview in the students, also a sustainable attitude towards the environment, whole also developing their skills of analysis.

The general skills developed in upper secondary school physics lessons differ from those gained in basic school in terms of more extensive use of deductive discussions and considerations of the validity of generalisations. Upper secondary school physics is more specific, but with knowledge s closely tied to knowledge acquired from other subjects and during basic school.

The physics curriculum in upper secondary school consists of five compulsory courses and two optional subjects. The first course “Introduction to Physics. Kinematics of Translational Motion” explains what physics is, what it can do and how it differs from and is associated with other natural sciences. The implementation of natural science methods is deeper, widening knowledge and skills regarding measuring as the basis of experimental sciences.

The second course “Mechanics” unlocks the central role of mechanical models in describing and explaining natural phenomena.

As all modern physics is dominated by the need to take into consideration the special characteristics of substances and fields, the third course “Electromagnetism” uses the example of electromagnetic fields to discuss the main methods of describing fields, but also the most important electrical and optical phenomena.

The fourth course “Energy” takes a look at the environment from the viewpoint of energy. Direct current, alternating current and thermal phenomena are discussed, as well as mutual transformations between mechanical energy, thermal energy, luminous energy and nuclear energy.

The fifth course "Physics of the Micro and Mega Worlds" examines the laws and processes of physics in dimensions, which are more than a million times different from the measurements characterising humans (1 m).

The order of teaching the last two compulsory courses is the teacher's decisions. The list of practical work provides general topics, on the basis of which the teacher will plan activities based on either practical work. ICS, demonstrative or participatory experiments.

The primary aim of the two optional courses described in the curriculum is to offer possibilities to broaden and deepen discussions of the latter two compulsory courses. Both of these courses consist of 15 modules, each consisting of 2-6 lessons. The teacher chooses up to 8 modules. The course "Physics and Machines" broadens and deepens students' knowledge of the topics discussed in the compulsory course "Energy", focusing on the technological applications of physics. The optional course "A Different Kind of Physics" expands the topics discussed in the compulsory course "The Physics of the Micro and Mega Worlds".

2.4.3. Learning outcomes

Physics lessons at the upper secondary school level are designed for students to:

1) describe, explain and predict natural phenomena and their technological applications;
2) value knowledge in physics in understating the mutual relations of nature, technology and the society;
3) formulate research questions on the basis of a given situation, plan and carry out experiments, process the results of the experiment and draw conclusions on the validity of the hypothesis framed in the research question;
4) solve situational, computational and graphical exercises and critically evaluate the veracity of the results obtained;
5) transform a description of the physical model of a natural phenomenon into other communicative formats (verbal description into a formula or figure and vice versa),
6) use different sources of information, evaluate and analyse the information included in them and find solution to physical problems arising in everyday life;
7) acknowledge the problems and developmental directions in the living environment associated with the development of science and technology and has a responsible attitude towards nature and society;
8) have an overview of professions, specialities and options for continuing studies related to physics, implements the knowledge and skills acquired in Physics in daily life.

2.4.4. Learning outcomes and learning content of the courses.

2.4.4.1. 1st course "Introduction to Physics. Kinematics of Translational Motion"
Physics method

Learning outcomes

By the end of the course, students are expected to have the capacity to:

1) explain the meaning of terms *nature*, *world* and *observer*, evaluate the position of physics among other natural sciences and define the field of study of physics;
2) recognise the micro, macro and mega worlds on the scheme of structural levels of nature and name the differences between these levels.
3) explain the nature of natural science method and know that generalising the results of an experiment leads to a model;
4) explain the need for rules of measurement for obtaining generally accepted measurement results;
5) understand the difference between a measuring unit and the measured quantities;

6) know and implement the main units of the International System of Units (SI) and their measurement units;
7) know that a correct measurement result also includes uncertainty and use the standard deviation when evaluating the measurement uncertainty in measuring;
8) bring examples of causal associations;
9) understand that the general principles of physics are the most general acknowledgements about nature and prove their validity with a confirmation experiment.

Learning content

Physics as a natural science. Physics as a science shifting the visibility horizons. Micro, macro and mega world. Natural science method. Observation, experiment, creating model. Verifying the conclusions of a model and model development. Measuring and measurement results. Measuring units and the value of the measured item. Measurement units and the development of corresponding agreements. International System of Units (SI). Measurement tools and measurement equipment. Measurement rules. Measurement uncertainly and its evaluation. Analysis of measurement results.
Causality and randomness in physics. Cognitive and predictive value of physics. Dangers related to physics. General principles.

Keywords: nature, natural science, measurement tool, calibration, visibility horizon, macro, micro and mega worlds; observation, hypothesis, experiment, measurement, measuring unit, system of measuring units, measurement uncertainly, measuring unit, value of the measured item, measurement result, measuring equipment, calibration.

Practical work and using ICT:

1) investigating a phenomenon of random nature (a bouncing ball, motion of a thrown body, slinging down an inclination etc.) along with analysing the measurement results;
2) measuring the linear measurements of a body and presenting correct measurement results;
3) creating a model describing different experiments on the basis of processing the measured results.

Kinematics of Translational Motion

Learning outcomes

By the end of the course, students are expected to have the capacity to:

1) understand that the physical quantities *length* (also *distance*), *time interval* (Δt) and *time* (t) are based on comparison of objects and their mutual motion (processes);
2) know that the state of motion of an body is characterised by velocity and give examples of the relativity of motion in the macro world;
3) know the main difference between relative physics and classical physics;
4) know that a field is always moving with the highest possible velocity, i.e. absolute velocity with regard to matter;
5) differentiate between scalar and vector quantities and give examples of them;
6) explain the meaning of the minus sign in physics formulas (the direction changing to the opposite of the original direction);
7) differentiate between the important characteristics of phenomena such as *even linear motion*, *evenly accelerating liner motion*, *evenly decelerating linear motion* and *free falling* and bring appropriate examples;
8) explain the meanings of physical quantities such as velocity, acceleration, distance and displacement and identify the methods of measuring and finding these quantities
9) solve problem tasks applying the definitions $v = \frac{\Delta x}{\Delta t}$ and $a = \frac{v - v_0}{\Delta t}$; describe constant liner motion and uniformly changing motion by respective motion formulas $x = x_0 \pm vt$ or

$$x = x_0 \pm v_0 t \pm \frac{at^2}{2};$$

10) analyse the charts of velocity and distance of constant and uniformly changing linear motion; be able to find the distance as the surface area in the velocity chart;
11) implement the following associations for finding the velocity, displacement and acceleration of uniformly changing linear motion, including free falling: $v = v_0 \pm at$; $s = v_0 t \pm \frac{at^2}{2}$; $a = \frac{v^2 - v_0^2}{2s}$.

Learning content

Centre of mass as a model of a body. Coordinates. Frame of reference, relativity of motion. Relativity principle. Distance and displacement. Constant linear motion and uniformly changing linear motion: velocity, acceleration, motion formula, time dependence of velocity and covered distance, corresponding graphs. Displacement, velocity and acceleration as vectoral quantities. Free fall as an example of uniformly accelerated motion. Free fall acceleration. Time dependence of velocity and height in vertical motion. Independence of vertical and horizontal motion.

Keywords: physical quantity, scalar and vectoral quantity, length, state of motion, translational motion, centre of mass, frame of reference, kinematics, distance, displacement, average velocity, instantaneous velocity, acceleration, free fall.

Practical work:

1) measuring velocity and acceleration;
2) investigating the motion of falling bodies;
3) investigating the motion of a ball rolling down a ramp;
4) investigating the motion of a projectile body.

2.4.4.2. 2nd course "Mechanics"

Dynamics

Learning outcomes

By the end of the course, students are expected to have the capacity to:

1) explain the occurrence of phenomena *interaction*, *gravitation*, *friction* and *deformation* and their application in nature;
2) supplement a given figure with vectors showing the forces affecting a body both when the state of motion is constant (*v* = const, *a* = 0) or changing (*a* = const ≠ 0);
3) able to find the net force trough force components;
4) explain and apply Newton's laws and associate them with everyday phenomena;
5) formulate the law of conservation of momentum and solve problem tasks using the relationship $\Delta(m_1\vec{v}_1 + m_2\vec{v}_2) = 0$;
6) associate reactive motion with the law of conservation of momentum, give examples of reactive motion in nature and its implications in technology;
7) give examples about phenomena where the velocity of the momentum changing is equal with the force causing the change;
8) apply the Law of Gravitation $F_G = G\frac{m_1 m_2}{R^2}$;
9) know the definition of field of gravity;
10) know that general theory of relativity describes the gravitational interaction through bending space-time;

11) use terms *gravitation*, *weight of body*, *reaction of supports*, *stress* and *pressure* when solving problem tasks and applies the relation P = m (g ± a);
12) explain terms *friction force* and *elastic force* and when explaining phenomena occurring in natural and artificial environments, applies the relations $F_h = \mu N$ and $F_e = -k \Delta l$;
13) apply terms *work*, *energy*, *kinetic and potential energy*, *power*, *output energy*, *energy conversion efficiency* when explaining phenomena in nature and artificial environments;
14) solve problems by applying relationships $A = Fs \cos \alpha$; $E_k = \frac{mv^2}{2}$, $E_p = mgh$ and $E = E_k + E_p$;
15) explain the validity of the principle of minimum energy in nature and artificial environments.

Learning content

Newton's laws, Force. Vectoral addition of forces. Resulting force. Motion of constant velocity upon the balancing of forces. Momentum of a body. Law of conservation of momentum. Reactive motion. Law of Gravity. Gravitation, weight of a body, reaction of support. Weightlessness. Elastic force. Hooke's law. Stiffness coefficient. Friction force and friction coefficient. Work and energy. Mechanical energy. Law of conservation of mechanical energy. Conversion of mechanical energy into other types of energy. Principle of minimum energy. Law of conservation of energy in nature and technology.

Keywords: deformation, reactive motion, net force, inertia and mass of a body, momentum, law of conservation of momentum, gravity, weight of a body, weightlessness, reaction of supports, elastic force, stiffness coefficient, friction force, friction coefficient, law of conservation of mechanical energy, energy transformation.

Practical work:

1) examining the essence of Newton's laws;
2) determining the stiffness coefficient;
3) determining the sliding coefficient of friction;
4) investigation stiction;
5) examining reactive motion and laws of conservation.

Periodic motion

Learning outcomes

By the end of the course, students are expected to have the capacity to:

1) make associations between the periodical phenomena in nature an technology and the uniform and non-uniform rotation and orbit;
2) use physical quantities *angle of rotation*, *period*, *frequency*, *angular velocity*, *linear velocity* and *centripetal acceleration* for explaining circular motion;
3) use the following relations for solving problems related to circular motion: $\omega = \frac{\varphi}{t}$, $v = \omega r$, $\omega = \frac{2\pi}{T} = 2\pi f$, $a = \omega^2 r = \frac{v^2}{r}$;
4) analyse orbiting using the concepts if inertia and centripetal acceleration;
5) use the terms free vibration and forced vibration for describing vibration occurring in nature and technology;
6) use physical quantities *deviation*, *amplitude*, *period*, *frequency* and *phase* for describing periodic motion;
7) use relations $\varphi = \omega t$ and $\omega = 2\pi f = \frac{2\pi}{T}$ for solving vibration problems;
8) analyse the validity of the law of conservation of energy in the oscillation of a pendulum;
9) analyse vibration charts;

10) explain resonance and give examples of it occurring in nature and technology;
11) explain the creation of longitudinal waves and transverse waves and give examples of them;
12) apply physical quantities *wavelength*, *wave propagation rate*, *period* and *frequency* for explaining wave phenomena;
13) use relations $v = \frac{\lambda}{T}$, $T = \frac{1}{f}$ and $v = \lambda f$ for solving problems;
14) give examples of phenomena *reflection*, *refraction*, *interference* and *diffraction* in nature and technology.

Learning content
Describing uniform circular motion: angle of rotation, period, frequency, angular and linear velocity and centripetal acceleration. Rotation and orbit in nature and technology, orbital motion. Vibration as periodic motion. Describing the oscillation of a pendulum: deviation, amplitude, period, frequency, phase. Changes in energy during oscillation. Vibration and resonance in nature and technology. Waves. Longitudinal and transverse waves. Quantities characterising waves: wavelength, velocity, period and frequency. Phenomena accompanying waves: reflection, refraction, interference and diffraction, waves in nature and technology
Keywords: angle of rotation, period, frequency, angular velocity, linear velocity, centripetal acceleration, vibration, deviation, amplitude, period, frequency, phase, free vibration, forced vibration, pendulum, resonance, wave, longitudinal wave, transverse wave, wavelength, reflection, refraction, interference, diffraction.
Practical work:
1) investigating circular motion, determining centripetal acceleration;
2) investigating the oscillation of a mathematical pendulum and spring pendulum;
3) determining the strength of a field of gravitation using a pendulum;
4) investigating wave phenomena;
5) determining the speed of sound.

2.4.4.3. 3rd course “Electromagnetism”
Electric and magnetic fields
Learning outcome
By the end of the course, students are expected to have the capacity to:
1) explain terms *charge*, *current* and *amperage* and the meaning of the formula $I = \frac{q}{t}$;
2) compare terms *matter* and *field*;
3) associate the electrostatic field with the existence of a charged body by applying the formula $E = \frac{F}{q}$;
4) use Coulomb’s law for solving problems $F = k\frac{q_1 q_2}{r^2}$;
5) use relations $U = \frac{A}{q}$, $\varphi = \frac{E_{pot}}{q}$, $E = \frac{U}{d}$ and $U = \varphi_1 - \varphi_2$; for solving problems;
6) use the principle of superposition for constructing the E-vector of an electrostatic field at a given point;
7) know that a homogenous electric field is created between two parallel charge-carrying plates with different charges;
8) know that there are two principally different causes for magnetic fields: permanent magnets

and current-carrying wires) and apply the formula $B = \frac{F}{I\ l}$;

9) apply Ampere's law $F = K\frac{I_1 I_2}{r} l$ for solving problems;
10) determine the direction of magnetic induction created by a straight wire in a given point;
11) use the formula $F = B\ I\ l\ \sin\alpha$ and Ampere's rules for determining the direction of a force;
12) apply the Lorentz force formula $F_L = q\ v\ B\ \sin\alpha$ for solving problems and determine the direction of Lorentz force;
13) explain the creation of a electrodynamic field upon changes in the magnetic flux by applying the definition of the electromotive force of induction;
14) compare the work principles of a generator and an electric motor;
15) explain the options for storing the energy of an electric field and magnetic field.

Learning content
Electric charge. Elementary charge. Law of conservation of charge. Electric current. Matter and field. Coulomb's law. Point charge. Magnitude of field. Potential and voltage of electric field. Correlation between voltage and potential. Visualisation of fields, field lines. Joining fields, superposition principle. Homogenous electric field between two charge-carrying plates with different charges. Permanent magnet and charge-carrying wire. Ampere's force. Magnetic induction. Lorentz force influencing a moving charge-bearing particle. Voltage induced at the ends of a piece of wire moving in a magnetic field. Electromagnetic induction. Electromotive force of induction. Magnetic current. Faraday's law of induction. Electric motor and generator. Lenz's rule. Self-induction. Induction coil. Homogenous magnetic field in a solenoid. Energy of an electric field and magnetic field.
Keywords: Electric charge, elementary charge, amperage, point charge, electric field, magnitude of electric field, potential, voltage, electron voltage, field line, capacitor, permanent magnet, magnetic field, magnetic induction, Lorentz force, electric field vortex, electromotive force of induction, magnet flux, self-induction.
Practical work:
1) examining the concept of field on the example of electric and magnetic fields
2) conducting experiments on electrostatics;
3) investigating the magnetic interference between two current-carrying wires;
4) examining the Ørsted experiment;
5) investigating electromagnetic induction;
6) applying Lenz's rule;
7) investigating an electric motor and its properties;
8) investigating the work of capacitors and induction coils.

Electromagnetic waves
Learning outcomes
By the end of the course, students are expected to have the capacity to:
1) explain the term electromagnetic wave and the applications of electromagnetic waves;
2) describe the oscillatory circuit as the basic equipment for radiating and absorbing electromagnetic waves;
3) describe the electromagnetic spectrum by applying the relation $c = f\ \lambda$, and know the bordering values of visible lights and the order of the wavelengths of the spectral colours;
4) explain wave amplitude and intensity of electromagnetic waves according to a chart;
5) describe the phenomena of interference and diffraction in optics using figures or computer imitation and bring examples of their applications;
6) explain the circumstances of light coherence and the need for their completion to obtain a

specific interference picture;
7) associate the characteristics of polarised light with applications in nature and technology;
8) apply the law of refraction of light using correlations $\frac{\sin \alpha}{\sin \gamma} = n$ and $n = \frac{c}{v}$;
9) describe the options for separating white light into a spectrum;
10) compare main types of spectrums;
11) explain the emergence of light on the scheme of energetic levels of an atom and apply the formula $E = h f$ for solving problems;
12) explains the principle of duality of light and is relation to the atomistic principle;
13) distinguish between thermal radiation and luminescence and associate them with corresponding sources of light.

Learning content
Electromagnetic spectrum. Wavelength and frequency. Correlation between the colour of visible light and its wavelengths in a vacuum. Amplitude and intensity of electromagnetic waves. Diffraction and interference, examples of their applications. Law of refraction. Correlation of the refractive index with the speed of light. Light dispersion. Operating principle of a spectroscope. Spectral analysis. Polarised light, the process of polarisation and properties and applications of polarised light. Duality of light and the principle of duality in nature. Energy of a photon. Atomistic principle. Light radiation. Thermal radiation and luminescence.
Keywords: electromagnetic wave, electromagnetic spectrum, wavelength, frequency, energy of a quantum (photon), principle of duality, amplitude, intensity, diffraction, interference, polarisation, electromagnetic field, refraction, absolute and relative refraction indicator, light dispersion in matter, prism, luminance.
Practical work:
1) investigating the diffraction picture obtained from a single slit, double slit and single hair;
2) determining the refraction indicator of a transparent substance;
3) building a spectroscope;
4) investigating different sources of light;
5) investigating the light spectrum;
6) investigating thermal radiation;
7) investigating the operating principle of polaroids;
8) investigating the polarisation of light in case of refraction.

2.4.4.4. 4th course "Energy"
Electrotechnology
Learning outcomes
By the end of the course, students are expected to have the capacity to:
1) explain the creation of electric current on the micro level, applying the correlation $I = q\,n\,v\,S$;
2) apply Ohm's law for a part of the circuit and the whole circuit: $I = \frac{U}{R}$, $I = \frac{\mathcal{E}}{R + r}$ in solving problems;
3) apply the following equations for the work and power of electric current: $A = IU \cdot \Delta t$, $N = IU$ in solving problems;
4) analyse the graph of temperature dependence of resistance of metals;
5) describe the intrinsic and extrinsic conductivity of a semiconductor, including electron conductivity and hole conductivity;
6) explain the nature of p-n transfer, including in case of forward bias and reverse bias, and associate it with the functioning of a light diode and photo element;

7) compare alternating and direct current;
8) analyse the chart of the dependence of the voltage and amperage of alternating current from time;
9) calculate the power of alternating current in the case of an active appliance, applying the relationship $N = IU = \frac{I_m U_m}{2}$;
10) explain the operating principle of a transformer and its applications in an alternating current main and transferring electric energy;
11) calculate the cost of used electrical energy and plan the implementation of new electrical devices on that basis;
12) value the requirements of electrical safety and justify the need for them.

Learning content

Mechanisms for electric current emergence, Ohm's law. Electromotor force and intrinsic resistance. Temperature dependence of the resistance of metals. Conductivity of liquids, gases and semiconductors; p-n transfer. Light diode and photocells. Alternating current as the forced oscillation of electric charges. Producing and using alternating current. Transmission of electric energy. Transformers and high-voltage transmission lines. Alternating current mains. Electrical safety. Output of alternating current at the active resistor. Effective values of amperage and voltage.

Keywords: direct current, concentration of charge carriers, electric resistance, electromotive force and internal resistance of a supplier of electrical energy, semiconductor, p-n transfer, work and power of electric current, alternating current, transformer, ground wire, effective and instant values of amperage and voltage.

Practical work:

1) measuring amperage, voltage and resistance with a multimeter
2) investigating sources electric energy;
3) measuring electromotive forces;
4) investigating semiconductor electronics (diode, light diode, photocells etc.).
5) investigating alternating current;
6) investigating the work of transformers and oscillatory circuits.

Thermodynamics, energetics

Learning outcomes

By the end of the course, students are expected to have the capacity to:

1) know the term *internal energy* and explain the difference between thermal energy and other types of energy;
2) compare the Kelvin temperature scale with the Celsius temperature scale and use the formula T = t (°C) + 273 K;
3) name the characteristics of the model *ideal gas*;
4) solve problems using correlations $E_k = \frac{3}{2} k T$; p = n k T; $p V = \frac{m}{M} R T$;
5) analyse the charts of iso-processes;
6) explain the transition of thermal energy through mechanical work or heat transfer, give examples from nature and distinguish between different types of heat transfer;
7) compares terms *open system* and *closed system*;
8) formulate the first law of thermodynamics and associate with the equation $Q = \Delta U + A$;
9) formulate the second law of thermodynamics and explain the term entropy qualitatively;
10) associate the laws of thermodynamics with the working principles of heat engines;
11) evaluate the more important renewable and non-renewable sources of energy considering

their environmental impacts and geopolitical factors, names the development directions of energetics both in Estonia and the world, justify these choices;
12) understand the need for saving energy and the responsibility of every citizen to do so.

Learning content

Internal energy and thermal energy. Temperature. Celsius and Kelvin temperature scales. Ideal gas and real gas. Equation of state of ideal gas. Open and closed systems. Iso-processes. Phenomena in nature and technology explained by the gas equation of state. Micro and macro parameters of ideal gas, correlations between them. Basics of kinetic molecular theory. Correlation between temperature and the average kinetic energy of molecules. Methods of transition of thermal energy: mechanical work and heat transfer. Amount of heat. First law of thermodynamics, its relations with iso-processes. Adiabatic process. Operation principles of a heat engine, efficiency of heat engines and heat engines in nature and technology. Second law of thermodynamics. Reversible and non-reversible processes in nature. Entropy. Life on Earth from the viewpoint of energy and entropy. Energy transfer in nature and technology. Basics of energetics and industrial sources of energy. Global energetic problems and their possible solutions. The energy needs of Estonia, energetic problems and their possible solutions.

Keywords: internal energy, temperature, temperature scale, ideal gas, equation of state, open and closed system, iso-process, amount of heat, adiabatic process, reversible and non-reversible processes, heat engine, entropy.

Practical work:

1) investigating expanding gases;
2) investigating iso-processes;
3) energy consumption;
4) investigating relations between the temperature and mechanic work of a body;
5) comparing the heat transfer properties of different substances.

2.4.4.5. 5th course “The Physics of the Micro and Mega Worlds”
Fundamentals of the structure of matter

Learning outcomes

By the end of the course, students are expected to have the capacity to:

1) describe the states of substance on the mircolevel;
2) compare the models of real gases and ideal gas;
3) use terms *saturated steam*, *absolute humidity*, *relative humidity* and *dew point* and associate these with climatic phenomena;
4) explain terms *surface tension*, *wetting* and *capillarity* with phenomena in nature and technology;
5) describe the states of matter by sing the terms *phase* and *phase transition* corrects;
6) explain the changes in phases if pressure and temperature vary;

Learning content

States of matter and their differences and similarities. Micro levels of states of matter. Molecular force. Real gas. Water vapour in air. Air humidity, Saturated and unsaturated steam. Absolute and relative humidity, dew point. Weather phenomena. Surface tension. Wetting and capillarity, their occurrence in nature. Phase transition and transition heat.

Keywords: state of matter, gas, liquid, condensate, solid, real gas, saturated steam, absolute and relative humidity, dew point, phase and phase transition.

Practical work:

1) determining the melting point;
2) comparing coolants;

3) determining the dependence of the boiling point of the concentration of the solution;
4) measuring air humidity;
5) investigating surface tension;
6) investigating the properties of soap water.

Physics of the micro world

Learning outcomes

By the end of the course, students are expected to have the capacity to:

1) name the major properties of the photo emissive effect and photoelectric effect;
2) use the term standing wave for describing the micro world phenomena;
3) describe the diffraction of electrons;
4) name pairs of physical quantities characterised by uncertainty relations;
5) analyse the chart of the correlation between binding energy and mass number;
6) know that the formula $E = m c^2$ describes the equivalence of mass and energy;
7) describe the nuclear fission and synthesis reaction;
8) explain the nature of radioactive dating and give examples of its application
9) explain the general operating principles of nuclear plants and analyse the advantages of nuclear power as well as the dangers associated with nuclear technology;
10) know the types and sources of ionising radiation, analyse the effects of ionising radiation on living organisms and suggest ways to reduce the danger of radiation.

Learning content

Photo emissive effect and photoelectric effect. Models of the atom. Wave functions of particles. Quantum mechanics. Electron diffraction. Uncertainty relation. Quantum numbers of the atom. Nucleus of the atom. Mass defect. Binding energy. Nuclear binding energy. Equivalence of mass and energy. Nuclear reactions. Nuclear energetics and nuclear weapons. Radioactivity. Half-life. Radioactive dating. Forms of ionising radiation and their effects. Radiation safety.

Keywords: Photo emissive effect and photoelectric effect, quantum numbers, energy level, quantum mechanics, uncertainty relations, nuclear binding energy, nuclear energetics, nuclear weapons, radioactivity, half-life, radioactive dating, ionising radiation, radiation safety.

Practical work:

1) investigating photo emissive effect and photoelectric effect;
2) measuring the radiation level;
3) building a mist chamber.

Physics of the mega world

Learning outcomes

By the end of the course, students are expected to have the capacity to:

1) know that information from space reaches us as electromagnetic waves, identify and differentiate between instruments of astronomic observation placed on the ground and moving in space;
2) compare the dimensions and motion of the main components of the solar system: the Sun, planets, satellites, asteroids, dwarf planets, comets, meteors;
3) describe stars, their evolution and the emergence of solar systems;
4) describe the structure and evolution of galaxies;
5) describe the emergence and evolution of the universe according to the Big Bang Theory.

Learning content

Instruments of astronomic observation and their development. Constellations. Periodic motions of the Earth and Moon as the foundation for measuring time. Calendar. Composition, structure of the

solar system and hypotheses regarding its emergence. The Sun and other stars. Evolution of stars, Galaxies. The Milky Way. Structure of the universe. Evolution of the universe.
Keywords: observatory, telescope, space telescope, solar system, planet, satellite of a planet, artificial satellite, asteroid, comet, dwarf planet, meteoroid, star, galaxy, Milky Way, cosmology.
Practical work:
1) viewing different celestial bodies;
2) making a sun-dial.

3. Syllabuses of optional courses

3.1. Optional course 'Applied Biology'
Description of the course

'Applied Biology' plays an important role in shaping the students' scientific and technology literacy. The course is based on the knowledge, skills and attitudes acquired during the compulsory courses of biology, but it is also linked to chemistry, geography, physics, mathematics and other subjects taught in upper secondary level. At the same time, the knowledge and skills concerning the phenomena, theories and future trends of biology gained from other upper secondary school courses are revised so that the applications and professions associated with them become more familiar, thus helping the students in their career choices.

The learning process is problem-based and student-centred, guided by the personality and age traits of the students as individuals and their different talents. The studies follow the principles of active learning with a focus on exploratory discourse based on scientific methods and solving scientific problems integrating the natural, technological and social environments, through which the students develop their higher mental processes.

The knowledge and skills of biology are learned predominantly by exploratory tasks based on scientific methods. Through these tasks the students learn the skills of problem-setting, framing hypotheses, planning experiments and observations, carrying them out and analysing and interpreting the results. Another important aspect is oral and written presentations of investigatory results, involving appropriate verbal and visual forms of presentation. At the same time, the skills of solving the scientific problems derived from everyday life and making competent socio-scientific decisions are developed, improving the students' ability to survive in the natural and social environments.

In the learning process, one focal point is developing the internal learning motivation of the students. To achieve this aim, various active learning methods – including problem learning and exploratory learning, project learning, roleplay, discussions, brainstorming, compiling definition cards, outdoor learning and educational visits – are used.

Technological equipment and ICT are used during all stages of the learning process. During the learning process, the students acquire the ability to use various sources of information, including electronic sources, and develop the ability to assess the validity of the information obtained from these sources. All of this develops the students' skills and knowledge of biology, thus enabling them to understand, explain and forecast various natural phenomena. At the same time, a positive attitude is produced towards biology as a science and a cultural phenomenon that considers scientific, economic, social, legislative, ethical and moral aspects in solving everyday socio-scientific issues.

Learning and educational objectives

This optional course is designed for students to:

1) develop their scientific and technological literacy, as well as creativity and systematic way of thinking;
2) be interested in biology and other sciences, understand the importance of sciences in everyday life and be motivated for lifelong learning;
3) derive a systematic overview of nature and its major processes and be able to use biological vocabulary correctly;
4) value a responsible attitude towards their immediate environment and value biological diversity and a sustainable, responsible way of life;
5) use different sources, including electronic sources, to obtain information about biology, and critically assess the information available from these sources;
6) apply scientific methods in solving problems of biology;
7) make competent decisions in their everyday lives on the basis of scientific, economic, ethical and moral perspectives, also taking legislation into consideration, and forecast the consequences of their decisions; and
8) gain an overview of professions linked to biology and use their knowledge and skills of biology in planning their career.

Learning outcomes and learning content
Branches of applied biology

Learning outcomes

Learning outcomes describe the level of achievement for a student.

By the end of the course, students are expected to have the capacity to::

1) associate applied biology with the basics of biology and other sciences;
2) by giving examples identify the uses of applied biology in agriculture, the food industry, the manufacturing of medicinal products and energy production;
3) analyse the links between applied biology and everyday life;
4) explain the relationship between basic and applied research in biology;
5) analyse and evaluate the biological applications of various groups of organisms and give examples of them;
6) explain cell and embryo technology and give examples of these fields;
7) sput forward justified decisions related to dilemmas concerning cell and embryo technology; and
8) interrelate applied biology to sustainable development.

Learning content

The purposes of applied biology and its links to other sciences; historical spheres of applied biology in agriculture (plant and animal breeding), the food industry, the manufacturing of medicinal products and energy production and the role of these applications in the economy and our everyday lives; the relationship between basic research and applied research in biology; traditional uses of animals, plants and fungi and their uses in modern applied biology; the importance of bacteria for applied biology and the uses of bacteria in industry and our everyday lives; an overview of cell and embryo technology and the methods used (shoot-tip grafting, embryo transfer, cloning and therapy using stem cells); and connections between applied biology and sustainable development.

Practical work and use of ICT: investigating the relationship between applied biology and the food industry based on a food group of the student’s choice.

Gene technology

Learning outcomes

Learning outcomes describe the level of achievements for students.

By the end of the course, students are expected to have the capacity to::

1) by giving examples of the applications of gene technology, explain the methods used;
2) analyse positive and negative aspects of gene technology applications for plants and animals;
3) explain the possibilities of using gene technology in medicine and the ethical and moral problems associated with it;
4) analyse the problems associated with using genetically modified organisms for human food;
5) make justified decisions about dilemmas concerning gene technology and show a responsible attitude towards the risks accompanying the use of gene technology; and
6) present an overview of developments in applied biology in Estonia and the professions associated with this field.

Learning content

Fields of application for gene technology and methods used; possible uses of viruses and bacteria in gene technology; applications of gene technology in plants and animals and the risks of these applications; gene technology and medicine and ethical and moral aspects of applying gene technology in medicine; using genetically modified organisms for food; scientific, economic, legislative, ethical and moral aspects of applying gene technology; applied biology in Estonia and professions associated with this field.

Practical work and use of ICT

1. Investigating methods used in gene technology using practical work or computer models.
2. Investigating gene technology (in a computer environment).

3.2. Optional course 'Geoinformatics'

Description of the course

The optional course 'Geoinformatics' introduces geographic information systems and an overview is also given of the web-based GIS systems used in Estonia as well as in other countries and their applications. The optional course of GI is based on the knowledge and skills learned in geography lessons during basic education and at the upper secondary school level and is also linked to the curricula of mathematics and informatics. In addition to GIS, thematic maps, scales of maps, various coordinate systems and projections are discussed in more detail. The students gain an overview of the data used in GIS, the types of information used and the quality of this information.

This optional course is designed to develop students' practical skills and computer skills. During this course the students compile and analyse thematic maps of Estonia and the world. Working with spatial data and maps improves the students' skills in mathematical and spatial thinking and develop their skills of reading and interpreting maps, while also giving them a basic understanding of spatial planning. In analysing GIS, the students also learn about basic principles of economy and sociology.

Learning and educational objectives

This optional course is designed for students to:

1) become interested in using computers and modern technological developments in geography;

2) gain an overview of the main terms of geoinformatics (GI) and the applications of geographic information systems (GIS);
3) be able to find various spatial data and evaluate the quality of this data;
4) be able to integrate spatial data about the world and about Estonia with other types of data;
5) explain the necessity of GIS in spatial planning and management and value its efficiency;
6) gain a broader and more varied perception of r career choices;
7) develop their graphical, mathematical and spatial thinking; and
8) develop ICT skills related to Geography.

Learning outcomes

Learning outcomes describe the level of achievements for students.
By the end of the course, students are expected to have the capacity to::

1) use computers and modern technology in geography;
2) explain the main terms of geoinformatics and the applications of GIS;
3) find various spatial data and evaluate the quality of such information;
4) integrate spatial data describing the world and Estonia;
5) explain and justify the need for and efficiency of GIS in spatial planning and management;
6) think spatially by applying mathematics in solving spatial problems, and by reading and understanding maps; and
7) solve tasks involving spatial problems using ICT skilfully.
8)

Learning content

Definition of GIS, its components and uses; geographic information, its types and methods of collecting such information; geographic databases, definition of metadata and why we need it; map projections, their purposes and options in geographic information systems; the scale of a map, map types and measuring distances; the concept of scale in GIS; geographical coordinates and rectangular coordinates; system of coordinates for Estonia; GIS analysis; inquiries and their types: spatial inquiries and attribute inquiries; presenting the results of GIS analysis; types of thematic maps and the principles followed in presenting them.

Practical work and use of ICT

1. Investigating different map servers.
2. Investigating vector and raster data and downloading data using software.
3. Determining rectangular and geographical coordinates in order to give explanations of their use in GIS.
4. Investigating maps with different projections and their matching.
5. Compiling thematic maps using data about Estonia and the world.
6. Analyse various complied GIS maps.

3.3. Optional course: The Globalising World

Description of the course

This optional course has an important role to play in fostering the awareness of students who care about the sustainable development of society, justice, tolerance, inclusion and cooperation, and in helping such students become active world citizens.
The course is based on the knowledge, skills and attitudes acquired in the compulsory courses in upper secondary school geography and is closely connected to what the students study in History, Civics and citizenship education and Economics. The content of the course is integrated with world

education, making it possible for students to understand the reasons for and effects of globalisation and to become active citizens by knowing the main international development goals and principles of sustainable human development.

The course equips students to deal in depth with topical problems of different regions of the world, with examples from both developed and developing countries. Knowing the natural, cultural, demographic and economic diversity and idiosyncrasies of the world enables students to cope in the globalising world. In studying regions, the main emphasis is on the development of environmental conditions, population, culture, economy and society in reciprocal relations. The course helps students acquire skills in solving problems related to everyday life and make competent decisions which increase their ability to manage in the natural and social environment.

During the course, students develop skills in using sources of information and critically evaluating the information they find. This helps to shape the knowledge and skills that enable them to understand and explain the processes that take place in society.

Learning and educational objectives

The aim of this optional course is to guide students to:

1) become interested in the problems of different regions of the world and investigate their causes and possible consequences at both the local and global levels;
2) analyse the reciprocal connections between the development of environmental conditions, population, culture, economy and society on the basis of one region studied;
3) gain an overview of the effects of globalisation on different regions of the world;
4) value the natural and cultural diversity of the world;
5) participate in solving problems and conflicts as well-informed and active citizens; and
6) use reliable sources of information in both Estonian and foreign languages to find geography-related information.

Learning outcomes

The learning outcomes of upper secondary school reflect the achievements of the students.
At the end of the course, students will be:

1) up to date on the topical problems of different regions of the world and know their causes and possible consequences;
2) able to give examples of the development of environmental conditions, population, culture, economy and society in reciprocal relations based on the regions studied;
3) able to give examples of the effects of globalisationon different regions of the world;
4) able to value natural and cultural diversity and respect the customs and traditions of different nations;
5) able to find geography-related information about different regions of the world from both Estonian and foreign language sources and interpret, generalize and evaluate this information critically; and
6) able actively to participate in problem-solving and conflict resolution, giving reasons for and defending their opinions and choices in a well-argued way.

Course content

The content of this optional course will be specified at the beginning of the course in collaboration between the teacher and the students. In putting this together, the main principle is to cover all of the topics on the basis of examples from different regions of the world. A chosen topic is presented in a problem-based way wherever possible, taking a specific region, area, country or city as an example. The examples are chosen according to their importance in the local, regional or global context. The analysis of these examples must enable students to achieve the learning outcomes required by the course.

The problems dealt with in the course must be important to the students and must have broad-ranging relevance in contemporary society, motivating them to study the concepts, theories and trends related to natural and social sciences in the context of contemporary sciences in depth. The topics listed below will help in making choices.

The use of natural resources and its effect on the environment

1. The influence of geographical location, natural resources, population and culture on the development of the economy

2. Environmental and social problems arising from the excavation of mineral resources
3. Problems arising from the use of energy resources and possible solutions
4. Application of modern technology in developing and developed countries
5. Environmental and social problems arising from the economic use of forests
6. Influence of agriculture on the environment in developed and developing countries
7. Problems related to the supply of clean water , their causes and effects and possible solutions
8. Natural resources as a source of conflict
9. Problems related to sea and ocean pollution and scarcity of fish resources

The influence of population trends on the development of society

10. Problems in society arising from the demographic situation and population policies (based on the example of a specific country)
11. Problems arising from migration for countries of consignment and countries of destination
12. Refugee problems in today's world
13. Spread of diseases and associated problems
14. Use of child labour and the modern slave trade
15. Over-urbanization and associated problems
16. Environmental problems in big cities

Differences between regions and countries and within countries

17. Reasons for regional differences (based on the example of a specific country) and associated problems
18. Advantages of and problems affecting multicultural societies
19. Misunderstanding cultures, its consequences and conflicts between cultures
20. City patterns of regions (based on Google Earth)
21. Agricultural patterns of regions (based on Google Earth)

Trade- and consumption-related conflicts and their resolutions

22. International trade and global injustice
23. Fair trade and its possibilities in today's world
24. Food problems in developing countries, their causes and possible solutions
25. Poverty and humanitarian aid in today's world

Global environmental problems and their effects on different regions

26. Climate change and its regional consequences
27. Causes of the decrease in biodiversity and associated problems
28. Soil erosion and problems related to the destruction of soil
29. Desertification, its causes and ways of avoiding it
30. Social and environmental problems arising from armed conflict

3.4. Optional course 'Principals of Chemical Processes'

Description of the course

This optional course of chemistry is based on the knowledge, skills and attitudes acquired from the compulsory chemistry courses of upper secondary level, and this course is also integrated with the curricula of other science subjects, while also offering support in the learning and teaching of other subjects.

This course extends the knowledge, skills and expertise gained from compulsory chemistry courses at upper secondary level, enabling the students to better understand the general laws of chemical processes and their various mechanisms, and giving them a better understanding of quantitative relations in chemical processes. The students gain a systematic overview of the physical foundations of chemical processes and the laws governing these processes, as well as of future trends in chemistry and professions linked to chemistry, thus helping them in their career choices.

The aim is to broaden the students' chemical and general scientific worldview and build a strong basis so that they can continue their education in fields connected to the sciences. At the same time, skills in solving everyday scientific problems and making competent and ethical socio-scientific decisions are learned, thus improving the students' ability to cope in the natural and social environment.

Through this, the students develop important competences and gain a positive attitude towards chemistry and other sciences, while also understanding the importance of sciences in the economic, technological and cultural development of human societies. The students develop a responsible attitude towards their immediate environment and learn to assess the potential consequences of their actions. Such knowledge, skills and attitudes form the basis for internally motivated lifelong learning.

The material of this curriculum is presented as problem-based, student-centred and linked to everyday life. The learning process is based on the personal traits and multi-faceted development of the students, while paying attention to developing internal learning motivation in the students. To achieve this, various types of active learning – problem, exploratory and project learning, discussions, etc. – are used. Curricular activities following the principles of active learning help the students to develop their higher mental processes. Another important aspect is developing the students' ability to work independently, use different sources of information, distinguish between the significant and the insignificant and use their knowledge in problem-solving.

Teaching the optional course is supported by the wide range of active learning methods: role play, discussions, debates, project learning, compiling learning folders and research papers, practical work (e.g. studying and analysing everyday life, production environmental problems or other related chemical processes, specifying the impact of factors influencing objects, solving complex problems) etc.

Learning and educational objectives

This optional course is designed for students to:

1) become interested in chemistry and other sciences, understand the role of chemistry in the development of societies, in modern technology and everyday life and become motivated for lifelong learning;
2) use scientific methods in solving problems of chemistry by applying systematic and logical thinking, skills of analysing and drawing conclusions as well as creativity;
3) better appreciate chemistry and the rules governing the main chemical processes;
4) explain the interrelatedness of nature, technology and society and their influence on our environment and on the sustainable development of societies;
5) make justified decisions that show a responsible attitude towards the environment and value a healthy and sustainable way of life;
6) make competent decisions on the basis of scientific, economic, legislative, ethical and moral perspectives and assess the possible consequences of their actions; and
7) gain an overview of professions linked to chemistry and use their knowledge and skills of chemistry in planning their career.

Learning outcomes

Learning outcomes describe the level of achievements for students.

By the end of the course, students are expected to have the capacity to::

1) explain the thermal effects of chemical reactions on the basis of changes in energy occurring when chemical bonds are formed or disintegrated;
2) analyse the effect of the factors influencing the speed of chemical reactions and explain the role of the speed of chemical processes in chemical technology, nature and everyday life;
3) explain the effect of external factors on chemical equilibrium (according to Le Chatelier's principle) and apply this principle in analysing equilibrium reactions;
4) explain modern concepts of acidity/basicity and estimate the pH value of a solution according to the properties (pK) of the substances;
5) explain the principles of buffer solutions and their role in technological processes and nature;
6) explain the definitions of radicals and reactions of radicals (using alkanes as an example);
7) identify electrophilic and nucleophilic centres and use this knowledge to interpret replacement reactions;
8) explain the addition reactions between alkenes and carbonyl compounds using the definitions of electrophility and nucleophility; and
9) explain the properties of aromatic compounds, including phenols and aromatic amines, through delocalisation of bonds.

Learning content

Thermal effects in chemical processes

Energetic reasons for chemical bonds, exothermic and endothermic reactions and thermal effects in chemical reactions; the problems associated with the direction of chemical reactions for the chemical industry, in nature and in our everyday lives.

Keywords: exothermic and endothermic reactions, thermal effect of reactions.

Speed and equilibrium of chemical reactions

Correlation between reaction speed and temperature; energy flow in reactions and what the activation energy of a reaction is; different options for activating reactions; the principles of catalysis, homogenous and heterogeneous catalysis (introduction) and using catalysis in chemical technology;

enzyme catalysis and its importance in regulating processes taking place in organisms; chemical equilibrium, changing the equilibrium point for opposing chemical reactions (Le Chatelier's principle) and using the equilibrium constant to describe chemical equilibrium (introduction); problems associated with reaction speed and the equilibrium of chemical reactions for the chemical industry, in nature and in our everyday lives (accelerating or slowing reactions and shifting the equilibrium point).
Keywords: reaction activation energy, catalysis, enzyme catalysis, chemical equilibrium, equilibrium constant

Practical work and use of ICT

1. Investigating factors influencing the speed and/or equilibrium of various reactions.
2. Compiling a review and making a justified decision on an issue in this field using materials available on the Internet and other sources of information.

Acids and bases

Modern idea of acids and bases; equilibrium in solutions of weak acids and bases, factors influencing the degree of dissociation and pH of solutions; quantitative characteristics describing the strength of acids and bases (dissociation constant and pK); acid oxides and aprotonic acids; buffer solutions and their role in technology and in chemical processes taking place in living organisms (introduction).
Keywords: dissociation constant of acids and bases, pK, aprotonic acid, buffer solution.

Practical work and use of ICT

Experimental investigations on the topic.

Mechanisms of reactions

Ways of breaking covalent bonds: radical and ion methods; radicals, electrophiles and nucleophiles; analysing reaction equations: reaction centre, attacking particle and leaving group; interactions between atoms inside the structure of a molecule: polarization of bonds, delocalisation of bonds and delocalisation of charges (carboxyl acids and phenols); reaction types: replacement of radicals, nucleophilic replacement reaction and nucleophilic addition to polarized double bond, electrophilic addition to double bond and electrophilic replacement in aromatic ring and reactions of esters and amides.
Keywords: radicals, reactions of radicals, nucleophile, electrophile, reaction centres, leaving group, delocalisation, aromatic ring.

Practical work and use of ICT

Experimental investigations on the topic.

3.5 Optional course 'Chemistry of Elements'

Description of the course

This optional course of chemistry is based on the knowledge, skills and attitudes gained from the compulsory chemistry courses at the upper secondary level and is integrated with the curricula of other science subjects, while also supporting the learning and teaching of other subjects.

This course extends the knowledge, skills and expertise learned from the compulsory chemistry courses at the upper secondary level, thus enabling the students to better understand the general laws of chemical processes and broadening their understanding of the chemical compounds in our bodies and the chemical processes taking place in organisms. Students gain a systematic overview of the main chemical elements and properties of these compounds and about future trends in and professions linked to chemistry, thus helping them in making career decisions.

The aim is to broaden the chemical and general scientific worldview of the students and give them a strong basis to continue their education in fields linked to the sciences. At the same time, skills in solving everyday problems and making competent and ethical decisions are learned, thus improving the students' ability to cope in natural and social environments.

Through this, the students develop important competences and achieve a positive attitude towards chemistry and other sciences, while also understanding the importance of sciences in the economic, technological and cultural development of human societies. Students develop a responsible attitude towards their immediate environment and learn to evaluate the potential consequences of their actions. Such knowledge, skills and attitudes form the basis for internally motivated lifelong learning.

The material of this curriculum is presented as problem-based, student-centred and linked to everyday life. The learning process is based on the personal traits and multi-faceted development of the students, while paying attention to developing internal learning motivation in the students. To achieve this, various types of active learning – problem, exploratory and project learning, discussions, etc. – are used. Curricular activities following the principles of active learning help the students to develop their higher mental processes. Another important aspect is developing the students' ability to work independently, use different sources of information, distinguish between the significant and the insignificant and use their knowledge in problem-solving.

Learning and educational objectives

This optional course is designed for students to:

1) become interested in chemistry and other sciences, understand the role of chemistry in the development of societies, in modern technology and everyday life and become motivated for lifelong learning;
2) use scientific methods in solving problems of chemistry by applying systematic and logical thinking, skills of analysing and drawing conclusions as well as creativity;
3) better appreciate chemistry and the rules governing the main chemical processes;
4) explain the interrelatedness of nature, technology and society and their influence on our environment and on the sustainable development of societies;
5) make justified decisions that show a responsible attitude towards the environment and value a healthy and sustainable way of life;
6) make competent decisions on the basis of scientific, economic, legislative, ethical and moral perspectives and assess the possible consequences of their actions; and
7) gain an overview of professions linked to chemistry and use their knowledge and skills of chemistry in planning their career.

Learning outcomes

Learning outcomes describe the level of achievements for students.

By the end of the course, students are expected to have the capacity to:

1) explain atom structure using electron configurations (for the first four periods) and draw conclusions from these explanations;
2) evaluate the polarity of covalent bonds on the basis of differences in the electronegativity of the elements forming them and distinguish between polar and non-polar substances;
3) analyse the effect of the types of bonds and intermolecular (physical) forces on the properties of substances and on their potential practical uses, together with examples;
4) associate the properties of metals and their compounds with their practical applications and their role in nature, including in living organisms;

5) write reaction equations for the typical reactions of metals and their compounds (within the reaction types learned);
6) associate the properties of non-metals and their compounds with their practical applications and their role in nature, including in living organisms;
7) write reaction equations for the typical reactions of non-metals and their compounds (within the reaction types learned); and
8) make calculations in the framework of this topic using electron configurations, taking into consideration the composition of the solution, yield of reaction, etc.

Learning content

Structure of substances

Electron layers and sub-layers in the atom; summary of the types of chemical bonds: non-polar and polar covalent bonds, ionic bond, metallic bond and hydrogen bond; interactions between molecules and intermolecular (physical) forces; the properties of substances depending on the type of bond and the structure of the substance and types of crystal lattice.

Keywords: orbital, electron configuration, non-polar and polar covalent bond, ionic and covalent compounds, intermolecular (physical) force, crystal lattice.

Practical work and use of ICT

Investigate, using molecule models or computer programmes, the structure of substances.

Most important metals and their compounds

Comparison of the characteristics of metals and their compounds: highly reactive metals (alkali metals and alkaline earth metals), p-block metals (Al, Sn and Pb), better-known d-block metals (Fe, Cr, Cu, Ag, Zn and Hg) and their uses; reactions between metals and nitric acid or strong sulphuric acid; metal compounds in nature, including in living organisms, and the most important biometals; environmental risks associated with heavy metals.

Practical work and use of ICT

Experimental investigation on the topic.

Most important non-metals and their compounds

Comparison of the characteristics of non-metals and their compounds: halogens, oxygen and sulphur, nitrogen and phosphor and carbon and silicon; non-metals and the fields in which their compounds are used; non-metals and their compounds in nature, including in living organisms; natural circulation of carbon, oxygen, nitrogen and sulphur.

Practical work and use of ICT

1. Experimental investigation on the topic.
2. Compiling a short survey or overview on the topic using materials available from different sources of information (may be group work).

3.6 Optional course 'The Chemistry of Life'

Description of the course

This optional course of chemistry is based on the knowledge, skills and attitudes learned during the compulsory chemistry courses at the upper secondary level and is also integrated with the biology curricula at the upper secondary school level, discussing the fundamental chemical processes of biology, thus enabling students to understand the subject of biology more profoundly.

This course helps the students to obtain a deeper understanding of the chemical processes taking place inside living organisms. The aim is to broaden the chemical and general scientific worldview of the students and build a strong basis for them to continue their education in fields linked to the sciences. At the same time, skills in solving everyday problems and making competent and ethical decisions are learned, thus improving the students' ability to cope in the natural and social environments.

Through this, the students develop important competences and achieve a positive attitude towards chemistry and other sciences, while also understanding the role of sciences in the economic, technological and cultural development of human societies. The students develop a responsible attitude towards their immediate environment and learn to value a healthy and sustainable lifestyle. The knowledge, skills and attitudes learned form the basis for internally motivated lifelong learning.

The material of this curriculum is presented as problem-based, student-centred and linked to everyday life. The learning process is based on the personal traits and multi-faceted development of the students, while paying attention to developing internal learning motivation in the students. To achieve this, various types of active learning – problem, exploratory and project learning, discussions, etc. – are used. Curricular activities following the principles of active learning help the students to develop their higher mental processes. Another important aspect is developing the students' ability to work independently, use different sources of information, distinguish between the significant and the insignificant and use their knowledge in problem-solving.

Learning and educational objectives

This optional course is designed for students to:

1) become interested in chemistry and other sciences, understand the role of chemistry in the development of societies, in modern technology and in our everyday lives and become motivated for lifelong learning;
2) use scientific methods to solve problems of chemistry by applying systematic and logical thinking, skills in analysing and arriving at conclusions and a creative approach;
3) have a systematic overview of the definitions of chemistry concerning living organisms and the rules governing chemical processes;
4) explain the interrelatedness of nature, technology and society, their influence on our environment and the sustainable development of societies;
5) make justified decisions showing a responsible attitude towards the environment and the valuing of a healthy and sustainable way of life;
6) make competent socio-scientific decisions on the basis of scientific, economic, ethical and moral perspectives, as well as legislation, and evaluate the possible consequences of their actions; and
7) gain an overview of professions linked to chemistry and use their knowledge and skills of chemistry in planning their career.

Learning outcomes

Learning outcomes describe the level of achievements for students.

By the end of the course, students are expected to have the capacity to:

1) identify important biomolecules studied by their structural formula and vice versa and draw simplified sketches of the chemical structure of these biomolecules;
2) explain the role of substances studied, including vitamins, in the structure and functions of organisms, as well as in human nutrition;
3) present scientifically founded views on common myths and misapprehensions about nutrition;
4) explain the special features of enzyme catalysis compared with ordinary catalytic reactions;

5) give generalised explanations of metabolic processes, linking them to the energetic values of the metabolism;
6) explain the special features of stationary equilibrium compared with thermodynamic equilibrium and its crucial role in the existence of life;
7) interrelate their knowledge about the structure and functions of living organisms learned from lessons of physics, chemistry and biology; and
8) explain the functioning of organisms and ecological phenomena according to chemical channels of information.

Learning content

Isomerism. Biomolecules

Geometric isomerism: cis-trans isomerism and chirality; biomolecules; saccharides: monosaccharides and disaccharides, structural saccharides and polysaccharides for storage; lipids: fats and phospholipids; cell membrane and nutritional problems associated with lipids; proteins: coding amino acids, protein subunits, protein complex and nutritional problems associated with proteins; nucleic acids: nucleosides, nucleotides, nucleic acids.
Keywords: biomolecule, chirality.

General structure of metabolism: enzyme catalysis

General structure of metabolism (simple sketches): glycolysis, citric acid cycle, aerobic respiration and our understanding of biosynthesis; enzyme catalysis: enzymes, coenzymes, vitamins and special features of enzyme catalysis.
Keywords: metabolism, enzyme, coenzyme, enzyme catalysis.

Energetics of the metabolism: physical chemistry of life

Energetics of the metabolism, photosynthesis and an energetic picture of our biosphere; physical chemistry of life: chemical equilibrium and stationary equilibrium, entropy, physical principles of life and problems concerning the emergence of life.
Keywords: stationary equilibrium, entropy.

Chemical information in nature

Chemical information in nature at the cellular level (ATP/AMP, messenger substances, etc.), organism level (hormones and messenger substances), species level (pheromones) and interspecies level (allomones).
Keywords: chemical information, messenger substances.

3.7. Optional course 'Physics and Engineering'

Description of the course

This course is based on solving problems of physics and technology that the students are capable of solving themselves. The students are directed towards making reasoned and competent socio-scientific decisions concerning specific issues, while considering the scientific, technological, economic, environmental social, moral and ethical dimensions. At the same time, a balance is struck between applying, in a new context, earlier knowledge gained primarily from physics lessons, but also from other compulsory science subjects, and learning new technological knowledge and skills based on the physical core of modern high-tech products.

The structure of this course consists of three levels: (a) introducing the scientific problem (such as the need for corrective nanoscopic manipulations for scanning tunnelling microscopy); (b) gaining new knowledge through scientific problem solving, often based on an investigatory approach (piezoelectric materials and their properties); and (c) reaching a suitable socio-scientific decision (piezoelectric detectors and their actuators). Practical work is used extensively, mainly to determine the properties of the materials or technical equipment studied, but practical work could also be a source of gaining new knowledge in physics.

The educational learning content of this course lists 15 modules, each covering 3 to 6 lessons. Of these, the teacher, in cooperation with the students, can choose 8 modules, taking into consideration the needs or interests of the students. The modules in the learning content list are presented in the preferred order of taking them. The learning content of these modules is constantly updated to reflect the developments taking place in science and technology, and to correspond to the needs of the knowledge-based society.

If the same topics are discussed in compulsory courses and in optional courses, the qualitative discussion offered by the compulsory course is complemented by quantitative discussion in the optional course.

Learning and educational objectives

This optional course is designed for students to:

1) gain knowledge, skills, attitudes and values that will be useful in their future profession, most likely linked to technical or technological fields;
2) be able to identify physical and technical problems in their everyday life;
3) find reliable information to solve the problems becoming evident in the technological environment surrounding us;
4) apply scientific methods, including the exploratory approach in solving these problems;
5) make well-founded socio-scientificl decisions in less complicated situations;
6) examine technological problems with a creative and critical way of thinking;
7) use oral and written technical communication;
8) gain attitudes valuing scientific and technological knowledge and readiness for lifelong learning; and
9) evaluate technological risks and predict the effects new technological solutions could have on the environment.

Learning outcomes

Learning outcomes describe the level of achievements for students.
By the end of the course, students are expected to have the capacity to:

1) identify physical and technological problems in their everyday life and propose solutions to these problems;
2) analyse the given examples of problems concerning physics and technology and make reasoned decisions about them;
3) combine their new technological knowledge with earlier, basic scientific knowledge to form an integrated whole;
4) describe present solutions to physical or technological problems and analyse the strong and weak aspects of these solutions;

5) analyse the environmental or personal dangers accompanying physical or technological solutions and ways of minimising these risks;
6) explain the nature of physical sciences and the corresponding technology, their role in society and their relationship with other science subjects taught at school; and
7) become intrinsically motivated for lifelong improvement of their knowledge of physics and technology.

Learning content of the course

1. **Aerodynamics and hydrodynamics:** resistance force in the environment; other forces affecting aircraft; flowing of liquids in tubes; blood circulation in humans and animals and diastolic and systolic blood pressure; water turbines.
2. **Elastic waves:** energy of elastic deformations; energy of vibrations and waves; summing of vibrations; spectre of vibrations; Doppler effect for sound waves; volume of sound; decibel; noise and noise barriers.
3. **Unusual phases and phase transitions:** condensation of gases; production of low temperatures; cryoliquids and cryogenics; supercooling and superheating of liquids; frost (sublimation) and the dependence between melting temperature and pressure; carbon dioxide snow and other ices not based on H_2O; solutions and phase transitions.
4. **Heat engines and energy management:** manifestation of the first law of thermodynamics in iso-processes; the adiabatic process; ideal heat engine; efficiency of heat engines; cyclic processes; reversible and non-reversible processes; real heat engines (steam turbine, Otto engine, diesel engine and Stirling engine) and their efficiency; sources of energy, energy transfers, transport and storage.
5. **Entropy and negentropy:** definitions of ‘entropy’; information, energy and matter from the viewpoint of entropy; entropy and negentropy on Earth and in the universe; non-equilibrium processes; applications: freezer and heat pump.
6. **Capacitor and induction coil:** capacitance of parallel-plate capacitor; principles of the capacitor and its types; amount of energy stored in capacitors; examples of uses of capacitors; inductivity of a tall thin coil; energy of induction coil with current; electromagnets with superconductive winding and their applications.
7. **Conductors and dielectrics:** Polarisation of dielectrics; shielding; dielectric permittivity of a material; piezoelectric materials and ferroelectric materials and their applications: piezoelectric detectors and actuators, electronic scale and quartz clock.
8. **Magnetic properties of materials:** magnetic permeability of materials; diamagnetic and paramagnetic materials; hard and soft ferromagnetic materials; fields, structure and hysteresis of ferromagnetic materials; applications: electromagnets and magnetic storage of information.
9. **Electric current in liquids and gases:** electrolysis; Faraday’s First Law of Electrolysis; examples of electrolysis applications; environment-related and unrelated gas discharges.
10. **Semiconductor electronics:** differences between conductors, semiconductors and non-conductors according to band theory; intrinsic conductivity of semiconductors and its applications: thermistors, photoresistors and semiconductor radiation detectors; alloyed semiconductors; electron conductivity and hole conductivity; p-n transfer; rectifier, photodiode, light-emitting diode, diode matrix, CCD matrix and semiconductor laser; solar cells; bipolar transistor and field-effect transistor; chips and their applications in analogue and digital circuits.
11. **Applications of alternating current:** parameters characterizing alternating current; electrical safety; protective earthing; safety devices; resistive resistance, inductive resistance and capacitive resistance (capacitance) in alternating current circuits; impedance; total resistance; Ohm’s laws for alternating current circuits.

12. **Alternating current machines:** direct current motors and generators; operation principle of transformers and their applications; alternating current generator and non-synchronous machine; power factor for alternating current; three-phase electric power; production, transmission and distribution of electric power using Estonia as an example.
13. **Electromagnetic oscillation and electromagnetic waves:** oscillatory circuit; production of electromagnetic waves; the range of electromagnetic waves; radio waves and their propagation; the main principles of wireless communication; radio determination and GPS; modern means of communication.
14. **Optical equipment:** light ray; linear propagation of light; total reflection of light; optical fibres and their applications; optical systems (objective, telescope and microscope) and their resolving power; polarised light and methods of producing it; applications: Polaroid glasses and liquid crystal displays.
15. **Photometry:** light sensitivity of the human eye; luminous intensity and luminous flux; illuminance; solid angle; units: candela, lumen and lux; luminous efficacy of various sources of light.

3.8. Optional course ‘Another Kinds of Physics’

Description of the course

This course is based on solving problems of the physics of the micro world and/or cosmology that the students are capable of solving themselves. After taking this course, the students are directed towards making reasoned and competent socio-scientific decisions concerning these specific issues, while considering the scientific, technological, economic, social, moral and ethical dimensions. At the same time, a balance is struck between applying, in a new context, earlier knowledge gained primarily from physics lessons, but also from other compulsory science subjects, and learning new skills based on the physical essence of the concepts discussed.

The educational learning content of this course lists 15 modules, each covering 3 to 6 lessons. Of these, the teacher, in cooperation with students, can choose 8 modules, taking into consideration the needs and interests of the students. The modules in the learning content list are presented in the preferred order of taking them. The learning content of these modules is constantly updated to reflect new discoveries in micro physics and cosmology, and to correspond to the needs of the knowledge-based society. This course may be organised as a course discussing either the physics of the micro world or cosmology only (choosing the corresponding modules) if the students seek this.
If the same topics are discussed in the compulsory course and optional course, the qualitative discussion offered by the compulsory course is complemented by quantitative discussion in the optional course.

Learning and educational objectives

This optional course is designed for students to:
1) enhance awareness of potential profession, most likely linked to scientific research;
2) identify physics phenomena of the micro and mega worlds in their everyday life;
3) find relevant and reliable information about the chosen phenomena of the micro and mega worlds;
4) apply scientific methods, including an exploratory approach, in understanding the laws of the micro world and the universe;
5) give reasoned socio-scientific decisions about the physical models used in describing the micro world and the universe;

6) gain a creative view, based on knowledge of physics and critical thinking, of the concepts of the history of the Earth and the universe;
7) communicate oral and in written form concerning the topics of nuclear physics, radiation and cosmology;
8) develop attitudes valuing knowledge of nuclear physics, radiation physics and cosmology, as well as readiness for lifelong learning; and
9) evaluate the environmental and/or personal risks concerning nuclear technology, radiation and space technology, and ways of minimising these risks.

Learning outcomes

Learning outcomes describe the level of achievements for students.
By the end of the course, students are expected to have the capacity to:

1) identify problems concerning the physics of the micro world or cosmology in texts;
2) analyse illustrative problems and make reasoned decisions in solving them;
3) interrelate new knowledge with earlier, basic scientific knowledge to form an integrated whole;
4) identify present solutions to a problem and analyse their strong and weak points;
5) identify environmental and/or personal dangers accompanying the solutions to problems concerning nuclear technology, radiation and/or space technology and determine ways of minimising these risks;
6) explain the heuristic importance of particle physics and/or cosmology for the whole of mankind and recognising the connections between these fields and the science subjects taught at school; and
7) become intrinsically motivated to update their worldview throughout their life.

Learning content of the course

1. **Theory of relativity:** relativistic way of thinking; presentations of the principle of absolute velocity; relativity of simultaneity; relativity of time interval; relativity of length; addition of velocities for high speed; dependence between mass and velocity; equivalence of gravitational mass and inertial mass as the basic concept of the general theory of relativity; non-linear space-time model.
2. **Atoms and studying them:** planetary model of the atom, Bohr’s model and the modern model of the atom; selection rules as laws of conservation; value range of quantum numbers; periodic system of chemical elements; s, p, d and f orbitals in physics and in chemistry; electron microscopy, tunnelling microscopy and atomic force microscopy.
3. **Quantum mechanics:** electron diffraction, wave functions and uncertainty relation; wave functions in quantum mechanics; particle tunnelling; interpretations of quantum mechanics; quantum teleportation.
4. **Radiations and spectrums:** emergence of radiation, emission lifetimes and wave series; spontaneous and stimulated radiation; lasers; applications of lasers; radiation spectrum; absorption spectrum; continuous spectrum and line spectrum; spectral analysis and its applications; infrared light; ultraviolet light; roentgen radiation, its production and applications.
5. **Thermal radiation:** properties of the radiation spectrum of black-body radiation; Stefani-Boltzmann law and Wien’s displacement law; explaining the short-wave part of the radiation spectrum of black-body radiation by using Planck’s quantum hypothesis; applications of thermal radiation.

6. **Photoelectric effect:** red limit; Einstein's mathematical description of the photoelectric effect; parameters of photons; photoemissive effect and photoelectric effect; applications of photoelectric effect: solar cells, photocells and CCD elements; pressure of light; photochemical reactions.
7. **Nuclear physics:** nucleons; nuclear forces; isotopes; mass defect; binding energy and nuclear binding energy; nuclear reactions: synthesis reactions and decay reactions; synthesis in nature and its potential in energy production; synthesising new heavy elements; emission of particles during decay reactions; radioactivity; chain reactions.
8. **Radiation accompanying radioactivity:** types of ionising radiation and their properties; law of radioactive decay; half time; source activity; intensity of radiation depending on distance; natural and artificial radiation sources; methods of nuclear physics used in medicine, archaeology and palaeontology; basics of radiation safety; limits on personal dose.
9. **Standard model:** elementary particles and quanta of field; parameters characterising elementary particles; leptons and quarks; baryons and mesons; antiparticles; accelerators and particle detectors; lack of human resources as the main limiting factor in attempts to shift our internal visibility horizon.
10. **History and methodology of astronomy:** instruments used in astronomy and their development; optical astronomy and radio astronomy; measuring cosmic radiation; Hubble space telescope; spectral measurements; Doppler effect; astronomy and cosmology in Estonia.
11. **Space technology:** technology that has made space flight possible; manned space flights; technological limitations concerning long-distance space flight; scientific research in space; applications of space technology: satellite navigation; environmental observation satellites and satellite communication; military technology in space.
12. **Solar system:** terrestrial planets and gas giants; satellites and ring systems of the planets; dwarf planets in the solar system; formation and evolution of planetary systems.
13. **Stars:** our nearest star: the sun; structure of the sun's atmosphere; active formations in the sun's atmosphere; internal structure of stars; star magnitude; main characteristics of stars: temperature, luminosity, diameter and mass; Hertzsprung-Russell diagram; variable stars and novae; white dwarfs, neutron stars and black holes; stellar evolution.
14. **Galaxies:** composition and structure of the Milky Way; clusters of stars; galaxies; clusters of galaxies; cellular structure of the universe; dark matter and dark energy.
15. **Cosmological models:** cosmological principle; evolution of the universe; Big Bang Theory and its physical principles: cosmological red shift and relict radiation; anthropic principle.

4. Interdiciplinary Optional Courses

4.1. Optional course 'Science, Technology and Society'

Description of the course

This course is developed with the aim of solving problems important to the students. During this course, reasoned and competent socio-scientific decisions are made, taking into consideration the scientific, technological, economic, social, moral and ethical dimensions of the problems discussed. At the same time a balance is struck between applying the knowledge gained from earlier science subjects in a new context demanding higher-level mental processes, and learning new knowledge and skills integrating various subjects based on the scientific core of modern social science problems. Sustainable development is reflected in skills and attitudes that help the students to grow into conscious and active citizens who are able to value alternative solutions while giving reasons for their choices, working out action plans to achieve their aims and participating in realising these plans using their knowledge of science.

The structure of this course consists of three levels: introducing the issue in everyday situations, gaining new knowledge through an exploratory approach to solving scientific problems, and making socio-scientific decisions and giving reasons for these decisions. An integral part of the course is experimental work modelling real-life situations: this part is also intended to give the students new scientific knowledge.

Up to 15 inter-subject modules are presented, each consisting of 4 to 5 lessons, of which the teacher chooses at least six modules according to the needs of the students and the teacher's own competence. The learning content of these modules is constantly being updated using new developments in science and technology and considering the needs of our knowledge-based society, and new modules are also developed in collaboration between teachers and scientists. All of the modules are tied to the three fields – society, technology and the sciences – but they are also integrated with other subjects, including social subjects.

Learning and educational objectives

This optional course is designed for students to:

1) through gained interdisciplinary knowledge, explain the achievements of the sciences and their future trends;
2) combine their knowledge and skills gained from various science subjects to form an integrated whole;
3) recognize scientific problems in ordinary life situations;
4) find and evaluate information concerning scientific problems with social impact;
5) use scientific methods, including an investigatory approach, in considering real-life issues;
6) make reasoned socio- scientific decisions;
7) develop a creative and critical as well as an innovative way of thinking;
8) develop written and oral skills of communication in discussing social and scientific problems;
9) value scientific knowledge and be prepared for lifelong learning; and
10) evaluate risk factors and forecast the implications that scientific and technological achievements may have on the environment.

Learning outcomes

Learning outcomes describe the level of achievements for students.
By the end of the course, students are expected to have the capacity to:

1) identify scientific problems in everyday situations widely discussed by society;
2) make reasoned socio-scientifi cdecisions in solving social issues;
3) combine their new, inter-subject knowledge with earlier knowledge of sciences to form an integrated whole;
4) explain the scientific background of social science problems discussed in the context of modern sciences;
5) discuss issues in our everyday lives through write critical essays with a scientific content;
6) explain factors associated with the nature of science and technology and their role in society, as well as their connections to science subjects;

7) give plans to solve scientific problems derived from socio-scientific issues, including applying the method of definition cards;
8) plan teamwork-based scientific problem-solving derived from socio- scientific issues and evaluate their risk factors;
9) show willingness to work in a team and be tolerant in regard to the opinions of their team mates;
10) value scientific problem-solving based on investigations and its role in deciding on socio-scientific issues in the cultural context of Estonia; and
11) become intrinsically motivated to update their scientific knowledge throughout their lives.

Learning content

Final specifications of the learning content depend on the curricula of other science subjects and other optional subjects. The aim is to avoid duplication in developing new knowledge and discussing similar problems in different subjects using different methodology. The problems discussed affect the lives of the students and are widely discussed in society, thus motivating the students to be more eager to learn the definitions, theories and laws of chemistry, physics, biology and geography in a context that describes modern sciences. The modules are divided between four fields – chemistry, biology, physics and geography – and are as follows:

1. Climate change: what will Estonia’s fate be?
2. Viruses: what will the future be like?
3. Holes in the ozone layer and ultraviolet radiation: is there a risk to life?
4. Food additives: pros and cons
5. Materials we use in our everyday lives: are we making sensible decisions?
6. Electromagnetic radiation: how does our domestic equipment influence our lives and health?
7. Genetically modified food: is it good or bad for us?
8. Alternative sources of energy: could biodiesel be a solution?
9. Weight loss products: is the pharmaceutical industry really serving our interests?
10. Traffic accidents: are they really caused by bad roads, high speed and drink-driving, or is technology at fault?
11. Poisonous chemicals around us: how great is the risk?
12. Smells: is it all just perfumery?
13. Alcometers, fat measuring devices, blood pressure and pulse measuring devices and other similar machines: who are they for and why? The truth and the risks involved.
14. Sustainable use of energy at home: warm and dark or well-lit and cold?
15. Is homemade soap viable in the modern world?
16. The paper industry: is it a problem for Estonia as well?

These modules are presented as a set of learning materials. In addition, materials are compiled for teachers to give them further information about methodological solutions and inter-subject scientific information. It is advised that these modules should be read by teachers of different science subjects in cooperation.

Physical learning environment

1. Carrying out practical work requires a classroom. The students are divided into groups to carry out experiments (one lesson per module).
2. It must be possible to use computer classes or computers with Internet access at school.
3. There should be cooperation between science teachers in the school.

4. The science teachers should be ready to develop and modify the educational materials and they should be able to do this on the basis of their experience in teaching the module and according to the individual needs of the students (guaranteeing relevance).
5. Additional materials are available for students on the Internet.

4.2. Optional course 'Mechatronics and Robotics'

Description of the course

This course discusses the main terms and divisions of mechatronics and robotic systems, their fields of application and special characteristics and the general principles for designing such machines, and general principles for integrating the mechanical, electronic and software parts into a whole, including an introduction to sensor technology and an overview of the field, the general principles of using sensors, an introduction to micro-controllers and programming such units, an introduction to actuator systems and their operating principles and compilation of conceptual plans for mechatronic systems.
The course is based on modules, thus enabling practical projects to be organised as competitions, contests between different schools or special projects. Essential and methodological support for the learning process is obtained from the network of teachers giving mechatronics classes and their supportive environment on the Internet.
This subject consists of four integrated topics supported by recurrent practical exercises and a practical team work project.

Learning and educational objectives

This optional course is designed for students to:

1) gain an overview of mechatronics and robotics in the world and in Estonia;
2) become interested in the field of technology;
3) explain the constructions and components of robotic systems;
4) solve simple, practical technological problems with the help of mechatronics and robotics;
5) gain an overview of sensors and motors and know their working principles;
6) use and programme micro-controllers;
7) keep records of their work and present their work; and
8) adopt a 'do-it-yourself' way of thinking.

Learning outcomes

Learning outcomes describe the level of achievements for students.
By the end of the course, students are expected to have the capacity to:

1) use the terminology of mechatronics and robotics and the main terms and basic principles of these fields;
2) explain the constructions and physical principles of operation for various sensors and actuators;
3) chose the right and most suitable components of mechatronics;
4) write scripts for micro-controllers in at least one programming language;
5) design and build a simple mechatronic system;
6) keep records on making their products;
7) present their products and make presentations to bigger audiences; and
8) become motivated to update their knowledge and continue their education in the field of technical sciences.

Learning content

Designing mechatronic and robotic systems: special features of designing integrated systems; planning the work process and safety measures; technical aids and software used for designing; components of robotics, including electronic components; choosing suitable components and reading data sheets; recording processes and presenting work.
Micro-controllers: types of micro-controllers and their architecture; structure of a micro-controller and its instructions; programming micro-controllers, debugging and compilation of a programme.
Sensorics: overview of sensors and their uses; digital and analogue sensors; analogue-to-digital converter.
Actuator mechanisms: electric motors and their special controlling features; controlling direct-current motors (H-bridge and speed control); controlling Servo motors (pulse-width modulation); controlling linear stepper motors; overview of alternative actuators (linear motors, solenoids and artificial muscles).
Practical project: building a robot or practical mechatronic system.

Study Activities

Every topic consists of a theoretical introductory overview followed by practical exercises (except in the first module). When the last module is completed, the curriculum continues with practical work: a team work project. This project could be a robot or some other practical problem that could be solved with the help of mechatronics or robotic systems. During the team work, the results are periodically presented to other teams and the supervisor. In these presentations the students talk about the progress they have made, their technical solutions and the problems encountered. The course ends with the presentation of the results of their work (participating in a robot contest, demonstrating working solutions, etc.).

Activities:

1) Investigations using micro-controllers;
2) Investigations using sensors and motors;
3) group work (teams of 2–3 students) to design and build a simple mechatronic system;
4) searching for evaluated information from electronic sources (including thematic forums, demonstration projects and video materials);
5) activities developing creativity: students identify and find their own solutions to a technical problem;
6) developing team work skills: planning the timeframe and work volume, using problem solving techniques and drafting a budget;
7) presentation of the work (public presentation, if possible); and
8) planning and carrying out innovative projects.

Physical learning environment

For practical work, the students need computers and special sets for learning mechatronics/robotics, which consist of modern, programmable micro-controllers, sensors and actuator systems. Depending on the nature of their team work project, the students may also need additional equipment and tools to develop their solution.

Recommended software:

1) IDE for programming micro-controllers;
2) software for compiling electronic circuits;

3) CAD system; and
4) presentation software.

4.3. Optional course '3D Modelling'

Description of the course

This optional course is based on three fundamental competences:

1) undertaking technical drawing;
2) using 3D modelling software to create products; and
3) adjusting a computer-controlled CNC milling machine and the skills to use its operating software.

Integration with other subjects:

1) to pass this optional course successfully, the students need to experience and gain skills in mathematics, primarily spatial thinking and an understanding of numerical scales and units;
2) designing aesthetically pleasant but also practical products supports art competence and the development of innovative thinking; and
3) using the CNC milling machine demands some idea of the properties of materials (timber, aluminium, plastics, etc.) and the tools used to process these materials. These issues are discussed in manual training and technology lessons.

Learning and educational objectives

This optional course is designed for students to:

1) develop their creativity and skills in systematic and spatial thinking;
2) develop skills to set aims and plan their activities in stages;
3) take responsibility for implementing their ideas and plans and applying team work methods;
4) use various sources of information in planning technological processes and critically evaluate the information from these sources; and
5) explain the importance of modern technology in countries' economies.

Learning outcomes

Learning outcomes describe the level of achievements for students.
By the end of the course, students are expected to have the capacity to:

1) explain the role of product design in our everyday lives and see the links between theory and practice;
2) gain an overview of major 3D modelling software and can use it in the practical modelling of a product;
3) explain the logic behind computer-controlled technological equipment using the CNC milling machine as an example; and
4) give justified reasons for their own choice of materials and technology, record their work processes and present the results.

Learning content

General principles of product design
Learning outcomes

After this part of the curriculum, the students understand the importance of product design in our everyday lives and can see the links between theory and practice.

Learning content
Definition of design, its methods and criteria; overview of the history of applied art and design; definition of technology, its methods and criteria; computer-controlled instruments and their applications.

Using 3D modelling software
Learning outcomes
After this part of the curriculum, the students are expected to have the capacity to give an overview of the main 3D modelling software and can use it in the practical modelling of a product.

Learning content
Starting a programme; opening and saving files; overview of taskbars; solids, solids of revolution and lettering: drafts and formation of body; virtual assembly; fitting surfaces and required spaces.

Using the controlling software of a CNC milling machine
Learning outcomes
After this part of the curriculum, students are expected to have the capacity to use effectively and meaningfully the controlling software of a milling machine.

Learning content
Naming the file created and bringing the part created into the work space of the 3D-modelling software; creating a preform; controls and properties of the technical drawing environment; technical drawing; adding material; making the preform transparent; creating an anchorage body; adjusting the measurements of the anchorage body (preform); determining the milling technology; creating tools or choosing tools from the library of the software; geometry options; fitting the coordinate system; determining the geometry; setting the geometry for the part; setting geometry for the preform; setting the geometry for the anchorage body (the area forbidden for the cutter); creating the operations; creating a rough processing procedure; creating a fine processing procedure; continuing procedure creating; determining the processed area; generating the process pathways; post-processor; processing the other half.

Adjusting the CNC milling machine
Learning outcomes
After this part of the curriculum, students are expected to have the capacity to
explain the logic behind computer-controlled technological equipment and can meaningfully adjust the milling machine used in lessons.

Learning content
Fixing the pre-form in the workspace of the milling machine; determining zero for the intermediate plate; structure of the intermediate plate and marking down the perform; fixing the code when the zero of the coordinate system is shifted to the bottom side of the preform; adding the cutter to the library of the programme and using the library of cutters; changing advancing speed, adding automatic switch of vacuum cleaner and adding the position of changing the preform; adding tools (cutters) to the list of tool in the software.

Documenting the process and obtaining feedback
Learning outcomes

After this part of the curriculum, students are expected to have the capacity to
give justified reasons for their choice of materials and technology, record their work processes in an appropriate format and present the results in a meaningful manner.

Learning content

Documenting the design and production process (texts, photos and videos); compiling a presentation in a web 2.0 environment (such as a blog or wiki) chosen by the student; making a presentation.

Study Activities

During this optional course, the following learning activities take place:

1) work under the supervision of the teacher and independent learning to gain skills in using 3D modelling software;
2) designing a product using 3D modelling software;
3) adjusting the CNC milling machine and choosing the tools;
4) compiling a presentation on the design and milling of the product and making this presentation to fellow students;
5) analysing the products created by themselves and other students and discussing the topic; and
6) an educational visit to a technological enterprise and/or institute of higher education or a vocational school providing technical education.

Physical learning environment

1. Availability of 3D modelling software and controlling software of a CNC milling machine.
2. Computers (computer class) enabling the use of 3D modelling software.
3. CNC milling machine together with its protective compartment.
4. Availability of materials (different types of cutters, timbers and plastics).

4.4. Optional course 'Technical drawing'

Description of the course

Technical drawing is a practical skill playing an important role in developing the mental processes and spatial imagination of students, as well as developing their graphic literacy in technical and technological fields. This course is supported by the knowledge, skills and attitudes gained from the earlier compulsory courses of mathematics, but also art and manual training. A systematic overview is created of the range of information needed for technical drawing. Vocabulary, knowledge of spatial geometry and skills to use graphic methods to solve problems learned during this course are developed and the applications and professions associated with the field introduced, thus helping students in their career choices.

Within this course, the students learn to analyse the objects of spatial geometry and use graphic methods to solve problem tasks. They learn to use various sources (including electronic sources) of information and critically evaluate the information obtained from these sources. Through this, the students gain knowledge and skills of technical drawing that enable them to analyse, understand, explain and solve problems of spatial geometry. At the same time, a positive attitude is formed towards technical drawing as an applied branch of mathematics helping to design and create novel things, while scientific, economic, ethical and moral perspectives and legislation are also considered in solving problems.

Learning and educational objectives

This course is designed for students to:

1) become interested in machines, technology and/or the creative work of a designer, understand the practical importance of these fields and become motivated for lifelong learning;
2) develop their spatial imagination, mental processes, observation skills, graphic literacy, creativity and punctuality;
3) gain a systematic overview of the objects of spatial geometry and of graphical methods for solving problem tasks and use the vocabulary of technical drawing correctly;
4) show respect and a responsible attitude towards the creative products of their fellow citizens, value the abilities and skills to create and value careful planning, accurate work and practicality;
5) use various source (including electronic sources) of information independently to obtain information concerning technical drawing and critically evaluate the information obtained from these sources;
6) apply scientific methods in solving problems concerning spatial geometry;
7) gain an overview of the professions linked to applying the information of technical drawing and use the knowledge and skills from technical drawing lessons in planning their careers and in their future lives; and
8) make competent socio-scientific decisions in their everyday lives on the basis of scientific, economic, ethical and moral perspectives and legislation and predict the consequences of these decisions.

Learning outcomes

Learning outcomes describe the level of achievements for students.
By the end of the course, students are expected to have the capacity to:

1) value the knowledge, skills and attitudes linked to technical drawing as an important component of technological literacy and are internally motivated for lifelong learning;
2) put forward a systematic overview of finalizing drawings, designing, the methods of obtaining technical drawings and objects of spatial geometry and name object determination data;
3) analyse and describe the shape and size of objects and the relative position and location of the parts of objects from drawings of planar images and can read information about the shape, size and relative position of parts from these drawings;
4) analyse and evaluate the simplicity, measurability and figurativeness of projections and finalize drawings as customary;
5) solve problems of spatial geometry using scientific methods and planar graphical images, have an overview of various possibilities (including means of information technology) for presenting graphic information on drawings and critically evaluate the suitability of software for technical drawing;
6) demonstrate a well-developed concept of space, observation skills and the ability to think independently;
7) by giving examples of possible applications of technical drawing, explain the role of knowledge and skills in technical drawing in technical sciences and technology, as well as design and other applied creative fields and everyday life;
8) exhibit responsibility towards their own work and the work of others;
9) value creativity, carefully planned solutions and a responsible, sustainable way of life, and understand the effect of lifestyles on the environment and society;

10) use various sources (including electronic sources) of information to find information about technical drawing, synthesize and evaluate the information obtained from these sources and use it successfully in designing objects and solving problems concerning spatial geometry; and
11) make reasonable use of technological means, including the possibilities of ICT, in solving technical drawing problems.

Learning content

Requirements of technical drawings: standard lettering, lines, standard sizes of drawing, text box and borderline.
Geometrical constructions: drawing parallel and perpendicular lines, dividing straight lines, circles and angles into parts.
Designing and its subdivisions: central projections and parallel projections.
Main methods of obtaining technical drawings: principles of quoted orthographic projection and principles of Monge's method; point: its coordinates, two views and three views; line: determining data, trace point, two views and three views; position of a line in reference to screens: general position and special position; line of special position: horizontal, frontal and profile line; relative position of two lines: parallel, intersecting and skew lines; derivation of the length and angle of inclination of a finite straight line; plane: determining data; position of a plane in reference to screens: general position and special position; derivation of the real size of a planar object; the principles of axonometric method; types; constructing an isometric projection and isometric image of a point.
Geometric objects: types of objects (solids and solids of revolution) and their division (regular and irregular and symmetric and asymmetric), two views and three views of objects; point on a geometric object: deriving the missing projection for the point; planar cuts of geometric objects and development of geometric objects.

Study Activities

According to the specific educational comptencies, the topics discussed and learning outcomes presumed, the following activities are carried out in technical drawing lessons:
1) searching for information concerning technical drawing from various sources of information, including electronic sources, followed by analysis, synthesis and assessment of this information;
2) solving problems of spatial geometry graphically (at home) and in a computer-based learning environment;
3) practical work, including exploratory work, in the classroom (at home) and in a computer environment;
4) solving problems as group work in a computer environment; and
5) planning, making, finalizing and defending technical drawings.

Physical learning environment

For technical drawing, the students need technical drawing instruments and paper and demonstration equipment.

4.5. Optional course 'Using Computers for Inquiry'

Description of the course

This course is provisionally a subject of informatics, but it focuses on the main questions of informatics in quite a narrow context, directly limited by the needs of investigative work, which acts as a substitute for transition exams. Informatics is the branch of science and technology that looks at the structure of information and the way it is formed, obtained, processed, interpreted and forwarded. In this course, practical work is used to teach the students about methods and software that may make the process of gathering, processing, analysing and presenting research information easier.

Learning and educational objectives

This optional course is designed for students to:

1) use computers to undertake investigations (including collecting, processing and analysing) data and present investigation results;
2) select methods and software suitable for collecting and processing data;
3) frame meaningful hypotheses and test their validity; and
4) draw conclusions on the basis of data collected during investigations and give reasons for these conclusions.

Learning outcomes

Learning outcomes at the upper secondary school level describe the level of achievement of students.

By the end of the course, students are expected to have the capacity to :

1) find information from suitable sources, evaluate its reliability and compile accurate reference items;
2) use references in text correctly;
3) compile a web-based questionnaire consisting of different types of question-and-answer scales;
4) organise a web-based poll and present the information collected as part of the questionnaire as a table;
5) code, sort and filter data in a database; (
6) use a data table to compile cross-tables and frequency tables and different diagrams;
7) present descriptive and statistical characteristics (means, standard deviation, minimum, maximum and quartiles) together with explanations;
8) evaluate generalization power from a sample to the population of the hypothesis and the validity of the null hypothesis using a suitable test;
9) present a correct research report; and
10) compile a presentation about this research report and make the presentation.

Learning content

The course is divided into seven modules, each consisting of five lessons; the last module is meant for students' independent work on their final report under the supervision of the teacher. The first six modules focus on the following topics:

1. Searching for information from the Internet and in libraries; working with sources and referring to sources; writing reference items and managing references with special software.
2. Collecting investigative material; types of variables; types of questions and scales for answers; using special software to compile a web-based questionnaire.
3. Basics of data processing; using spreadsheet software to compile data tables; coding, sorting and filtering data and compiling frequency tables and cross-tables; descriptive

statistics: mean, modal value, median, standard deviation and quartiles; using diagrams to visualise data.

4. Conclusive statistics: generalization from sample to population, confidence levels, null hypothesis and establishing statistically significant difference (z-test, t-test and chi-square test).
5. Processing the data of qualitative research: coding the data and forming categories.
6. Formation of investigative report: tables, figures, styles, table of learning content, index, headers, footers and footnotes; making and giving a presentation about the research report.

Study Activities

In planning and organizing curricular activities:

1) the starting point is basic values, general competences, the aims of the subject, the Learning content of education and the expected results of the curriculum, while also supporting integration with other subjects and recurrent topics;
2) the aim is to achieve a moderate learning load (including homework), which is divided evenly throughout the school year and which leaves students with enough time for rest and recreational activities;
3) the students are given the opportunity to learn individually and in groups (individual, pair and group work) to support their development into active and independent learners;
4) differentiated study assignments are used whose essence and level of difficulty should support an individualised approach and increase students' motivation to study;
5) standard office software, modern web-based learning environments and free web-based tools and learning materials are used;
6) in data collecting, the learning environment is broadened outside of the computer class: natural environments, libraries, the school yard, museums, exhibitions, enterprises, etc.;
7) practice exercises are done using databases given by the teacher; only in exceptional cases can students use their own data, because usually this course is meant for the students to prepare for their own investigative project, and not as part of their own investigation;
8) usually the students are not given homework demanding the use of a computer, in order to guarantee equal possibilities and similar software for all; and
9) at the end of the course all students get the chance to present a summary of their investigation.

Physical learning environment

In the classroom, the students can use the following devices:

1) usually, every student has their own workplace with a computer; in exceptional cases there may be up to two students per computer;
2) standard office software;
3) the students can use their own laptops (power supply, network connection and work table);
4) presentation equipment;
5) the option to save files to a network drive or an Internet environment supported by the school;
6) supplementary equipment (printer and memory stick);
7) access to information systems (e-school, intranet or web-based Learning content management system and group-working environment);
8) computer workplaces with adjustable chairs, computer table, mechanical ventilation system and window covers;

9) computers with different operation systems;
10) ID card facilities (card-reading device and software);
11) earphones and microphones; and
12) digital camera and video camera.

Assessment

The results of the optional courses of informatics are graded according to the current learning achievements and, in summary, usually according to the e-portfolio compiled by the student. The e-portfolio is a personal web-based environment where the students host their projects and reflections of their learning experience compiled over a longer period. By the end of the course, students make a selection offering the best proof of their competence from the materials kept in their e-portfolio and, if possible, defend their work before an audience. Learning tasks and e-portfolios may be individual or group-based. The grade received for defending the portfolio provides the summary grade for the course. In the tasks and presentation of the e-portfolio, the following aspects are assessed:

1) the methodical, creative and rational learning process;
2) achieving the aims set by the curriculum, and giving convincing proof of the competences associated with this curriculum;
3) technical, aesthetic and original realization of materials created with the help of a computer;
4) making sense of their own practical activities; and
5) the development of the students.

4.6. Optional course 'Basics of Programming and Development of Software Applications'

Description of the course

The main elements of the course are:

1) principles of creating applications;
2) models and basics of modelling; and
3) basics of algorithms and programming.

The parts and their topics are not presented one after the other, but rather the teacher finds a suitable approach according to the programming tools available, the purpose of the course and considering their methodical experience and preferences and other factors.
The principles and main stages of application creating are introduced through practical work: projects containing elements of modelling, analysis and design. In modelling, the main aim is to compile and present algorithms for projects realized with the help of Unified Modelling Language (UML). The nature of class models may be discussed briefly and in a generalized form, taking into consideration the students' ability to read and understand the structures of the systems and data presented in these models. The majority of the time is used to gain programming and algorithm skills through practical work.

To achieve the aims of this course, it is important to become aware of and experience the essence of programmes and controlling by programmes, and for this, practical work of compiling programmes and realizing them in computer environments is used. In order to facilitate and speed up this process, while also avoiding the formation of reluctant attitudes in students, the first or only programming language used should be a language with as simple a syntax as possible, and with an attractive programming language or environment enabling the use of multimedia instruments.

Recently, special languages and environments designed for learning programming (such as Scratch, Alice, Game Maker and new generation languages based on Basic or Logo) have been developing and spreading rapidly. These languages are good for teaching programming to children and students. Compared with the traditional methods (such as Pascal), these new tools enable the learners to acquire the main principles and skills of programming two to three times faster.
At present, the first environment (language) used could be the rapidly spreading software Scratch (http://scratch.mit.edu), a tool created and developed by the Massachusetts Institute of Technology (MIT). This freeware is available on the Internet and includes a variety of teaching materials (including those in Estonian and in Russian). Considering the aims and coverage of the course, other tools may be introduced in addition to Scratch, such as Alice, MS Small Basic, application development system Visual Basic (VBA) or Python.

The course should predominantly be oriented towards practical activities and using electronic learning materials.

Learning and educational objectives

This optional course is designed for students to:

1) develop creativity, a logical, analytical and algorithmic way of thinking and systematic discussion of problems and problem-solving;
2) acknowledge and experience the working principles of programme-controlled systems and the nature of the main processes of presenting and processing information;
3) become familiar with using the instruments and the methods for creating applications and programmes;
4) gain basic skills in writing programmes and algorithms and solving problems with the help of programme-controlled systems;
5) be introduced to the principles of object-oriented modelling, analysis and design;
6) explain the nature of objects and data, their properties and the roles these properties play in algorithms and programmes; and
7) acquire the main concepts and definitions of algorithms and programming, the skills to plan, compile, smooth and test programmes consisting of interworking units (procedures), use objects, scalar data and massifs and describe various processes.

Learning outcomes

Learning outcomes at the upper secondary level describe the level of achievement of students.
By the end of the course, students are expected to have the capacity to:

1) distinguish between and describe the main stages of creating an application: setting the task, analysing, designing and realizing;
2) compare and evaluate various tools and methods for creating applications;
3) explain the main terms of object-oriented modelling, analysis and design and understand the class and operation diagrams of the Unified Modelling Language (UML);
4) create, write, fill, smooth and test programmes;
5) distinguish between different types of data (numbers, texts, Boolean, graphic and sound data) and use them in programmes and algorithms and have some idea of their presentation methods;
6) explain the nature of constants, variables, massifs and objects and use them rationally in algorithms and programmes;

7) distinguish between various types of operations, expressions, and functions and use them to find scores;
8) explain experience the essence of the ‘attribution’ operation and use it in algorithms and programmes;
9) use instruments for importing and exporting data;
10) explainthe main data formats for graphic data, determine operations with graphic objects and use instruments and methods for creating graphic images;
11) explainprocess-controlling instruments and use them in algorithms and programmes and describe different kinds of processes, such as sequential processes (sequences), cyclical processes (repetitions), branching processes (choices) and parallel processes;
12) create a massif in a programme, use it and describe typical algorithms such as calculating sums and means, finding extrema and searching and sorting; and
13) organise the process of dividing programmes into sub-units (procedures, functions or scripts) and coordinate work and data exchange between these units.

Learning content

Principles of creating applications; the nature of applications; methods and instruments for creating applications; general purpose programming systems and languages; application programmes and their development tools; tools for creating web applications; main stages of creating applications: setting the task, analysing, designing and realizing.
Introduction to models and modelling; the essence of models; types of models; geometric, mathematical and physical models; simulation models; object-oriented modelling and modelling language (UML); objects and classes; properties and operations of objects; events; relationship between objects and classes and class plots; operations and operation plots; using operation plots to present algorithms.
Introduction to algorithms and programming; the essence of programmes; principles of creating, processing and filling programmes; programming languages and systems; sentences and programming units: procedures, functions and scripts; translators: interpreters and compilers; the essence of algorithms; ways of presenting algorithms: activity diagrams, algorithm languages, programming languages, etc.
Handling objects and data in programmes; using the properties of objects, methods and events; types and organization of data; constants and variables; massifs; operations with data; expressions and functions; attribution; importing and exporting data.
Using graphic data in programmes; importing graphic objects; creating graphic images (drawing) with the help of a programme; main features of graphic objects and changing these features; typical operations with graphic objects; animation.
Types of processes in algorithms and programmes: sequential processes (sequences), cyclical processes (repetitions), branching processes (choices) and parallel processes; describing and filling principles for different types of processes; types of repetitions: infinite repetition and repetition with a given number of repetitions; iterative repetitions with before-and-after verifications; select one of one and of two and multiple selection.
Massifs; main properties of massifs: name, dimension, measurements and dynamics; defining and creating massifs; referring to the elements of massifs; typical algorithms for massifs: calculating sums and means, finding extrema, searching and sorting, etc.
Cooperation and data exchange between the sub-units of a programme; inquiries and sending notifications; global and local data.
Creating user interfaces; smoothing and testing programmes; final touches to programmes.

Study Activities

1. The learning process takes place in a computer class in the form of practical work and seminars.
2. The learning process is supported by a set of electronic learning materials: main chapters of theory, exercises, examples, links, electronic worksheets, etc.
3. The students have three or four independent tasks (in the classroom or at home), and these form the basis for their grade.

Physical learning environment

Educational environment for learning programming.