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Report on how IBSE is involved in national curricula and assessment in the participating countries

SAILS

Strategies for Assessment of Inquiry Learning in Science

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Contents

1. Introduction

The aim of the SAILS project is to equip teachers across Europe with assessment strategies to evaluate a number of key IBSE skills and competencies developed in the classroom, when an IBSE methodology is adopted. Using existing materials developed through national programmes or in similar European IBSE initiatives to support teachers use of IBSE in the classroom, the assessment strategies provided by SAILS will enable teachers to recognise and evaluate the benefits of teaching by this methodology. The inquiry approach in science teaching has been defined as the “intentional process of diagnosing problems, critiquing experiments, and distinguishing alternatives, planning investigations, researching conjectures, searching for information, constructing models, debating with peers, and forming coherent arguments”[2]. We assert that to fully employ the potential of IBSE, it is paramount that the assessment component is given due prominence. Therefore, SAILS aims to build on the existing IBSE curricula and teacher education programmes to motivate and support current practitioners of IBSE in the classroom, and in addition, develop a systematic approach to the assessment of IBSE skills.

The information presented in this report has been provided by national representatives from SAILS beneficiaries. Section 2 presents a review of national education and science education structures aimed at informing the activities of the SAILS project in developing appropriate professional development programmes in each of the 12 participating countries of the SAILS consortium. As well as looking at how Science Education and IBSE are involved in the national curriculum and assessment in the SAILS beneficiary countries, an account of how inquiry is implemented in other countries has also been included. Finland, Australia, Canada and USA were selected as relevant contexts for review given their international standings.

Section 3 outlines the role of IBSE in the national curriculum and Section 4 highlights how IBSE skills are considered in national assessment. In particular, contributors were asked to indicate which of the nine elements of inquiry are mentioned in respective national curriculum or assessment documentation. In addition, specific examples of IBSE assessment items were collated from across 13 countries and are also included in Section 4. An overall review of the role of IBSE in national curricula and assessment strategies in the SAILS beneficiary countries has been collated and is presented in Section 5.

[2] Linn, M. C., Davis E.A., & Bell, P. (2004). Internet Environments for Science Education. Mahwah, NJ.: Lawrence Erlbaum Associates.

2. Structure of education and science education

The following section presents educational structures from the Eurydice Network accompanied by information provided by national representatives from SAILS beneficiaries. This review of national education and science education structures aims at informing the activities of the SAILS project in developing appropriate professional development programmes as well as tools and instruments for assessing inquiry in science at secondary level.

Each beneficiary was asked to provide brief details on the educational structure in their country and in particular highlight when students change school levels (e.g. primary to secondary, or lower secondary to upper secondary, etc.) and up to what age is school compulsory. Each account of national science education structures reflects on what science subjects/disciplines pupils take at each level, how much class time is spent on science and whether science is taken as a compulsory or optional subject.

The educational and science education structures for Finland, Australia, Canada and USA are also presented here for international comparison.

2.1 Belgium

Education in Belgium is regulated and for the larger part financed by one of the three communities: Flemish, French and German-speaking. Responsibility for education in Belgium has been transferred to the communities. Only the determination of the starting and finishing ages for compulsory education, minimum requirements for diploma conferrals and the pension system are still federal matters. Education is compulsory for 6-18 year olds. After 15, students may combine work with part-time education. The educational structures for the Flemish, French and German communities are presented in Figures 1, 2 and 3 respectively but only the case of the Flemish community will be considered in this project.

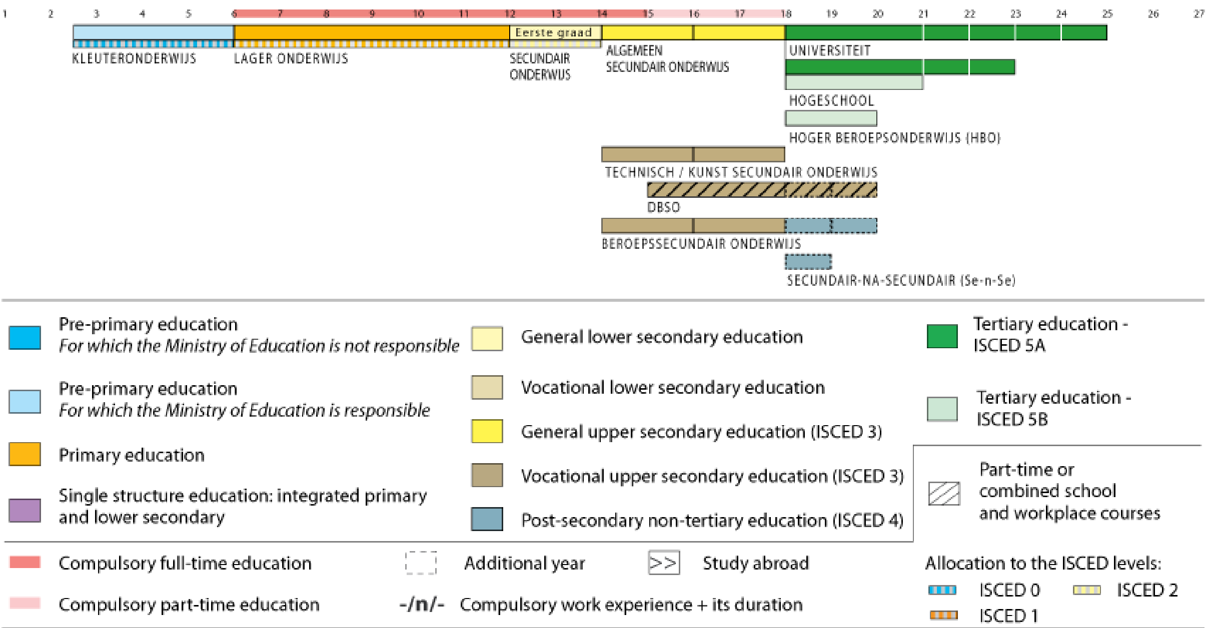


FIGURE 1 STRUCTURE OF EDUCATION IN BELGIUM. FLEMISH COMMUNITY (EURYDICE)

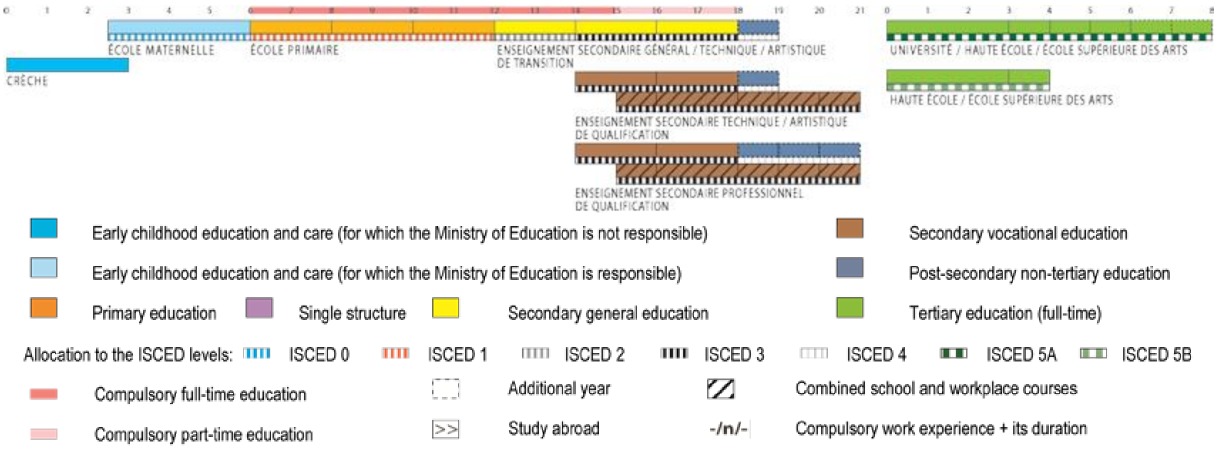


FIGURE 2 STRUCTURE OF EDUCATION IN BELGIUM. FRENCH COMMUNITY (EURYDICE)

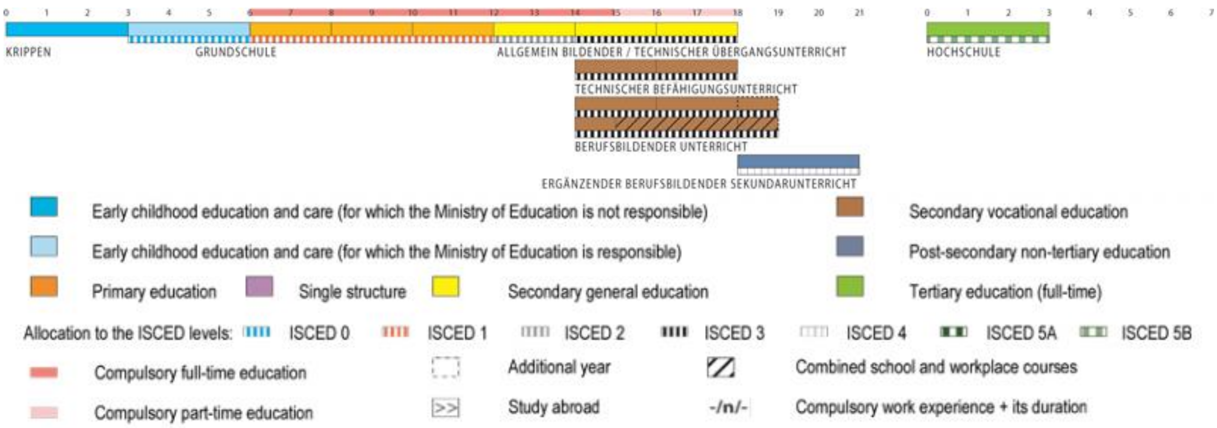


FIGURE 3 STRUCTURE OF EDUCATION IN BELGIUM. GERMAN COMMUNITY (EURYDICE)

In the Flemish Community the Department for Education and Training takes care of policy preparation and 4 internal autonomous agencies are responsible for policy implementation. Together they form the Flemish ministry of Education and Training. Primary education begins at age six and lasts for 6 years. There are four different types of secondary education, ASO, TSO, KSO, and BSO, with a common curriculum for the first two years (First Grade) for all secondary education. Science in primary school is focused on Environmental Science, while lower secondary students study integrated science. The curriculum for the first grade (the first two years of secondary education) was revised in 2010. During the first grade of secondary education, all students study science.

From the second grade (year 3 and 4) onwards, education is divided in 4 different categories**.**
ASO - General Secondary Education which provides a very broad, general education and prepares students for higher education.
TSO -Technical Secondary Education. With a TSO diploma, students can either choose to study further or go directly into employment.
BSO Vocational Secondary Education. In this case several options offer seven, sometimes eight, specialisation years. BSO is the only type of secondary education that does not qualify students to pursue higher education.
KSO Art Secondary Education. These schools link general and broad secondary education development with active art practice, ranging from performance arts to display arts. Depending on the direction, several subjects might be purely theoretical, preparing students for higher education.

2.2 DENMARK

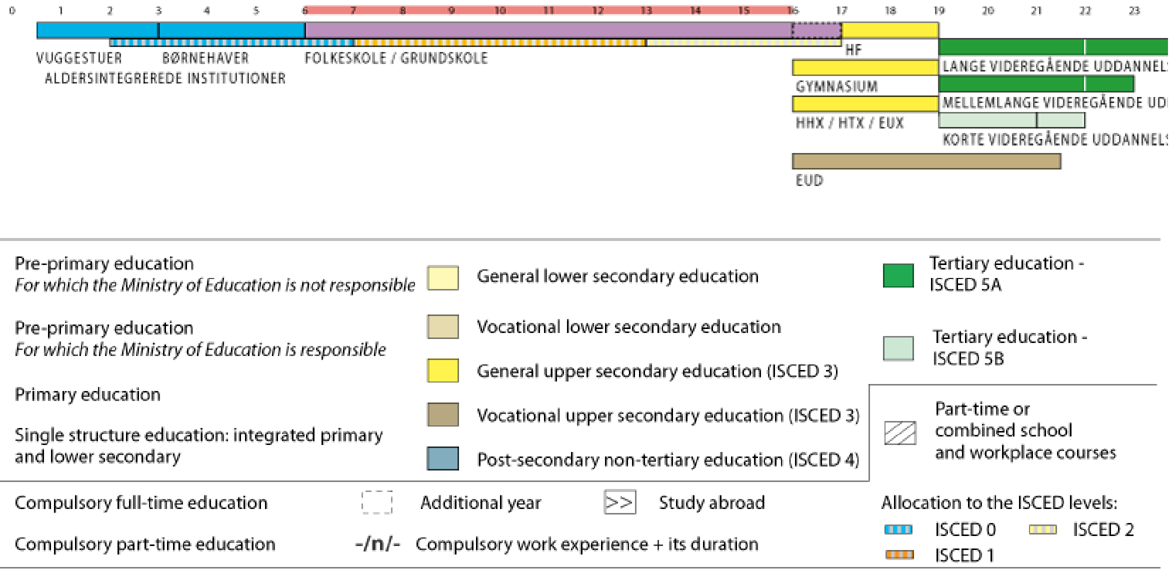


FIGURE 4 STRUCTURE OF EDUCATION IN DENMARK (EURYDICE)

Compulsory education is for ten grades and is called Folkeskole. From grades one to six, students take a general science course called "Nature and technique". From grade 7, there are separate courses in biology and earth science and an integrated course of physics/chemistry. All students study these science courses at the same level, i.e. there is no streaming during compulsory education.

This may be followed by "youth education" (upper secondary education). Youth education can be vocational or more academic in nature. Non-vocational upper secondary education is a requirement for further education while vocational education, EUD, is designed for students who wish to directly enter the workplace.

There are two types of upper secondary schools, the standard Gymnasium, called STX, and HTX, which has a more inquiry based structure. In upper secondary school, all students must study natural science subjects for the first six months of study. There are also separate courses in physics, chemistry and biology and these can be studied at three levels (A, B and C). A level is a three-year course, B level is a two-year course, and C level is a one-year course. Throughout upper secondary education, students complete a course of "General study preparation" where they have subjects like scientific theory and learn about interdisciplinarity, etc. During the final year, they undertake a multi-subject project in this course. This project is mainly theoretical and philosophical in nature. They also complete an interdisciplinary project across subjects that they are specialising in. This course is concentrated on subject matter and for students specialising in science, these projects almost always contain elements of empirical lab work.

2.3 GERMANY

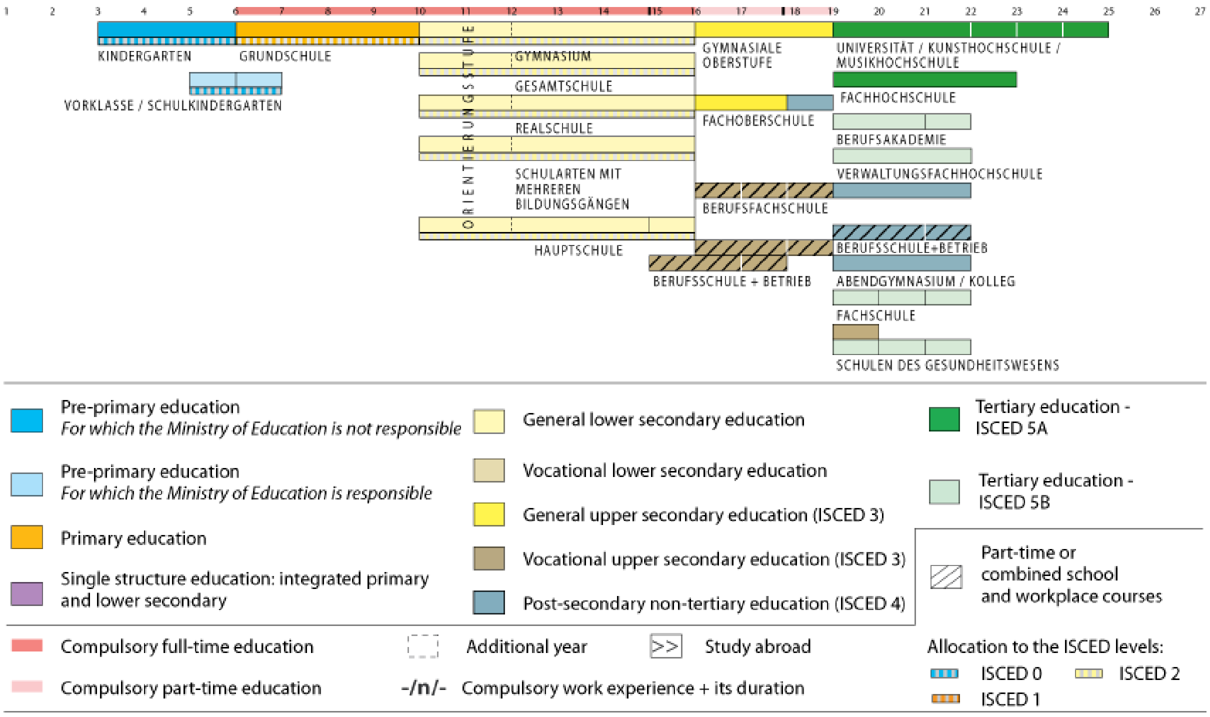


FIGURE 5 STRUCTURE OF EDUCATION IN GERMANY (EURYDICE)

Due to the federal system of states in Germany, every state is responsible for its educational system. Therefore, 16 different systems exist. Additionally, Germany has a Federal Ministry of Education and Research (BMBF) and the Standing Conference of the Ministers of Education and Cultural Affairs of the Länder in the Federal Republic of Germany (KMK). We will restrict our analysis mainly on the federal state Lower-Saxony (Niedersachsen) and will include information from BMBF and KMK.

In Germany, the schools are divided into primary schools, lower-secondary and upper-secondary schools of different types. Education is compulsory up to the 9th grade. In addition, there are schools for vocational education. In Lower-Saxony the students change from primary to lower-secondary school after the 4th grade (age 10) but there are states where students change after the 6th grade, too.

Sciences are taught in primary schools as an integrated subject called "Sachunterricht" (i.e. science). History and geography belong to this subject too. Sachunterricht is a main subject in primary schools and is taught in about four 45-minutes lessons a week.

There are differences between the different types of lower-secondary schools in the curricula, in the manner sciences are taught and science lessons are distributed over the years. There are even differences between single schools of the same type. Traditionally, the sciences are taught separately at the Gymnasium, i.e. there are compulsory courses in physics, chemistry and in biology, but not in every grade. Students have two 45-minutes lessons in a typical course. In the lower-secondary school type Gesamtschule, sciences are taught in an integrated subject called Naturwissenschaften.

In upper-secondary school students have compulsory and optional courses. Students can choose between different compulsory science courses and even might choose not to have a specific science subject like physics in upper-secondary school. There are courses of basic and advanced level. For example, students have four 45-minutes lessons of physics in an advanced physics course per week.

2.4 GREECE

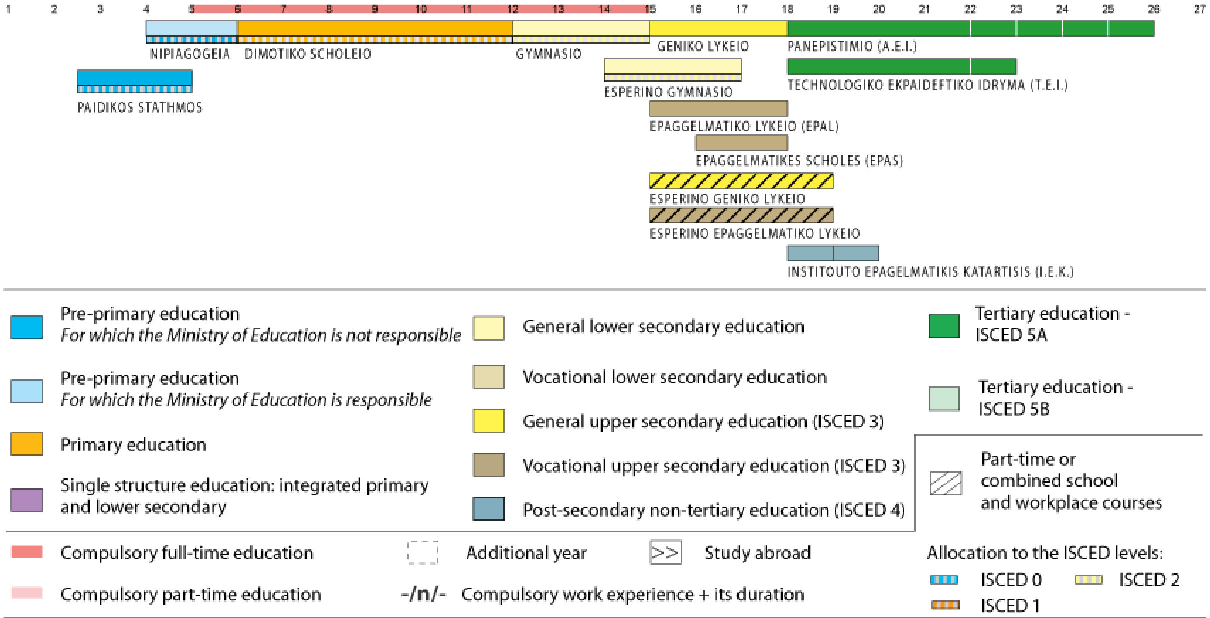


FIGURE 6 STRUCTURE OF EDUCATION IN GREECE (EURYDICE)

Education is divided into primary education (ages 6 to 11), gymnasium (11 to 13/14) and lyceum (14 to 18).

Sciences are taught in primary schools as an integrated course called "Φυσικά Δημοτικού-Ερευνώ & Ανακαλύπτω" ("Physics in Primary Education-Inquire & Discover"). Biology and Chemistry belong to this subject too. This is a main course subject in primary schools and is taught in three 45-minutes sessions per week. The course is taught in the fifth grade and sixth grade (i.e. for 10 and 11 years old students, respectively).

According to the curriculum for Primary Education the main aim of teaching Science in Primary Education is to familiarize students with the systemic observation and the awareness of the evolution of phenomena (observational dimension of the Science).

The curriculum for lower secondary education is the same for all students. Science subjects are taught for 4 or 5 periods in a 35-period per week programme of study. Table 1 shows the hours of teaching per week of each science subject across classes (A, B, C) in lower secondary schools as specified in the school curriculum decided by the Ministry of Education (Greek Ministry of Education, 2011a).

Science related Course Subjects of Lower Secondary School Class			
Course Subject	**Hours**		
	A	**B**	**C**
Physics	-	2	2
Chemistry	-	1	1
Biology	2	-	2
Geography	2	2	-

TABLE 1 TEACHING HOURS FOR SCIENCE COURSE SUBJECTS BY CLASS IN LOWER SECONDARY SCHOOL (A, B AND C ARE YEARS 1, 2 AND 3 IN LOWER SECONDARY SCHOOL)

The curriculum for upper higher secondary education has recently been reformed. In General Lyceum (Lykeio), the more academically oriented type of school, science covers a significant part of the curriculum via compulsory courses. Table 2 shows the teaching hours per week of each science related course of the upper secondary school. In addition, students of the second and third class of lyceum may select one extra science related course subject to attend for two hours per week. (these are also shown in table 2). Finally, after having finished first class of lyceum, students should select a direction of studies. They may select the theoretical direction, where there is no science related course taught at all, or one of the following directions: the science direction or the technological direction (with two strands). Both of them include science course subjects as shown in Table 2.

		Class		
		A	B	C
COMPULSORY COURSES				
Physics		3	2	1
Chemistry		2	1	-
Biology		1	2	1
ELECTIVE COURSES				
Chemistry		-	2	-
Biology		-	2	-
Astronomy and space studies		-	2	-
History of science		-	-	2
DIRECTION COURSES				
Science direction	Physics	-	2	3
	Chemistry	-	2	2
	Biology	-	-	2
Technological direction- Technology & production strand	Physics	-	2	3
	Chemistry and biochemistry	-	-	2
Technological direction – Information science and services strand	Physics	-	2	3

TABLE 2 TEACHING HOURS FOR SCIENCE BY CLASS IN GENERAL LYCEUM (UPPER SECONDARY SCHOOL)

Upper secondary education has also the form which concern vocational secondary training. Their programmes of study have the same structure with the one aforementioned for lyceum of General Education. EPAL and EPAS also have strands, which students choose according to the profession they wish to follow. The science-related course subjects, which are being taught, are more technologically oriented. For example, students studying to become car mechanics are introduced to elements of thermodynamics in the context of how car engines work.

2.5 Hungary

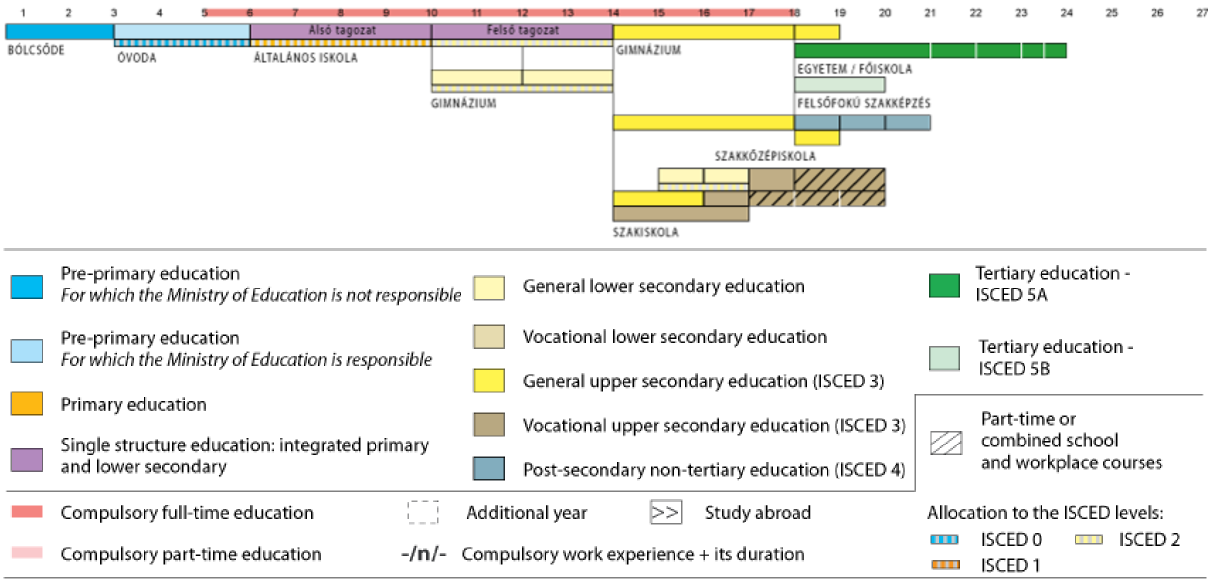


FIGURE 7 STRUCTURE OF EDUCTAION IN HUNGARY (EURYDICE)

Compulsory education is from five years (1 year pre-primary) to 18 years (end of secondary education). Primary school can be for four, six or eight years, with eight years being the most common structure. During primary education, all students study environmental science for the first six grades. Biology, chemistry and physics are compulsory from grade 7.

Learning Domain / Grade	1 to 4	5 to 6	7 to 8
Hungarian language and literature	32 to 42	17 to 24	10 to 15
Living foreign language	2 to 6	12 to 20	12 to 20
Mathematics	17 to 23	15 to 20	10 to 15
Human and society	4 to 8	4 to 8	10 to 15
Human in nature	4 to 8	7 to 11	15 to 20
Our Earth and environment	-	4 to 8	4 to 8
Arts	10 to 18	12 to 16	8 to 15
Information technology	2 to 5	4 to 8	6 to 10
Life style and practical skills	4 to 8	4 to 9	5 to 10
Physical exercise and sports	15 to 20	11 to 15	10 to 15

TABLE 2 – RECOMMENDED PERCENTAGE PROPORTIONS FOR NCC LEARNING DOMAINS (SOURCE: GOVERNMENT DECREE NO. 243/2003, P. 23.)

Secondary education follows on from primary education and can be for 5, 6 or 8 years. Secondary schools may be vocationally or academically focused. Usually subject specialists teach the different subjects in lower secondary school. There is a small integrated subject that integrates biology and geography in grades 5 and 6. But physics and chemistry and later biology and geography are taught by subject specialists.

Most of the Hungarian students (above 95%) spend their first eight years of schooling in the so-called “general school” (it is in purple on the diagram) which comprises two parts. The first four grades is the primary school, and – often in the same building – students attend the next four years as their lower secondary education.

In grades 1 to 4, science as an integrated subject (literally called "Knowledge about nature") is taught by generalist elementary teachers, and it is compulsory for everyone. In lower secondary years, in grades 5 and 6, science is an integrated subject with the main stress on a combination of geographical and biological content knowledge. In grades 7 and 8, separated subjects are taught: biology, physics, chemistry and geography.

There are three types of upper secondary schools (ISCED 3 in yellow on the diagram). Science must be taught in each of them but with different emphases and in very different time frames. In high school ("Gimnázium"), students are prepared for later higher studies, and they have to learn physics, biology and chemistry for at least two years. Although it might be possible to define an integrated science subject, in most schools, subject-specialist teachers teach their subjects. Teacher education in the past decades trained teachers with two subjects that were often paired according to strict rules. There are frequent pairs of subjects in teacher training (e.g., math-physics, physics-chemistry, chemistry-biology, biology- geography), and the isolated structure of science lessons in the upper secondary school reflects and probably will still reflect for a while the structure of teacher training.

In other types of upper secondary schools, it depends on the types of the vocational secondary ("Szakközépiskola") schools which subjects are taught at all. Of course, in a vocational secondary school specialized in mechanics, physics and chemistry will have a leading role, while in vocational secondary schools in the fields of health or forestry, biology and chemistry will be taught with greater emphases.

2.6 IRELAND

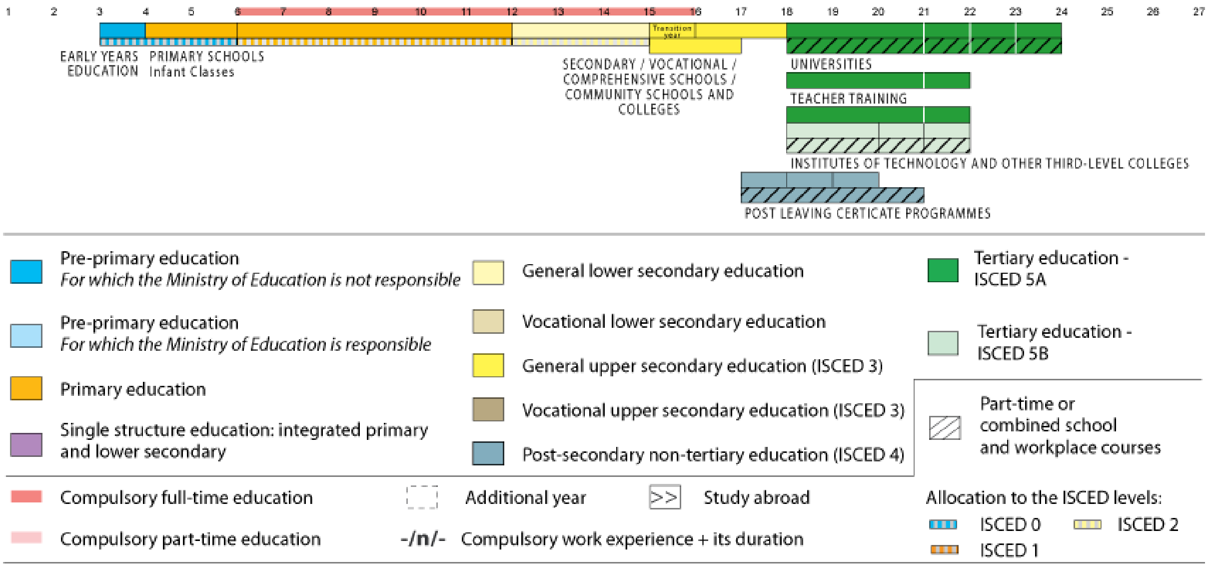


FIGURE 8 STRUCTURE OF EDUCATION IN IRELAND (EURYDICE)

The curriculum for Ireland's primary and post-primary schools is determined by the Minister for Education and Science who is advised by the National Council for Curriculum and Assessment. The curriculum sets out not only what is to be taught, but how, and how learning in the particular subject area is to be assessed.

While Ireland has a centrally devised curriculum, there is a strong emphasis on school and classroom planning. At school level, the particular character of the school makes a vital contribution to shaping the curriculum in classrooms. Adaptation of the curriculum to suit the individual school is achieved through the preparation and continuous updating of a school plan.

In Ireland, compulsory education is from 5 until the end of Junior Cycle Programme, but most complete education up until the end of the Senior Cycle. Science was re-introduced in primary schools (ages 4-12) in 2003. It comprises four content areas: Living things, Energy and forces, Materials, Environmental awareness and care. Science is part of a wider SESE (Social, environmental and scientific education) umbrella which also comprises Geography and History. Guidelines suggest 3 hours per week are allocated to SESE, so we may estimate that about 1 hour a week is dedicated to Science.

Science is optional in secondary school; however, the majority of students (about 85%) study science until the end of the Junior Cycle Programme (State Examinations Committee, 2012a). Science in the Junior Cycle Programme (ages 12-15) covers physics, chemistry and biology as separate topics, albeit taught under the umbrella of Science. Science is typically allocated four 40-minute slots per week. Senior Cycle students (two years; ages 15-18) may choose from physics, chemistry, biology, combined physics and chemistry, agricultural science. Each subject is typically allocated four 40-minute slots per week. The most popular science subject in the Senior Cycle is biology (taken by 58% of all students taking the Senior Cycle), followed by chemistry (15%), agricultural science (13%) and physics (12%), (State Examinations Committee b, 2012).

Within the Senior Cycle, students may choose to take a "Transition Year" which provides an opportunity for students to experience a wide range of educational inputs, life skills and work experience at a remove from the examination focus. Science may be offered as a subject in Transition year.

2.7 POLAND

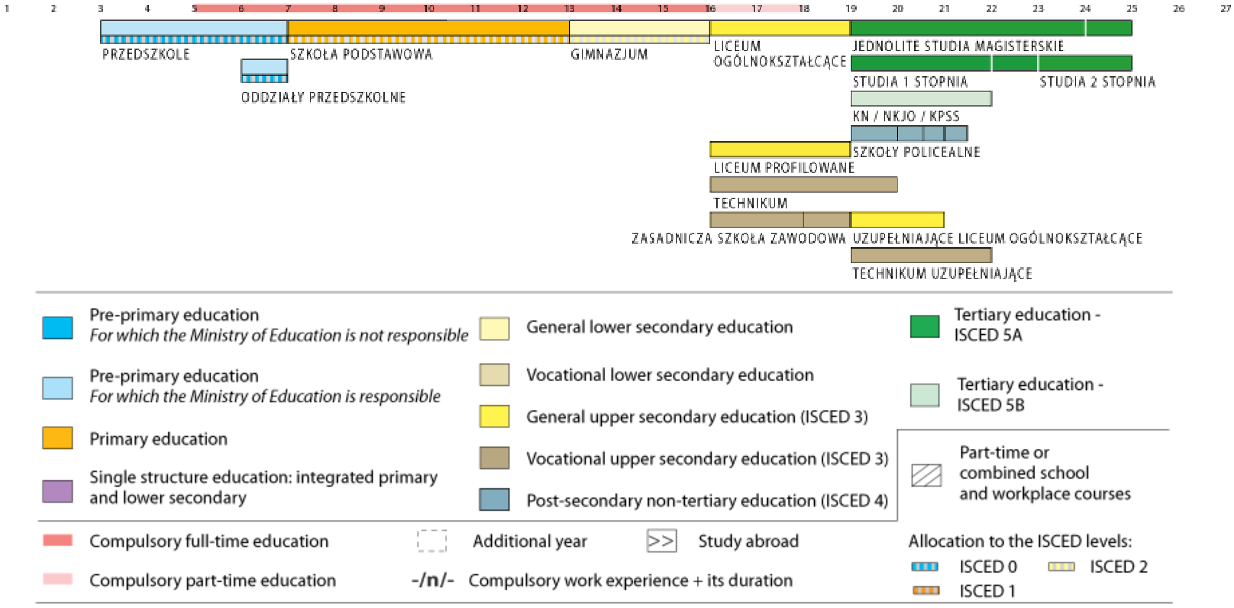


FIGURE 9 STRUCTURE OF EDUCATION IN POLAND (EURYDICE)

Currently pupils enter the primary school at age 6 or 7, depending on parents' choice, but in the near future enrolment at age 6 will be compulsory. Polish education has undergone a reform since 2009, focused mainly on the implementation of the new curriculum. In the school year 2012/2013, the new curriculum has been implemented in primary school (only grades 1-4), lower secondary school, called gymnasium, (all grades 7-9) and in upper secondary school, called lyceum (only grade 10). The rest of school education (primary, grades 5-6 and upper secondary, grades 11-12) still follows the old curriculum. The reform will be completed in school year 2014/2015.

Science is taught as one separate subject only in grades 4-6 (primary school). Topics from biology, chemistry, physics and geography exist together in this science curriculum, but cross-discipline topics are not obligatory. Starting from 7th grade, all science subjects are separated from each other, so four of them: biology, chemistry, physics and geography are obligatory in a school system. In the new curriculum in 10th grade separated science subjects continue on basic level and in addition, an integrated science subject is introduced. During the last 2 years of schooling students choose either humanities or science path of education. In case of the latter – science subjects may be elected at advanced level. Education is compulsory until 16. One of the most important goals of general education in view of the new curriculum is to achieve skills of scientific thinking (scientific literacy) – ability to use scientific knowledge to identify and solve problems and formulate conclusions based on empirical observations of the world of nature. "Research method" is highlighted in learning science at all school levels.

In the Polish school system one school period lasts 45 minutes. In grades 1-3 of primary school, only integrated education exists, covering also some topics in science but the amount of lessons given to science depends on the teacher. In grades 4-6 of primary school science is taught for 3 h per week. In lower secondary school, the number of hours depends on school time-table. In government regulation only the minimum number of hours per each subject is mentioned and some additional hours are decided by the headmaster. So in a three-year period (grades 7-9), as a minimum 130 hours of biology, 130 hours of chemistry, 130 hours of physics and 130 hours of geography should be taught, which means on average 5-6 hours of science subjects per week. In grade 10 (first year of upper secondary school) all science subjects are taught 1 hour per week, so including an integrated science subject – altogether 5 hours of science are present in a week time-table.

2.8 PORTUGAL

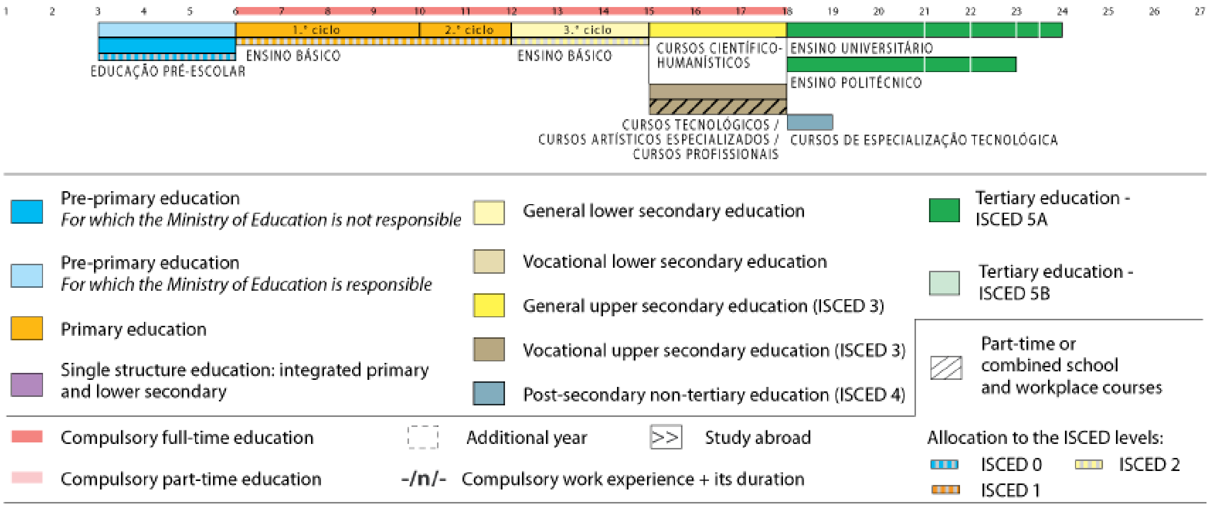


FIGURE 10 STRUCTURE OF EDUCATION IN PORTUGAL (EURYDICE)

Education in Portugal is compulsory until the age of 18. By law, preschool education is considered as the first step in Basic Education in the process of lifelong learning, being complementary to the education which is received at home and with which it should establish close cooperation. Preschool education is intended for children aged between 3 and 5/6 years old. Participation in preschool education is optional.

The Portuguese education system is divided into four stages: 3 stages or “cycles” comprising Basic Education (the first cycle corresponds to primary education, ages 5/6-9/10), the second cycle (ages 10/11-11/12), the third cycle (ages 12/13-14/15)), and Secondary Education and Professional Education (corresponding to upper secondary school, ages 15/16-17/18). On completion of secondary school, students may enter higher education.

For ease of comparison, we identify lower secondary as the third cycle and upper secondary as the secondary education system. In practice it is common to find schools with preschool and 1st cycle together, schools with the 2nd and 3rd cycles together, and schools that combine 3rd cycle and secondary level.

According to the curriculum guidelines, familiarization with science should commence with preschool education, under the specific area of “Knowledge of the World” which introduces aspects of different fields of human knowledge: history, sociology, geography, physics, chemistry and biology. Topics should be covered in an age-appropriate manner but be scientifically rigorous. Preschool education is regulated by the ministry of education and science, as are all subsequent levels.

Secondary education aims to provide a diverse learning and training and includes:

a) Scientific-humanistic courses geared towards further study at tertiary level;
b) Courses with specific plans;
c) Specialized art courses, aimed, according to the artistic area, for further study or oriented in the double perspective of immersion into the world of work and further education;
d) Professional courses geared towards the professional qualification of the students, focusing on their insertion in the labour market and permitting further studies;
e) Secondary education in the form of recurrent education;
f) Vocational education courses.

In secondary education, this report relates specifically to the scientific-humanistic courses in science.

From primary school and subsequent years, science education develops as shown in the following table:

Education Degree		Science Education	Hours/Minutes Week	Observations
Basic Education	Primary 1st cycle (4 years) 1st, 2nd, 3rd and 4th years	Environmental Studies	Not Specified - have a total of 25 teaching hours per week in each year.	A Training Program in Experimental Science Education (2006/2010) The school can manage teaching periods but not assign less than 7 hours/week for mathematics and 7/hours/week for Portuguese (native language).
	2nd cycle (2 years) 5th and 6th years	Mathematics and Natural Sciences	350 minutes to be distributed to both per week in each year.	The school can manage teaching periods but not assign less than 270 minutes per week for mathematics.
	3rd cycle (3 years) 7th, 8th, and 9th years	Natural Sciences and Physics/Chemistry (together as one subject)	270 minutes to be distributed to both per week in each year.	
Secondary Education	Secondary (3 years) 10th, 11th and 12th years	Course Scientific-Humanistic of Sciences and Technologies	(270 or 315 minutes) in each year -Biology and Geology (together as one subject) in both years - 10th and 11th -(270 or 315 minutes) in each year -Physics and Chemistry (together as one subject) in both years – 10th and 11th	In the final year of secondary education, students can choose, among others, between Biology, Geology, Physics or Chemistry as separate subjects.

The curriculum for secondary school was introduced in 2004-2005. In upper secondary school, students may study biology-geology or physics-chemistry for two years, starting in grade 10 or 11. They may study physics, chemistry, biology or geology as single subjects in grade 12.

2.9 SLOVAKIA

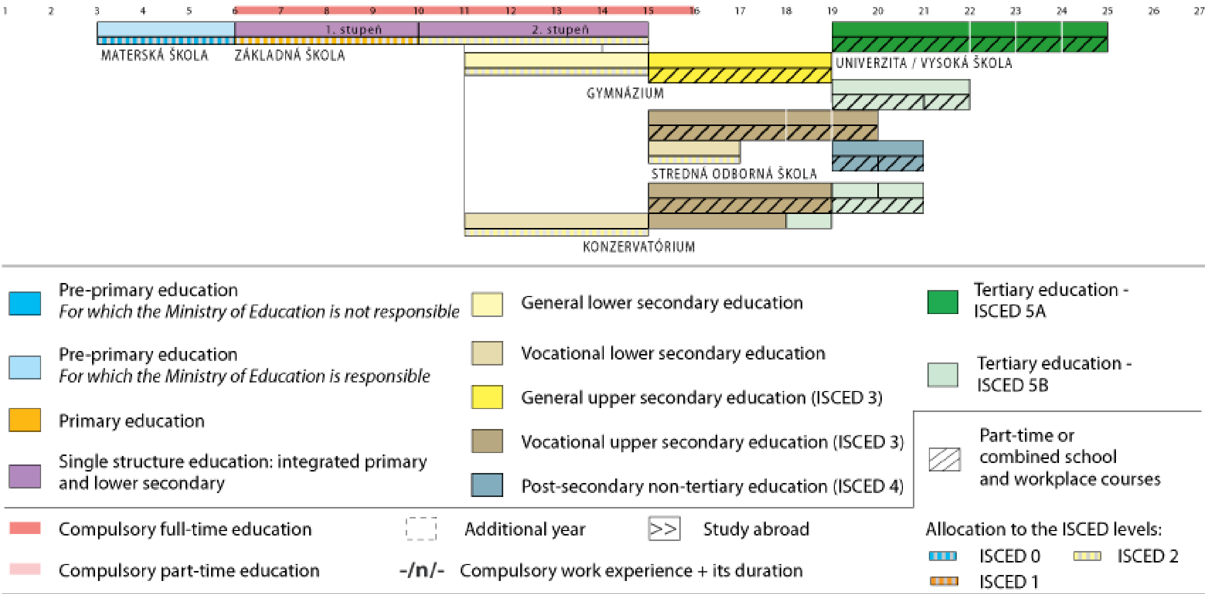


FIGURE 11 STRUCTURE OF EDUCATION IN SLOVAKIA (EURYDICE)

The teaching in schools takes place in agreement with the **State educational programmes**. They represent a starting point and a binding document for development of individual school educational programme of the school where the specific local and regional conditions and needs are envisaged. **The school educational programme** is the basic document of the school according to which the education and training is carried out at schools according to this Act.

Gymnáziá offer general education (varies across schools) which prepare the students for higher education studies, postsecondary studies, and eventually, for performance of some activities in administration, culture and in other areas. This level of education is carried out on a high-quality basis in compulsory subjects with a wide spectrum of optional and elective subjects. The education at four-year gymnasium is focused on the achievement of general educational foundation and key competences of pupil. The study is completed by a school-leaving examination.

Sciences are represented by individual subjects: mathematics, physics, chemistry, biology, geography and informatics. Each subject under the state educational programme in grades 1 – 4 is taught in total from 4 – 6 hours per week, which means e.g. for physics 2+2+1 hour per week within the grade 1 – 3. Under the school educational programme there is possibility to add more lessons per subject or to add additional subjects.

The main topics in upper secondary level in physics are: World around us, Communication, Science knowledge and ideas, Scientific inquiry, Data processing, Experimentation.

2.10 SWEDEN

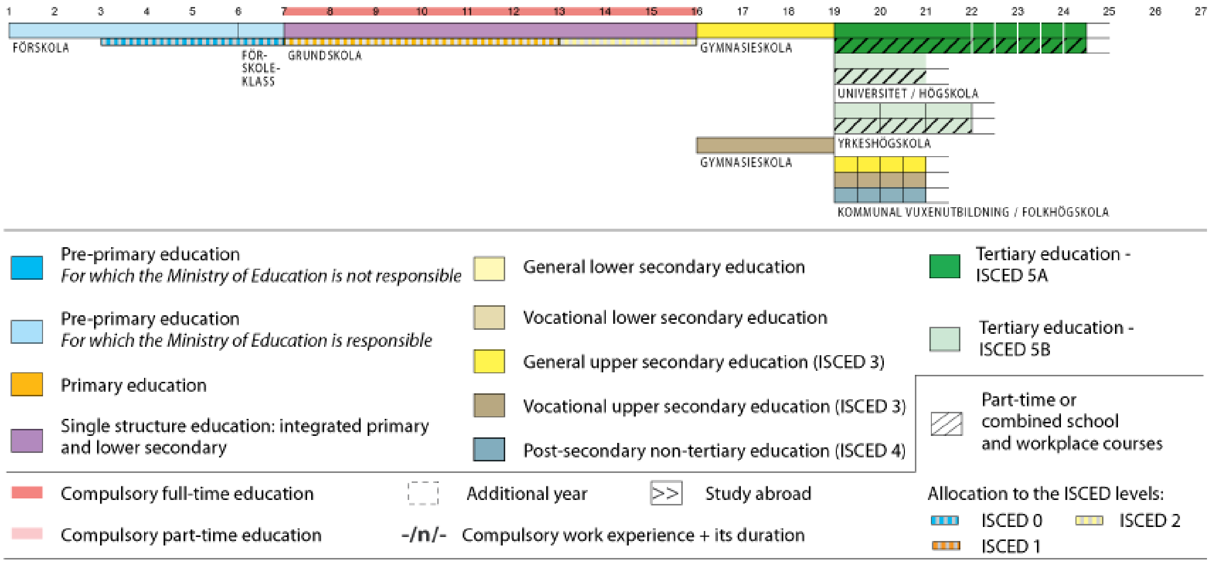


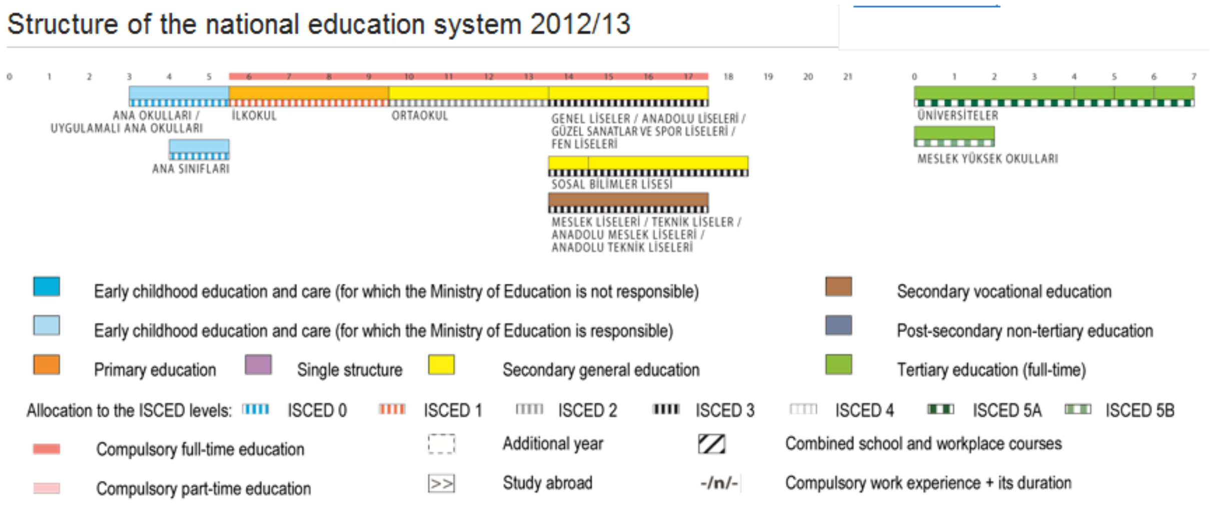
FIGURE 12 STRUCTURE OF EDUCATION IN SWEDEN (EURYDICE)

Sweden has a number of different national curricula (e.g., for pre-school, compulsory school, and upper secondary school), which all contain general goals and guidelines, as well as detailed course syllabuses. Compulsory school consists of nine years of schooling (ages 7-16) and is divided into three stages: grades 1 to 3, grades 4 to 6, and grades 7 to 9. Upper secondary school includes a number of programmes, both theoretical and vocational. Each school may have different subjects and provide different courses.

For compulsory school, a new national curriculum came into force July 1, 2011, including separate syllabuses for biology, chemistry, and physics. In grades 1–3, the course syllabuses for all sciences are identical, which means that students may be taught general science during these grades. In grades 4–9, students are to be taught biology, chemistry, and physics as separate subjects.

Upper secondary school is optional in Sweden and free of charge. Upper secondary school programs run for three years (ages 16-18). Almost all students who finish compulsory school start upper secondary school. To be accepted into a national programme, students must have passing grades in Swedish or Swedish as a second language, English and mathematics. For senior high school, students also require passing grades in nine additional subjects. For a vocational programme, students must have passing grades in five additional subjects.

2.11 TURKEY



source: Eurydice

FIGURE 13 STRUCTURE OF EDUCATION IN TURKEY (EURYDICE)

All children in Turkey receive compulsory education for 12 years, between the ages of six and eighteen years. Compulsory education in Turkey lasts 12 years, starting at the age of six until the age of 18. Compulsory education is divided into three four-year periods: primary school, middle school (lower secondary), and high school (upper secondary). In terms of grade levels, grades one through four are primary school, grades five through eight are middle school, and grades nine through twelve are high school (Turkish Ministry of Education (MEB), 2013).

In Turkey, the curriculum was changed very recently in 2013, and it will be implemented starting in primary schools in autumn 2013 and later in lower secondary and in upper secondary schools (MEB, 2013). In the new curriculum Science is taught as a separate and compulsory subject starting in grade 3. Science is nominally an integrated subject in the primary and lower secondary levels, but subject units are separated, so it is not truly integrated. In the upper secondary school, chemistry, physics, and biology are taught as separate subjects.

In the primary and lower secondary science curricula, four broad topics were determined as learning areas. These are:

- Living things and life
- Matter and change
- Physical events
- Earth and universe

Skills, Attitudes and Science-Technology-Society-Environment were also determined as three common learning areas integrated within each of the first four learning areas. Science classes are divided into seven or eight units based on the main four learning areas (roughly two units per learning area) for an academic year in each grade level. In grades 3 and 4, students take 108 hours of science (an hour here means a class period of 40 - 45 minutes) per year; in grades five through eight, students take 144 hours of science per year.

The most important feature of the new curriculum is that it aims to explicitly promote the use of inquiry based education and use of formative assessment approaches.

2.12 United Kingdom

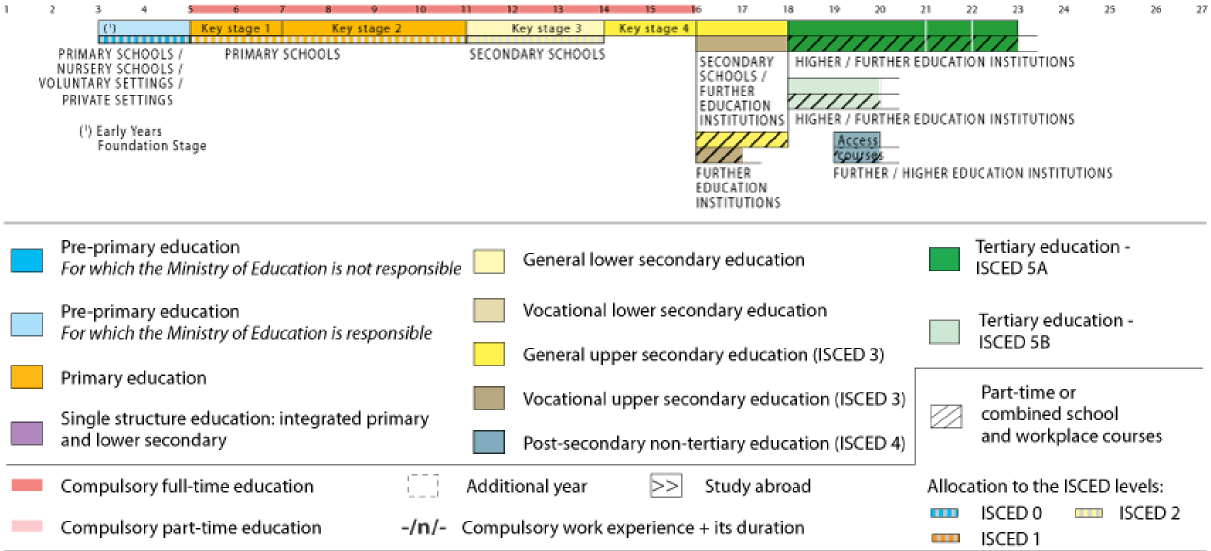


FIGURE 14 STRUCTURE OF EDUCATION IN ENGLAND (EURYDICE)

Education is a devolved power in the United Kingdom, with separate systems in each country. The following description focuses on science education in England.

Primary education starts from age 4/5 and ends at 11. Secondary schools are for 11-18 year olds. The main examination is the GCSE (General Certificate of Secondary Education), taken at age 16, which marks the end of compulsory education. Some students continue studying for A-Levels (GCE Advanced Level) after GCSE which is a requirement for university entrance. Science is a core subject for all students from 11 – 16. It is possible to take a single subject combined or coordinated science, a double subject science or separate physics, chemistry and biology courses. The national curriculum is a single curriculum covering education from 5 to 16. The academic courses are for the last two years beyond 16. They are in physics, chemistry, and biology.

Learning and undertaking activities in science contribute to achievement of the curriculum aims for all young people to become:

- successful learners who enjoy learning, make progress and achieve
- confident individuals who are able to live safe, healthy and fulfilling lives
- responsible citizens who make a positive contribution to society

The study of science fires pupils' curiosity about phenomena in the world around them and offers opportunities to find explanations. It engages learners at many levels, linking direct practical experience with scientific ideas. Experimentation and modelling are used to develop and evaluate explanations, encouraging critical and creative thought. Pupils learn how knowledge and understanding in science are rooted in evidence. They discover how scientific ideas contribute to technological change – affecting industry, business and medicine and improving quality of life. They trace the development of science worldwide and recognise its cultural significance. They learn to question and discuss issues that may affect their own lives, the directions of societies and the future of the world.

For the 11-14 curriculum (keystage 3) the following are considered key aspects of the curriculum.

1. Key concepts

There are a number of key concepts that underpin the study of science and how science works.

Pupils need to understand these concepts in order to deepen and broaden their knowledge, skills and understanding.

Scientific thinking	(a) Using scientific ideas and models to explain phenomena and developing them creatively to generate and test theories. (b) Critically analysing and evaluating evidence from observations and experiments.
Applications and implications of science	(a) Exploring how the creative application of scientific ideas can bring about technological developments and consequent changes in the way people think and behave. (b) Examining the ethical and moral implications of using and applying science.
Cultural understanding	(a) Recognising that modern science has its roots in many different societies and cultures, and draws on a variety of valid approaches to scientific practice.
Collaboration	(a) Sharing developments and common understanding across disciplines and boundaries.

2. Key processes

These are the essential skills and processes in science that pupils need to learn to make progress.

Practical and enquiry skills	Pupils should be able to: (a) use a range of scientific methods and techniques to develop and test ideas and explanations (b) assess risk and work safely in the laboratory, field and workplace (c) plan and carry out practical and investigative activities, both individually and in groups.
Critical understanding of evidence	Pupils should be able to: (a) obtain, record and analyse data from a wide range of primary and secondary sources, including ICT sources, and use their findings to provide evidence for scientific explanations (b) evaluate scientific evidence and working methods.
Communication	Pupils should be able to: (a) use appropriate methods, including ICT, to communicate scientific information and contribute to presentations and discussions about scientific issues.

3. Range and content

This section outlines the breadth of the subject on which teachers should draw when teaching the key concepts and key processes. The study of science should include:

Energy, electricity and forces	(a) energy can be transferred usefully, stored, or dissipated, but cannot be created or destroyed (b) forces are interactions between objects and can affect their shape and motion (c) electric current in circuits can produce a variety of effects
Chemical and material behaviour	(a) the particle model provides explanations for the different physical properties and behaviour of matter (b) elements consist of atoms that combine together in chemical reactions to form compounds (c) elements and compounds show characteristic chemical properties and patterns in their behaviour.

Organisms, behaviour and health	(a) life processes are supported by the organisation of cells into tissues, organs and body systems (b) the human reproductive cycle includes adolescence, fertilisation and foetal development (c) conception, growth, development, behaviour and health can be affected by diet, drugs and disease (d) all living things show variation, can be classified and are interdependent, interacting with each other and their environment (e) behaviour is influenced by internal and external factors and can be investigated and measured.
The environment, Earth and universe	(a) geological activity is caused by chemical and physical processes (b) astronomy and space science provide insight into the nature and observed motions of the sun, moon, stars, planets and other celestial bodies (c) human activity and natural processes can lead to changes in the environment.

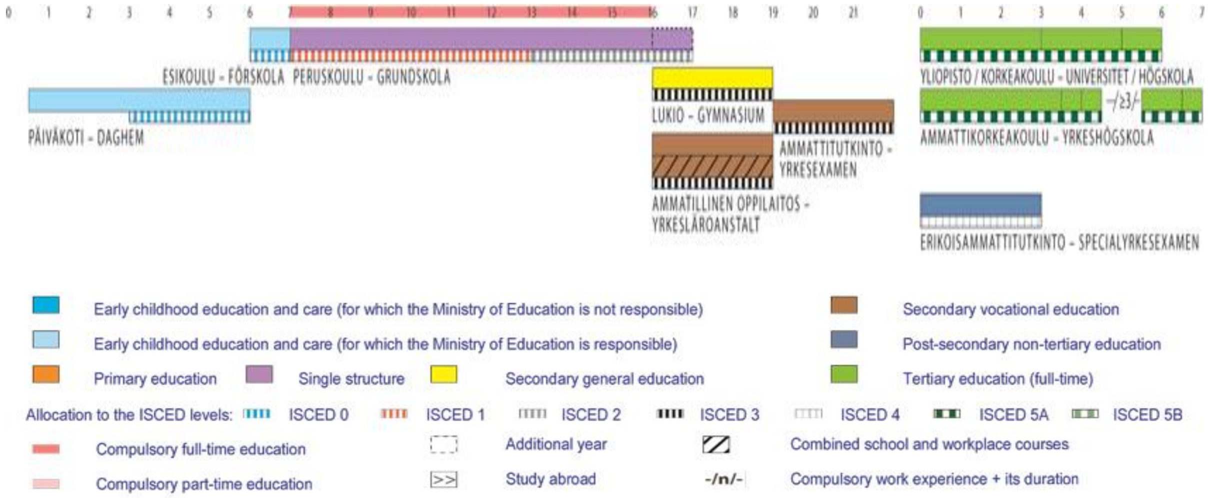
4. Curriculum opportunities

During the key stage pupils should be offered the following opportunities that are integral to their learning and enhance their engagement with the concepts, processes and content of the subject. The curriculum should provide opportunities for pupils to:

(a) research, experiment, discuss and develop arguments
(b) pursue an independent enquiry into an aspect of science of personal interest
(c) use real-life examples as a basis for finding out about science
(d) study science in local, national and global contexts, and appreciate the connections between these
(e) experience science outside the school environment, including in the workplace, where possible
(f) use creativity and innovation in science, and appreciate their importance in enterprise
(g) recognise the importance of sustainability in scientific and technological developments
(h) explore contemporary and historical scientific developments and how they have been communicated

For the 14-16 curriculum, there is a core National Curriculum but the five main examination boards derive and design their own curricula from these and so there is a greater variety in approach, range and outcome depending on the examination board selected by the school. Some boards are very traditional and decide to test mainly science content while others are more progressive and assess a range of skills including inquiry alongside content.

2.13 Finland



Compulsory education in Finland starts at age seven and continues for nine years, after which students may attend either a vocational or academic upper secondary school. More than 90 per cent (Finnish National Board of Education, 2012) of those completing basic education continue their studies in general upper secondary schools or vocational upper secondary education and training. The Finnish National Board of Education sets out the curriculum for compulsory (Finnish National Board of Education, 2004) and upper secondary education (Finnish National Board of Education, 2003) and schools must implement a local curriculum that complies with the stipulations of the core curriculum. Science is compulsory in both basic and upper secondary education.

The revised National Core Curriculum introduced in 2004 pays more attention to knowledge structures of different natural sciences, as well as ways of acquiring information and their applications. The aim is to achieve in-depth understanding of knowledge by means of exploratory learning. Accordingly, instruction in natural sciences is characterised by a problem-based approach and experiential working methods. The allocation of science subjects to grades in comprehensive school is presented in the following table:

<table>
<tr><td>Grade</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td></tr>
<tr><td>Student’s Age</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td></tr>
<tr><td>Level</td><td colspan="6">Primary School</td><td colspan="3">Lower Secondary School</td><td colspan="3">Upper Secondary School</td></tr>
<tr><td></td><td colspan="9">Comprehensive School, Basic Education</td><td colspan="3"></td></tr>
<tr><td>Science Subjects</td><td colspan="4">Integrated Environmental and Natural Studies

Altogether 9 hours/week/4 year =2.25 hours/week/year</td><td colspan="2">Integrated Biology and Geography
1.5 hours/week/year

Integrated Physics and Chemistry
1.5 hours/week/year</td><td colspan="3">Separate
Biology 1.2 hours
Geography 1.2 hours
Physics 1.2 hours
Chemistry 1.2 hours /week/year
Health Education
1 hour/week/year</td><td colspan="3">Separate
Biology 2+3 courses
Geography 2+2 courses
Physics 1+7 courses
Chemistry 1+4 courses
Health Education</td></tr>
<tr><td>Compulsory/ Optional</td><td colspan="9">C</td><td colspan="2">C+O</td><td>O</td></tr>
</table>

2.14 AUSTRALIA

A national curriculum (ACARA,2012), covering Foundation to Year 10, has been developed by ACARA – the Australian Curriculum, Assessment and Reporting Authority following a decision, *Melbourne Declaration on Educational Goals for Young Australians,* by the Ministerial Council on Education, Employment, Training and Youth Affairs in 2008. Education Authorities in each state and territory have responsibility for the implementation of the Australian Curriculum and for supporting schools and teachers with implementing the new curriculum. Prior to this, each state was responsible for developing its own curriculum. This first phase of this curriculum, focusing on English, Science, Maths and History has been developed and it is planned that the new curriculum will be phased into schools between 2013-2014.

Science education is compulsory from Foundation to Year 10 and afterwards students may choose to continue to study one or more science subjects. Similar, to many developed countries, the proportion of Australian continuing to study science subjects past the compulsory stage has declined in recent years (DITR & DEST, 2003, pg. 197). In 2002, the percentage of students taking Year 12 biology, physics and chemistry were 25%, 16% and 17% respectively, in comparison to 54%, 29% and 33% in 1980.

The science curriculum promotes six overarching ideas that highlight certain common approaches to a scientific view of the world and which can be applied to many of the areas of science understanding. These overarching ideas are patterns, order and organisation; form and function; stability and change; systems; scale and measurement; and matter and energy.

The Australian Curriculum: Science aims to ensure that students develop:

- an interest in science as a means of expanding their curiosity and willingness to explore, ask questions about and speculate on the changing world in which they live
- an understanding of the vision that science provides of the nature of living things, of the Earth and its place in the cosmos, and of the physical and chemical processes that explain the behaviour of all material things
- an understanding of the nature of scientific inquiry and the ability to use a range of scientific inquiry methods, including questioning; planning and conducting experiments and investigations based on ethical principles; collecting and analysing data; evaluating results; and drawing critical, evidence-based conclusions
- an ability to communicate scientific understanding and findings to a range of audiences, to justify ideas on the basis of evidence, and to evaluate and debate scientific arguments and claims
- an ability to solve problems and make informed, evidence-based decisions about current and future applications of science while taking into account ethical and social implications of decisions
- an understanding of historical and cultural contributions to science as well as contemporary science issues and activities and an understanding of the diversity of careers related to science
- a solid foundation of knowledge of the biological, chemical, physical, Earth and space sciences, including being able to select and integrate the scientific knowledge and methods needed to explain and predict phenomena, to apply that understanding to new situations and events, and to appreciate the dynamic nature of science knowledge.

2.15 CANADA

Education is compulsory up to the age of 16 in every province in Canada, except for Manitoba, Ontario and New Brunswick, where the compulsory age is 18, or as soon as a high school diploma has been achieved

Typically, education is broken down into four categories: early childhood (ages 5 -6), elementary education (grades 1-6, ages 6-12), junior high/middle school (grades 7-9, ages 12-15), high school (grades, 10-12, ages 15-18), but there are state-to-state differences.

Information on science education requirements for graduation is described below [Canadian Council of Ministers of Education, 2008]. The number of credits and hours of teaching per credit varies considerable from state to state. However, the ratio between science credits to required credits for graduation hopefully provides some indication of the importance of science education.

State	No. of credits graduation	No of credits science	Science options
Alberta	100	5	1 Grade 11 course in Science, Biology, Chemistry or Physics or the 10-credit combination of Science 14 (Grade 10) and Science 10 (Grade 10)
British Columbia	28 credits	8	1 Science subject from Year 10 (4 credit subject) and 1 science subject year 11 or year 12 (4 credit subject)
Manitoba	30	1	Science compulsory grades 9 and 10, optional after this
New Brunswick (Anglophone Sector)	20	1	Science compulsory in Grades 9 and 10, Science or approved Technology course (1 credit) in Grades 11 or 12 necessary for graduating
New Brunswick (Francophone Sector)	30 credits from Grade 10 to Grade 12.	3 compulsory credits	– Natural Science grade 10, – Technology grade 10 – 1 credit from the following elective courses: Biology grade 12, Physics grade 11, Chemistry grade 11, Environmental Science grade 12, Astronomy grade 12, or Natural Science Grade 11
Nunavut	73 specified and 27 unspecified credits	2 credits in Science	Based on Alberta classes
Ontario	minimum of 30 credits	3	2 credits in science plus one additional compulsory credit from one of the following: science (Grade 11 or Grade 12) or technological education (Grades 9 to 12)
Quebec	54 units, including 20 required units for Secondary 5	1	Physical Science in Secondary 4
Saskatchewan	24 credits (5 of which must be at the 30-level)		Science is a compulsory course in Grades 1–10. In addition, one science course at the 20 or 30 level is required for graduation
Yukon	minimum of 80 credits	8	One Science Grade 10, 1 Science Grade 11 or 12

2.16 USA

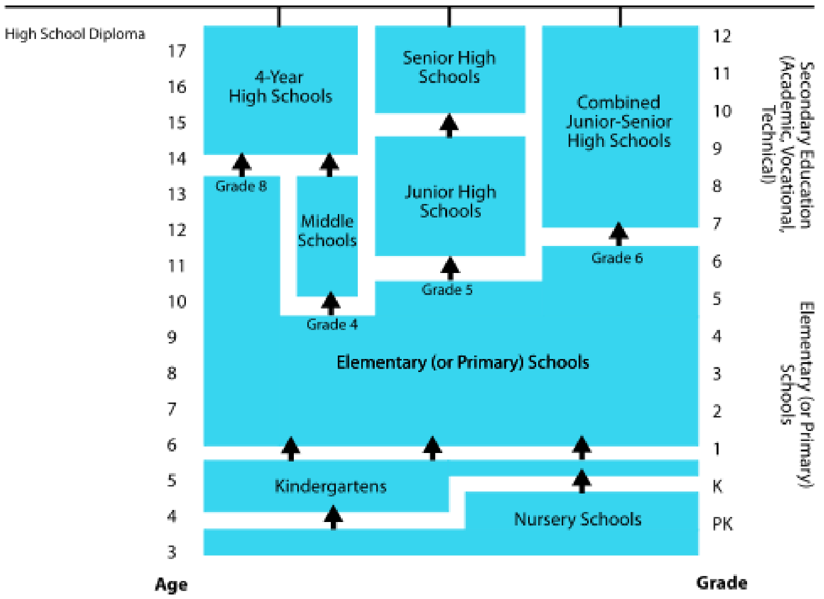


FIGURE 15 STRUCTURE OF EDUCATION IN USA

The beginning and end of compulsory education is a state decision but students normally start kindergarten by at least age 5 and start primary education, first grade, at age 6. Typically, students end high school education at age 18 but in some states, this may be reduced with parental permission. Local districts determine curriculum and the text books used in classes. Educational standards are determined on a state-by-state basis. Science is typically compulsory from elementary level to at least three years in high school.

New guidelines for science education have been launched in 2013, known as the Next Generation Science Standards, and are the first broad national recommendations for science instruction since 1996. The standards are based largely on the 2011 NRC A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. The purposes of the standards include combatting ignorance of science, creating common standards for teaching in the U.S., and developing greater interest in science among students so that more of them choose to major in science and technology in college. Overall, the guidelines are intended to help students understand the scientific process of developing and testing ideas and have a greater ability to evaluate scientific evidence. The resulting curricula may cover fewer topics, but will go more deeply into specific topics, using a case-study method and emphasizing critical thinking and primary investigation. The new approach may even replace traditional high school courses such as biology and chemistry. The nature of science is included in the Next Generation Science Standards. The basic understandings about the nature of science are:

- Scientific Investigations Use a Variety of Methods
- Scientific Knowledge is Based on Empirical Evidence
- Scientific Knowledge is Open to Revision in Light of New Evidence
- Scientific Models, Laws, Mechanisms, and Theories Explain Natural Phenomena
- Science is a Way of Knowing
- Scientific Knowledge Assumes an Order and Consistency in Natural Systems
- Science is a Human Endeavor
- Science Addresses Questions About the Natural and Material World

The first four of these understandings are closely associated with practices and the second four with crosscutting concepts.

3. Inquiry in national curricula

This section presents information from national curriculum pertaining to inquiry at lower and secondary level. Specific extracts of national statements supporting inquiry have been translated and presented for each SAILS beneficiary country. It is important to note that while all educational policies support IBSE, some for several decades, that this may not truly reflect classroom practice, as there are large variations between schools and teachers in and across each country.

3.1 Belgium

This report describes the curriculum for the Flemish community.

Diagnosing problems		Critiquing experiments		Distinguishing alternatives		Planning Investigations		Researching conjectures	
LS	US	LS	US	LS	US	LS	US	LS	US
✓	✓		✓	✓	✓	✓	✓	✓	✓
Searching for information		Constructing models		Debating with peers		Forming coherent arguments			
LS	US	LS	US	LS	US	LS	US		
✓	✓				✓		✓		

TABLE 3 ELEMENTS OF INQUIRY IN THE NATIONAL CURRICULUM IN BELGIUM; LS IS LOWER SECONDARY CURRICULUM, US IS UPPER SECONDARY CURRICULUM

Statements supporting inquiry from the curriculum for lower secondary (first grade)

Students studying at the A-stream level should (with the assistance of the teacher) be able to:

- translate a scientific problem into a research question, and formulate a hypothesis or expectation from this question;
- collect data and perform an experiment, a measurement or an observation;
- research information and distinguish the essential steps of the science method
- handle collected and provided data to classify, determine or formulate a decision;
- report results from an experiment, a measurement or a field study
- to make correct use of the quantities length, mass, area, volume, temperature, time, pressure, speed, strength and energy units and their symbols in different contexts and assignments;

Students studying at the B-stream level should (with the assistance of the teacher) be able to:

- Make observations
- Make measurements and choose appropriate instruments;
- Investigate a hypothesis on natural and observed phenomenon
- Make use of simple tables, charts and diagrams

Statements supporting inquiry from the curriculum for upper secondary school for ASO (second and third grade) and KSO, TSO (only second grade), general science course

With regard to a concrete scientific or applied scientific problem, question or phenomenon, pupils can

- Point out, look up and justify relevant parameters or data information
- Formulate a hypothesis (assertion, expectation) and indicate how these can be examined.
- Recognize and indicate conditions and circumstances that a hypothesis (assertion, expectation) refutes or supports
- Gather ideas and information on a hypothesis (assertion, expectation) to test and to illustrate it.
- Estimate conditions that may affect an observed effect
- Indicate which factors can play a role and how they can be examined.
- Consider results of experiments and observations that are the opposite of those that are expected, taking into account the circumstances that could influence the results.
- Know how to generalize results of experiments and observations by way of a new hypothesis.
- Connect experiments or observations in classroom situations with situations from the real world
- Report data in an oral and written way, display it in tables, charts, diagrams or formulas.
- Do an assignment alone or in group, and report on it afterwards.

Statements supporting inquiry in the ASO (second grade) curriculum for students specialising in science

The pupils can

- under supervision, formulate a given research problem and research question.
- collect and organize information in a systematic manner, on the basis of selected sources for a given research question.
- under supervision, research a given problem with a offered research method.
- under supervision, interpret search results, and formulate conclusions.
- report, according to a given template, the results of their own research activity.
- under supervision, reflect on the obtained results and on the method used.

Statements supporting inquiry in the ASO (third grade) curriculum for students specialising in science

The pupils can

- orient themselves on a research problem by collecting, organizing and editing information;
- prepare, implement and evaluate a research assignment with a scientific component.
- report research results and conclusions and confront them with other opinions.

3.2 DENMARK

Diagnosing problems		Critiquing experiments		Distinguishing alternatives		Planning Investigations		Researching conjectures	
LS	US	LS	US	LS	US	LS	US	LS	US
✓	✓	✓	✓	✓		✓	✓	✓	✓
Searching for information		Constructing models		Debating with peers		Forming coherent arguments			
LS	US	LS	US	LS	US	LS	US		
✓	✓		✓	✓	✓	✓	✓		

TABLE 4 ELEMENTS OF INQUIRY IN THE NATIONAL CURRICULUM IN DENMARK; LS IS LOWER SECONDARY CURRICULUM, US IS UPPER SECONDARY CURRICULUM

Statements supporting inquiry from the curriculum for lower secondary
Biology (compulsory forms 7-9)
The education must give the students confidence with scientific working methods and shape their view and insight into how biology and biological research contribute to our understanding of the world in interaction with other sciences. The education must use varying working methods and to a great extent build on the students' own observations and investigations, i.e. through lab and field work. The education must develop the students' interest and curiosity towards nature, biology, science and technology and make them want to learn more.

At the end of the 7th grade, there is an expectation that students develop the following skills and competencies.

- Identify and phrase relevant issues and construct hypotheses
- Plan, complete and evaluate studies and experiments in nature and in the lab
- Read, understand and evaluate information in academic texts
- Use information technology in connection with information search, collection of data, data processing and communication
- Know examples of biological research which has expanded the knowledge of humans
- Use suitable technical terminology
- Communicate the result of their work with biological issues
- Distinguish between the background for and the objective with different digital information

At the end of the eighth grade, students should also be able to:

- Distinguish between attitudinal and factual statements
- Use simple equipment for studies and experiments in nature and in the lab, including microscopes, stereo microscopes and equipment for analysis of physical and chemical relations (also physics/Chemistry)
- Use IT technology for information search, collection of data, data processing and communication ((also physics/Chemistry)
- Give examples of how biological knowledge comes into existence through experiments, systematic studies and interpretation of data
- Know examples of narratives of natural history which have expanded the knowledge of humans
- Define biological knowledge and connections by using relevant terminology
- Account for biological knowledge and insight obtained through various forms of knowledge search, including their own studies.

At the end of the ninth grade, students should also be able to:

- Phrase and recognize relevant biological issues
- Construct and test scientific hypotheses on the basis of their own studies

- Make suggestions for biological experiments and systematic studies in connection with questions regarding nature, the environment and health
- Design and complete relevant studies and choose suitable equipment
- Formulate conclusions on the basis of the results of both themselves and others
- Refine and experiment with the use of IT-based resources during the work with and communication of biological topics and issues in nature as well as the lab
- Use IT for data retrieval and information search regarding relevant biological issues
- Give examples where the results of newer biological research has had an impact on the knowledge and living conditions of humans
- Use biological terms and knowledge regarding biological processes in different contexts
- Communicate the results and conclusions of the work with biological topics and issues through the use of versatile methods.

Physics/Chemistry (compulsory forms 7-9)
This education will give the students confidence with scientific working methods and shape their view and insight into how Physics and Chemistry – and research in both subjects – contribute to our understanding of the world in interaction with other sciences.
The education will use varied working methods and will, to a large degree, build on the observations and studies of the students themselves, e.g. through lab work. The education must develop the students' interest in and curiosity towards Physics, Chemistry, science and technology and make them want to learn more.
IBSE is not explicitly written in the curricula at lower or upper secondary. However, the goals of the curriculum may be met by using IBSE. Standards for student competencies are defined at the end of each grade.
Skills and competencies for physics/chemistry are very similar to those for biology.

Statements supporting inquiry from the curriculum for upper secondary
Although the Danish curriculum does not mention inquiry, it is obvious that inquiry skills are recognised in the goals for education. Examples include proficiency with making observations, planning experiments, taking part in open-problem investigations, searching for and evaluating information, etc.

The standards that a student should reach after taking part in a Level A course of study is Biology include:

- Phrasing and analysing biological issues with a confident use of biological terminology in known as well as new contexts
- Completing independent observations and studies and planning experiments in the lab as well as in the field, including evaluating elements of risk and the safety precautions when using biological material, apparatus and chemicals
- Analysing and processing data from experimental work and process and communicate results from biological studies
- Analysing and evaluating articles with biological content
- Searching for and evaluating information regarding the environment, health, medicine and biotechnology
- Demonstrating knowledge about the identity and methods of the subject
- Evaluating comprehensive biological issues and their impact, both locally and globally
- Expressing themselves structurally, both orally and in writing, regarding biological topics, while including ethical and attitudinal circumstances
- Having an academic background for decision making and action regarding their own and societal issues that have a biological content.

3.3 GERMANY

Diagnosing problems		Critiquing experiments		Distinguishing alternatives		Planning Investigations		Researching conjectures	
LS	US	LS	US	LS	US	LS	US	LS	US
✓	✓	✓	✓	✓	✓				
Searching for information		Constructing models		Debating with peers		Forming coherent arguments			
LS	US	LS	US	LS	US	LS	US		
✓	✓		✓	✓	✓	✓	✓		

TABLE 5 ELEMENTS OF INQUIRY IN THE NATIONAL CURRICULUM IN GERMANY; LS IS LOWER SECONDARY CURRICULUM, US IS UPPER SECONDARY CURRICULUM

The Standing conference of the Ministers of Education and Cultural Affairs of the Länder in the Federal Republic of Germany (KMK) has published in 2004 educational standards in physics (and chemistry and biology) for grade 10, i.e. the end of lower-secondary school in Germany. They are called "Bildungsstandards für den Mittleren Schulabschluss Physik". Four different fields of competence are distinguished: subject-specific knowledge as a content-related competence and three process-related fields of competence like communication competence. Standards for all four fields have been formulated and some of them can be related to typical activities of inquiry learning.
<u>Examples:</u>
Standard E3: *Students use analogies and models for the purpose of knowledge activation.*
Standard E6: *Students formulate hypothesis in simple tasks.*
Standard E8: *Students plan simple experiments, conduct these experiments and document their results.*
Standard K3: *Students investigate different sources of information.*
Standard K5: *Students document their work.*
Standard K7: *Students discuss their results and data under a physical viewpoint.*
Standard B1: *Students illustrate on simple examples the possibilities and constraints of a physical viewpoint in contexts within and outside physics.*
Standard B2: *Students compare and evaluate alternative technical solutions with regard to physical, economical, ecological and social facets.*

The new curricula in lower- secondary and upper-secondary school in in the state Lower-Saxony refer strongly to the educational standards of the KMK, but there are some differences concerning for example the structure of the content-related competence. The curriculum details the competencies students should have for different grades. For example, the competencies are specified for the grades 5/6, grades 7/8 and grade 9/10 in the lower-secondary school Gymnasium.
<u>Examples:</u>
At the end of grade 6: Students formulate problem-related questions.
At the end of grade 6: Students use the model of molecular magnets for the interpretation of observations.
At the end of grade 8: Students use their knowledge to evaluate energy-saving measures.
At the end of grade 8: Students report on work results and use for this purpose demonstration experiments and media.
At the end of grade 10: Students draw suitable data tables on their own.
At the end of grade 10: Students test hypothesis with experiments that have been planned by them.

There are similar fields of competence specified for the upper-secondary level. The examination requirements for the final examination of upper secondary school, Abitur, of the KMK is one reference. Of course, the contents and the level of competencies in upper-secondary school are different compared to lower-secondary schools.

3.4 Greece

Diagnosing problems			Critiquing experiments			Distinguishing alternatives			Planning Investigations			Researching conjectures		
PE	LS	US	PE	LS	US	PE	LS	US	PE	LS	US	PE	LS	US
✓	✓	✓	✓	✓	✓	✓	✓	✓						
Searching for information			Constructing models			Debating with peers			Forming coherent arguments					
PE	LS	US	PE	LS	US	PE	LS	US	PE	LS	US			
✓	✓	✓			✓		✓	✓		✓	✓			

TABLE 6 ELEMENTS OF INQUIRY IN THE NATIONAL CURRICULUM IN GREECE; PE IS FOR PRIMARY EDUCATION, LS IS FOR LOWER SECONDARY CURRICULUM, US IS FOR UPPER SECONDARY CURRICULUM

Inquiry in Curriculum for Primary Education

According to the Curriculum for Primary Education the teachers' priority should be to familiarize students with the utilization of knowledge so that they are able to interpret the living and non-living beings around them. Special emphasis is given to the acquisition of scientific attitudes such as the observation, the formulation of hypothesis, the performance of experiments, the ability to make conclusions and generalizations. Previous experience and knowledge is utilized during the practical implementation and experiments that are introduced. The development of material is displayed in a spiral manner from easy to difficult, from simple to complex.

The types of practical activities taking place in the school lab vary. Different types are shown in table 7a, followed by examples of specific activities.

Type of activity	Examples
Observation	• Observation of different types of teeth • Observation of the results of electricity • Observation of propagation of light
Measurement of magnitudes (including considerations about error in measurement)	• Measurement of length, weight, time and force • Measurement of mass and volume
Identification	• Identification of reaction of the substances between each other (chemical reactions) • Identification of micro-organisms in the environment
Confirmation of laws (fair-testing)	• It is not included in the Curriculum

TABLE 7A TYPES OF PRACTICAL ACTIVITIES CARRIED OUT IN PRIMARY EDUCATION

Scientific inquiry has come into focus within the Greek national curriculum for secondary education during the last fifteen years.

Within the broader aims of science education, scientific inquiry aims at enabling students to:

- familiarise themselves with lab equipment and assemble simple apparatus
- understand and follow directions
- learn how to observe and measure accurately
- formulate conclusions
- increase their satisfaction with studying science
- learn to co-operate and take initiative
- combine elements of their theoretical and practical knowledge so as to gain a deeper understanding of phenomena.

At the moment, all higher secondary schools and some lower secondary schools are provided with school labs equipped so that a standard package of practical activities can be carried out. In addition, there is the possibility for schools to borrow specific equipment from a centre for inquiry in science education (CISE), which is responsible for providing support to teachers for carrying out scientific inquiry activities in schools. One limitation of how inquiry is carried out is that, due to resources being limited, the majority of practical activities are performed as demonstrations. Furthermore, even when there is the possibility for multiple sets of equipment to be used, this might be hard to materialise due to time constraints in the use of the school lab (when there are not enough classrooms in the school, the school lab may also be used as a typical classroom).

The Ministry of Education publishes regulations at the beginning of each school year, which contain the minimum number of activities that are to be carried out in each class. For example, for a subject taught for two periods a week, the minimum number of practical activities is four (Ministry of Education, 2009a; 2009b).

Inquiry in curriculum for lower secondary school
The types of practical activities taking place in the school lab vary. Different types are shown in table 7b, followed by examples of specific activities.

Type of activity	Examples
Observation	• Observation of animal and plant cells (Biology, LSS, class A)
Measurement of magnitudes (including considerations about error in measurement)	• Measurement of length, weight, time and force (Physics, LSS, class B)
Identification	• Identification of proteins, sugars and starch in food samples (Biology, LSS, class A) • Identification of halogen ions (Chemistry, LSS, class C)
Confirmation of laws (fair-testing)	• Ohm's law (Physics, LSS, class C)

TABLE 7B EXAMPLES OF TYPES OF PRACTICAL ACTIVITIES CARRIED OUT IN LOWER SECONDARY SCHOOLS

Inquiry in curriculum for upper secondary school
The types of practical activities taking place in the school lab vary. Different types are shown in table 7c, followed by examples of specific activities.

Type of activity	Examples
Observation	• Observation of the spectrum of gases (Physics, HSS, class C, general education)
Measurement of magnitudes (including considerations about error in measurement)	• Measurement of the pH of solutions (Chemistry, HSS, class A)
Confirmation of laws (fair-testing)	• Factors which affect the speed of a chemical reaction (Chemistry, HSS, class, B, science direction)
Calculation of the size of specific magnitudes	• Calculation of the acceleration of gravity with the use of a pendulum (Physics, HSS, class B, general education) • Calculation of the speed of a chemical reaction (Chemistry, HSS, class B, science direction)
Making things	• Making of soap (Chemistry, HSS, class B, general education)

TABLE 7C TYPES OF PRACTICAL ACTIVITIES CARRIED OUT IN UPPER SECONDARY SCHOOLS

Students in both lower and upper secondary school are provided with coursebooks and guides for inquiry to guide them through the activity. Typically, the materials for each activity include a statement of the objectives of the practical, an estimation of the time required for the completion of the exercise and a quick review of the scientific knowledge which forms a pre-requisite for carrying out the activity. Then follows a list of the equipment required and detailed instructions on how the experiment is to be performed. Students are also provided with worksheets to note down their measurements. The instructions on how the activity is to be performed are so specific that there is little room for students to make choices in the planning phase of the experiment. However, in most cases, towards the end of the activity, students are required to think about and explain why part of the procedure was as instructed or to evaluate their findings. For example, in the case of confirmation of the conservation of the mechanical energy of a plastic sphere (Physics, USS, class C, science/technological direction), students are asked to explain whether a metallic or a glass sphere could be used in the experiment instead of a plastic one. Or in the case of study of Hooke’s law, students are asked to compare the magnitude of the spring contact they calculated experimentally to the one derived by Hooke’s law and to account for any difference.

3.5 HUNGARY

Diagnosing problems		Critiquing experiments		Distinguishing alternatives		Planning Investigations		Researching conjectures	
LS	US	LS	US	LS	US	LS	US	LS	US
✓	✓		✓		✓	✓	✓	✓	✓
Searching for information		Constructing models		Debating with peers		Forming coherent arguments			
LS	US	LS	US	LS	US	LS	US		
✓	✓		✓	✓	✓		✓		

TABLE 8 ELEMENTS OF INQUIRY IN THE NATIONAL CURRICULUM IN HUNGARY; LS IS LOWER SECONDARY CURRICULUM, US IS UPPER SECONDARY CURRICULUM

Statements supporting inquiry from the curriculum for lower secondary
Students must get acquainted with planned observation, experimentation, the presentation of results, mathematical description of supposed relationships, the method of checking, validation and falsification, the essence of argumentation based on scientific statements and model construction.

The learning environment shall be designed in such a way that it supports the different forms and techniques of active learning depending on the composition and size of the group of students and on the available equipment. Certain methods of active learning (for example PBL or cooperative learning) shall be chosen in line with the development task, content and the needs of the student-group.

Development tasks related to IBSE
It develops general skills such as abstraction, deduction, evaluation of data, the development of probabilistic thinking, the examination of variables, the differentiation of data, facts and explanations, the recognition of special (technical, economic, social, ethical) applications, connections, the evaluation of others' viewpoints, exposition of the own viewpoint and appreciation of the role of the scientific community.

The development of skills and abilities is embedded into contents connected to the key concepts of basic theories and models of science. Scientific literacy develops the skills of communication, simplification, developing structures, classification, definition, systematic observation, experimentation, measurement, collection and processing of data, conclusion, prediction, verification and falsification. The structure of development tasks:

1. Science, technology, culture
2. Matter, energy, information
3. Systems
4. The connection between structure and function
5. Permanence and change
6. Getting acquainted with the human being and its health
7. Environment and maintenance

The skills and methods related to IBSE appear only in the first point of the list above, therefore the following relates only to the strand Science, technology, culture. For example in lower secondary education, during grades 5-6, students should be developing skills to

- gather and process information
- make observations and perform experiments
- participate in group work
- carry out investigations on their own at least twice a year
- prepare a project on a scientific topic

- raise questions and solve problems
- understand the relationship of science and technology with everyday life, the formulation of the idea of individual responsibility.

In grades 7-8, students should further develop these skills and also begin to develop the following competencies:

- differentiation of scientific methods and non-scientific ideas.
- use of methods of computer supported learning (looking for information, use of library, internet, databases, simulations, designing presentations)
- guided use of methods of observation, experimentation and measurement.
- interpretation of measurement data and diagrams
- further development of methods of group-work.
- carrying out examinations or experiments at least twice a year per subject in biology, physics and chemistry.
- keeping records of examinations or experiments presented in class at least four times a year per subject in biology, physics and chemistry.
- preparation of a project work within the topic of hygiene.
- looking for, monitoring and interpreting scientific educational resources individually; presentation of the results of the search, interpretation of peers' results.

Under the topic Environment and maintenance, during grades 5 and 6, students should be able to

- interpret and analyse weather and climate based on the examples from the Carpathian Basin.
- participate in teacher-guided observations, make individual measurements or participate in group work

For grades 7 – 8, students should be able to:

- recognise and explain the interactions in the geographical spatial based on the regional examples.
- undertake research and construct models
- search for information

Statements supporting inquiry from the curriculum for upper secondary
The competencies that should be developed during upper secondary school in the area of Science, Technology and Culture are listed below.

- The deliberate use of the operations of scientific thinking.
- Seeing the reason of the usefulness of scientific thinking in everyday life and the deliberate application of methods
- Making measurements, searching for information, presentation and communication.
- Critical evaluation of the process and results of acquiring information.
- Efficient search for information aimed at problem solving.
- Deliberate identification of problems, examinations of suppositions.
- Planning of experiments for problem solving, analysis of experiments, differentiating alternatives.
- Formulation and examination of models, formulation of coherent and critical argumentation.
- Preparing presentations alone and in group-work.
- Carrying out examinations or experiments at least twice a year per subject in biology, physics and chemistry.
- Keeping records of examinations or experiments presented in class at least four times a year per subject in biology, physics and chemistry.
- Presentation of experience of at least one out-of-school practice.

- Looking for, monitoring and interpreting scientific educational resources individually; presentation of the results of the search, interpretation of peers' results.
- Interpretation of science-historical processes, the births and changes of models, ideas, theories complementing and giving place to one another.
- Analysis of the advantages and disadvantages of cognitive methods.
- Critical analysis of the complex system of coherence of science, technology and society, raising problems, getting acquainted with alternative solutions, formulation individual viewpoints.
- Recognition and explanation of the interactions within and between geospheres.

3.6 IRELAND

Diagnosing problems		Critiquing experiments		Distinguishing alternatives		Planning Investigations		Researching conjectures	
LS	US	LS	US	LS	US	LS	US	LS	US
		✓	✓			✓	✓		
Searching for information		Constructing models		Debating with peers		Forming coherent arguments			
LS	US	LS	US	LS	US	LS	US		
✓	✓			✓	✓	✓	✓		

TABLE 9 ELEMENTS OF INQUIRY IN THE NATIONAL CURRICULUM IN IRELAND; LS IS LOWER SECONDARY CURRICULUM, US IS UPPER SECONDARY CURRICULUM

Statements supporting inquiry from the curriculum for lower secondary
The National Council for Curriculum and Assessment have described skills that students should obtain during the Junior Cycle Programme. These fit into 6 categories; skills relating to self-management, staying well, communication, creativity, working with others and managing information and thinking (Department of Education and Skills, 2012).

Managing myself	**Staying well**	**Being creative**
• Knowing myself • Making considered decisions • Setting and achieving personal goals • Being able to reflect on my own learning • Using digital technology to manage myself and my own learning	• Being healthy, physical and active • Being social • Being safe • Being spiritual • Being confident • Being positive about learning	• Imagining • Exploring options and alternatives • Implementing ideas and taking action • Learning creatively • Stimulating creativity using digital technology
Communicating • Listening and expressing myself • Using numbers and data • Performing and presenting • Discussing and debating	**Working with others** • Developing good relationships • Co-operating • Respecting differences • Learning with others	**Managing information and thinking** • Gathering, recording, organising and evaluation of information and data • Thinking creatively and critically • Reflecting on and evaluating my own learning

TABLE 10 DESIRED SKILLS FOR LOWER SECONDARY SCHOOL IN IRELAND

The Junior Cycle science syllabus (National Council for Curriculum and Assessment, 2003) states that "Teaching strategies should promote the aims, objectives and learning outcomes described in the syllabus, and they should encourage investigative work as well as experimental work". Investigations are defined as "an experience in which the student seeks information about a particular object, process or event in a manner that is not pre-determined in either procedure or outcome". In practice however, teachers often feel that they do not have sufficient time in the three years to allow students to take part in real investigations.

The syllabus aims to:

- Encourage the development of manipulative, procedural, cognitive, affective and communication skills through practical activities that foster investigation, imagination, and creativity
- Provide opportunities for observing and evaluating phenomena and processes and for drawing valid deductions and conclusions

Students will develop skills associated with:

- procedural plans and the use of the scientific method in problem solving
- observation, measurement and the accurate recording of data
- obtaining and using information from a variety of sources
- numeracy, and the manipulation and interpretation of data in a variety of forms, including the use of symbols, charts and graphs
- logical thinking, inductive and deductive reasoning, and the formation of opinions and judgments based on evidence and experiment
- the preparation and presentation of reports on scientific topics, experiments, etc.
- independent study and co-operative learning
- the application of scientific knowledge to everyday life experiences.

Examples of activities from the syllabus include:

- investigate the conversion of chemical energy in food to heat energy
- investigate the action of amylase on starch;
- investigate the growth response of plants to gravity (geotropism) and light (phototropism)
- investigate the relative reactivities of Ca, Mg, Zn, and Cu based on their reactions with water and acid
- investigate examples of friction and the effect of lubrication

It is not immediately obvious how these examples tie in with students working "in a manner that is not pre-determined in either procedure or outcome." The curriculum also recommends that there should be an emphasis on the development of investigative process skills as well as on the thought processes of science and the knowledge content. Skills and processes of science include observation, communication, planning and designing investigations (defining the problem, planning the investigation and controlling variables if necessary, testing and observing/recording, interpreting the results and drawing conclusions).

Statements supporting inquiry from the curriculum for upper secondary

The senior cycle is currently under a consultation process. As part of this, the National council for Curriculum and Assessment have developed five key-skills that students should develop throughout the senior cycle (NCCA, 2012a)

Key Skill	Element
Information-processing	• Accessing information from a variety of sources • Selecting and discriminating between sources based on their reliability and suitability for purpose • Recording, organising, summarising and integrating information • Presenting information using a range of information and communication technologies
Critical and creative thinking	• Examining patterns and relationships, classifying and ordering information • Analysing and making good arguments, challenging assumptions • Hypothesising and making predictions, examining evidence and reaching conclusions • Identifying and analysing problems and decisions, exploring options and alternatives, solving problems and evaluating outcomes • Thinking imaginatively, actively seeking out new points of view, problems and/or solutions, being innovative and taking risks
Communicating	• Analysing and interpreting texts and other forms of communication • Expressing opinions, speculating, discussing, reasoning and engaging in debate and argument • Engaging in dialogue, listening attentively and eliciting opinions, views and emotions • Composing and performing in a variety of ways • Presenting using a variety of media
Working with others	• Working with others in a variety of contexts with different goals and purposes • Identifying, evaluating and achieving collective goals • Identifying responsibilities in a group and establishing practices associated with different roles in a group (e.g., leader, team member) • Developing good relationships with others and a sense of well-being in a group • Acknowledging individual differences, negotiating and resolving conflicts • Checking progress, reviewing the work of the group and personally reflecting on one's own contribution
Being personally effective	• Being able to appraise oneself, evaluate one's own performance, receive and respond to feedback • Identifying, evaluating and achieving personal goals, including developing and evaluating actions plans • Developing personal qualities that help in new and difficult situations, such as taking initiatives, being flexible and being able to persevere when difficulties arise • Becoming confident and being able to assert oneself as a person

TABLE 11 DESIRED SKILLS FOR UPPER SECONDARY SCHOOL IN IRELAND

The science curriculum is currently going through a consultation process. In the proposed Physics curriculum (NCCA, 2012b) for example, the syllabus objectives are:

- enable learners to build on their existing knowledge and understanding of physics terminology, facts, principles and methods and to develop the skills needed to apply this knowledge and understanding to familiar and unfamiliar situations
- develop skills in scientific inquiry including the ability to interpret and analyse qualitative and quantitative data from different sources and to consider the validity and reliability of data in presenting and justifying conclusions
- develop the ability to explain, evaluate and communicate the results of their experimental and investigative activities in verbal, graphical and mathematical form, using ICT where appropriate
- develop in learners qualities that enable them to make informed conclusions about contemporary physical and environmental issues, including those that raise ethical questions.

Students will be able to:

- Examine patterns and relationships, analyse hypotheses, explore options, solve problems and apply solutions to new contexts.
- Work together to research, design, plan and conduct investigations and to research and present their findings.
- Use careful observation, thoughtful analysis and clarity of expression to evaluate evidence, give their own interpretation of that evidence and make a clear presentation of their proposed solution.
- Research up-to-date and balanced information to develop a critical approach to accepted physics theories and beliefs and in so doing come to understand the limitations of science.
- Share their ideas and present their work using a variety of media.
- Make reasoned arguments and to express and justify their position

Examples of syllabus content

- Investigate experimentally the relationship between an object and its image in a plane mirror
- Investigate variation in the thermometric property of a material with temperature and use it in the design of a thermometer
- Establish a relationship between force and acceleration experimentally
- Evaluate arguments for the use of nuclear energy, based on research into its advantages and disadvantages
- Investigate the effect on the current of changing the intensity and frequency of the incident radiation

Included in the syllabus learning outcomes are a number of practical activities which are categorised under three headings

- prescribed activities develop skills in science process, laboratory techniques and safety procedures. These skills include: following experimental procedure, identifying controls and variables, collecting and recording data, observing and measuring, analysing data for patterns and meaning, and communicating conclusions
- open-ended, investigative activities develop skills in application of the strategies of scientific inquiry. These skills include identifying and refining good inquiry questions, developing testable hypotheses, initiating and planning, performing and recording, analysing and interpreting, problem solving and assessing results
- research activities develop skills in accessing information that has been gathered previously, selecting the relevant details, analysing that information for patterns and meaning, identifying bias and communicating findings or conclusions.

3.7 POLAND

Diagnosing problems		Critiquing experiments		Distinguishing alternatives		Planning Investigations		Researching conjectures	
LS	US	LS	US	LS	US	LS	US	LS	US
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Searching for information		Constructing models		Debating with peers		Forming coherent arguments	
LS	US	LS	US	LS	US	LS	US
✓	✓		+	✓	✓	✓	✓

TABLE 12 ELEMENTS OF INQUIRY IN THE NATIONAL CURRICULUM IN POLAND; LS IS LOWER SECONDARY CURRICULUM, US IS UPPER SECONDARY CURRICULUM

+Only in advanced level physics

Statements supporting inquiry from the curriculum for lower secondary

In the new curriculum you can find many aspects of IBSE, but in fact IBSE is not named and inquiry is not named explicitly in our new curriculum. But many IBSE skills are in fact compulsory.

Biology

C1. Knowledge of experimental biology methodology

The student plans, conducts and records observations and simple biological experiments; the student determines the conditions of experiment and one is able to distinguish between control and experimental trial, one is able to formulate conclusion; the student performs optical microscopy observations of fresh and permanent samples.

C2. The search, implementation and creation of information.

The student involves various sources and methods of retrieving of information, including informational and communication technologies; one can read, analyse, interpret and process textual, graphical, and numerical data; understands and interprets biological notions, knows basic biological terminology.

C3. Reasoning and argumentation.

The student is able to interpret information and to explain cause and effect dependencies between facts; one formulates conclusions, formulates and presents opinions connected with discussed biological facts.

Chemistry

C1. The search, implementation and creation of information.

The student uses various sources and methods of retrieving of information, including informational and communication technologies.

C2. Reasoning and application of acquired knowledge to solve problems.

The student describes the properties of substances and explains simple chemical reactions; knows the relationship between properties of the substance and its applications and impact on environment; perform simple calculations based on chemical theories.

C3. Practical skills.

The student uses safely simple laboratory equipment and basic chemicals; designs and carries out simple chemical experiments.

Physics

C1. Use of physical quantities to describe already known phenomena and to solve simple calculation problems.

C2. Conducting experiments and formulating the conclusions.

C3. Realizing examples of phenomena present in the surrounding that can be explained by acquired physical rules and laws.

C4. Use of information originating from the analysis of different types of texts (including popular science articles)

Statements supporting inquiry from the curriculum for upper secondary school
Integrated Science
C1. Understanding the scientific method that is based on hypotheses and its verification by observation and experimentation.

Biology– basic level
C1. The search, implementation and creation of information.
The student receives, analyses and assesses information from different sources, in particular from press, media and internet.
C2. Reasoning and argumentation.
The student interprets information and explains cause and effect dependencies between facts, formulates conclusions, assesses and expresses opinion concerning discussed facts of contemporary biology, ecology and environment.

Biology – advanced level
C1. Broadening of biological experiments methodology.
The student understands and applies biological notions, plans, conducts and records observations and biological experiments; formulates research problems, hypotheses and verifies them against observation and experiments; one defines experimental conditions, distinguishes between control and experimental trial and formulates conclusion based on conducted observations and experiments.
C2. The search, implementation and creation of information.
The student reads, selects, compares and processes information gathered from various sources, including informational and communication technologies.
C3. Reasoning and argumentation.
The student explains and comments on information, relates in a critical way to presented information, distinguishes between facts and opinions, explains cause and effect, formulates conclusions, formulates and expresses opinions supported with proper arguments based on discussed biological facts. One notices relations between biology and other scientific and social disciplines. One understands the importance of contemporary biology in human life.

Chemistry – basic level
C1. The usage and creation of information.
The student receives, analyses and assesses information from different sources, in particular from press, media and internet.
C2. Reasoning and application of acquired knowledge to solve problems.
The student gains chemical knowledge through inquiry - observes, checks, verifies, concludes and generalizes; sees the relationship between chemical composition, structure and properties of the substance and its applications, uses a chemical acquired knowledge in everyday life in the context of own health and the environment protection.
C3. Practical skills.
The student uses safely laboratory equipment and chemicals; designs and carries out chemical experiments.

Chemistry – advanced level

C1. The usage and creation of information.

The student uses various types of chemical texts (including popular science articles), proficiently uses modern information technology to find, process, create and present information. Critically assesses gained information.

C2. Reasoning and application of acquired knowledge to solve problems.

The student understands the basic concepts, laws and chemical phenomena and describes the main properties of elements and their compounds; sees the relationship between the structure of the substance and its physical and chemical properties, poses a hypothesis to explain the chemical problems and is able to plan experiments for their verification, formulate and justify opinions and judgments based on the experiment.

C3. Practical skills.

The student uses safely laboratory equipment and chemicals; designs and carries out chemical experiments.

Physics – basic level

C1. Use of physical quantities to describe already known phenomena and to solve simple calculation problems.

C2. Conducting experiments and formulating the conclusions.

C3. Realizing examples of phenomena present in the surrounding that can be explained by acquired physical rules and laws.

C4. Use of information originating from the analysis of different types of texts (including popular science articles)

Physics– advanced level

C1. Use of physical quantities and laws to explain processes and phenomena observed in nature.

C2. Critical analysis of popular science texts.

C3. Information processing and use of different representations (tables, texts, graphs, schemes, pictures)

C4. Development of simple physical and mathematical models.

C5. Planning and conducting simple experiment and analysis of their results.

3.8 PORTUGAL

Diagnosing problems		Critiquing experiments		Distinguishing alternatives		Planning Investigations		Researching conjectures	
LS	US	LS	US	LS	US	LS	US	LS	US
✓	✓		✓	✓	✓	✓	✓		✓

Searching for information		Constructing models		Debating with peers		Forming coherent arguments	
LS	US	LS	US	LS	US	LS	US
✓	✓	✓	✓	✓	✓		✓

TABLE 13 ELEMENTS OF INQUIRY IN THE NATIONAL CURRICULUM IN PORTUGAL; LS IS LOWER SECONDARY CURRICULUM, US IS UPPER SECONDARY CURRICULUM

Statements supporting inquiry from the curriculum for lower secondary (third cycle).
The curriculum for third cycle was introduced in 2002 and it focuses on four themes: earth in space; earth in transformation; sustainability on earth; and better living on earth across each cycle in the education system.

The role of inquiry is central. The content of the curriculum develops from a real problem and it is recommended that students are involved in developing means for solving particular problems. These are the curriculum recommendations, but in practice there is a gap between the guidelines and teachers' classes. Teachers have sometimes difficulties in understanding the curriculum proposals and most of them follow textbooks that typically focus on factual information and general activities far removed from the curriculum recommendations.

The curriculum for basic education includes descriptions of types of learning experiences that students should have when learning science. These include:

- Observing the surrounding environment.
- Gathering and organising material.
- Planning and developing different types of research.
- Designing projects, predicting all the steps to be taken – from defining the problem onwards. Students have to play an active role in the project.
- Carrying out experimental activities. In the third cycle, experimental activities should result from the investigated issue and not merely the application of a set of recipes. In any cycle, formulating hypothesis, predicting results, observing and explaining results should be included.
- Analysing and critiquing articles, applying scientific knowledge to daily life
- Carrying out debates on controversial and contemporary issues, where students have to come up with reasons and make decisions
- Reporting the results of research and projects
- Carrying out cooperative work

Statements supporting inquiry from the curriculum for upper secondary (secondary).
The curriculum for secondary education recommends the following set of activities for promoting and evaluating the desired competencies for students.

- Promoting practical activities to develop and/or enhance competencies for gathering data, presenting and interpreting data, writing reports, researching information, improving communication skills, using ICT. Students should be encouraged to plan experimental procedures.
- Exploring the relationship between science, technology and society by investigating scientific issues relevant to students' lives and society in general.
- Participating in informal learning situation to stress the importance of science in daily life.

3.9 SLOVAKIA

Diagnosing problems		Critiquing experiments		Distinguishing alternatives		Planning Investigations		Researching conjectures	
LS	US	LS	US	LS	US	LS	US	LS	US
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Searching for information		**Constructing models**		**Debating with peers**		**Forming coherent arguments**			
LS	US	LS	US	LS	US	LS	US		
✓	✓	✓	✓	✓	✓	✓	✓		

TABLE 14 ELEMENTS OF INQUIRY IN THE NATIONAL CURRICULUM IN SLOVAKIA; LS IS LOWER SECONDARY CURRICULUM, US IS UPPER SECONDARY CURRICULUM

Statements supporting inquiry from the curriculum for lower secondary

The national policy documents stipulate an orientation on skills. Many activities are described, focused on hands-on experiments, discoveries, creating predictions, learning by doing, etc. In practice, many teachers are unfamiliar with these approaches to teaching.

Statements supporting inquiry from the curriculum for upper secondary

Physics

Students have as opportunities to master different (mostly experimental) forms of exploring physical phenomena. Every student gains basis of scientific literacy in order to be able to express their own conclusions and to apply the knowledge gained to effective problem solving.

In education, attention should be paid to students' independent work – so called activities, i.e. assignments that lead to new knowledge construction. Discussion, brainstorming, construction of logical patterns and concept maps, and working with information should play a prominent role.

Besides the discovery of and learning new knowledge, a developing competencies-based physics education offers a possibility to acquire information about the connection between science development and technology, industry and society development.

A. Scientific inquiry

At the end of the course student should be able:

- to formulate a problem or research question that can be answered by experiment
- to formulate a prediction, to test a prediction, to plan an appropriate experiment
- to formulate a conclusion according to observation and experimentation and to comment on measurement errors
- to formulate the validity of conclusions based upon a series of measurements
- to evaluate the overall experiment including the procedures used in it

B. Data processing

At the end of the course student should be able:

- to organize, present and evaluate data in different ways
- to transform data presented in a form into another form (including calculations, tables, diagrams)
- to identify possible trends in data
- to create predictions based upon data
- to suggest conclusions based upon data
- to use knowledge to explain conclusions

C. Experimentation

At the end of the course student should be able:

- to follow written or oral instructions
- to select and use safely the experimental setup, materials, technology appropriate for measurement
- to carry out the experiment safely, to record data gained by observation and measurement
- to use appropriate tools and technology to collect data
- to work and cooperate in groups

Chemistry

Students should be able to:

- prove, show, substantiate patterns, context, theory, hypothesis
- observe chemical reactions, record results and observations, process them in the form of tables, graphs and diagrams
- make assumptions and hypotheses and design an appropriate experiment for their verification
- demonstrate basic laboratory skills and plan an experiment
- evaluate the results of the experiment, formulate conclusions which assesses hypothesis on the basis of the data and discuss the results of the experiment
- write lab reports, work collaboratively
- search in the chemical literature for information, data, graphs, charts needed to solve the problem
- understand academic texts, briefly summarize its contents and respond to questions about the text
- seek and process information obtained from the chemical literature, and the Internet., and know to use them to create papers and projects
- work with models
- express their opinion on current issues related to chemistry (pollution and environmental protection, energy production, etc.)

3.10 Sweden

Diagnosing problems		Critiquing experiments		Distinguishing alternatives		Planning Investigations		Researching conjectures	
LS	US	LS	US	LS	US	LS	US	LS	US
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Searching for information		**Constructing models**		**Debating with peers**		**Forming coherent arguments**			
LS	US	LS	US	LS	US	LS	US		
✓	✓	✓	✓	✓	✓	✓	✓		

TABLE 15 ELEMENTS OF INQUIRY IN THE NATIONAL CURRICULUM IN SWEDEN; LS IS LOWER SECONDARY CURRICULUM, US IS UPPER SECONDARY CURRICULUM

Statements supporting inquiry from the curriculum for lower secondary school

Inquiry based science education has been emphasised for a very long time in Sweden and it is also emphasised in the new national curriculum. An important characteristic for the new course syllabuses is that all goals and standards are competency based. The goals and standards for each of the science subjects are very similar, so we present the case for Biology only (Skolverket, 2011).
Suggested activities for biology, which relate to scientific inquiry, are listed below:

- Field studies and experiments.
- Formulating questions, planning and performing simple investigations, and evaluating investigations.
- Documentation of investigations, using tables, diagrams, pictures, and written reports.
- Critical examination of different sources of information and arguments in societal questions with a scientific content.

Performance standards (or "Knowledge requirements") for grade A at the end of year 9, which relate to IBSE

Pupils can:

- Talk about and discuss issues related to health, natural resource use and ecological sustainability
- Differentiate facts from values, and formulate their views with well developed explanations and describe some of the possible consequences
- Propose questions and put forward views and respond to views and arguments in a way which carries the discussions forward and deepens or broadens them
- Search for information about the natural sciences and use different sources
- Apply well developed and well informed reasoning about the credibility and relevance of their sources and information
- Use the information in discussions and create well developed texts and other communications with good adaptation to purpose and target group.
- Carry out field studies and other studies based on their own planning
- Formulate simple questions and planning
- Use equipment in a safe, appropriate and effective way
- Compare results with their questions and draw well developed conclusions with good connection to the models and theories of biology
- Apply well developed reasoning concerning the plausibility of their results in relation to possible sources of error and make proposals on how the studies can be improved and identify new questions for further study
- Draw up well developed documentation on their studies using tables, diagrams, pictures and written reports.

Statements supporting inquiry from the curriculum for upper secondary school

According to the national curriculum for upper secondary school, students should develop the ability to think critically, reason logically, solve problems, make systematic observations and assess different types of sources, and the ability to distinguish between statements based on scientific and non-scientific grounds. Experiments, laboratory experiments, field studies and other comparable practical areas should be central elements in the education. The education should thus develop students' ability to argue and express themselves in advanced writing and speaking situations related to science and mathematics. Students should also be able to understand, read and write about, and discuss basic science in English.

In science and mathematics, data collection and calculations are mainly carried out using computers. The ability to search for, select, process and interpret information, and acquire knowledge of new technology is important for scientists and mathematicians. The education should thus provide good practice in using modern technology and equipment.

The education should encourage students into taking responsibility and their ability to cooperate, and stimulate them into seeing opportunities, trying to solve problems, taking initiative and transforming ideas into practical actions.

Students can get closer to scientific approaches by using scientific methods such as:

- Proposing questions about phenomena in the surrounding world,
- Formulating their own hypotheses,
- Carrying out experiments,
- Drawing conclusions which describe the surrounding reality and
- Predicting results.

To be prepared for higher-education studies in the natural sciences, students need to develop critical thinking and scientific approaches. They need to train themselves in source criticism and receive tasks where they have to formulate questions, present results, draw conclusions and give their reasoning. Students should be given the opportunity to compare the natural sciences with other sciences, and discuss differences between science and non-science.

The upper secondary school has a broader aim than merely preparing students for working life immediately after education or for further studies in higher education. It should also give them a good foundation for personal development and active participation in society. The aim is expressed as follows in the Education Act:

> The upper secondary school should provide a good foundation for work and further studies and also for personal development and active participation in the life of society. The education should be organised so that it promotes a sense of social community and develops students' ability to independently and jointly with others acquire, deepen and apply knowledge.

There are nine subjects which are common to all programmes in the upper secondary school: English, history, physical education and health, mathematics, science studies, religion, social studies, and Swedish or Swedish as a second language. In the Natural Science Programme, the subject of science studies is replaced by the subjects typical of the programme (i.e. biology, physics and chemistry), and similarly in the Technology Programme with the subjects typical of the programme (i.e. physics and chemistry).

3.11 TURKEY

Diagnosing problems		Critiquing experiments		Distinguishing alternatives		Planning Investigations		Researching conjectures	
LS	US	LS	US	LS	US	LS	US	LS	US
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Searching for information		Constructing models		Debating with peers		Forming coherent arguments			
LS	US	LS	US	LS	US	LS	US		
✓	✓	✓	✓	✓	✓	✓	✓		

TABLE 16 ELEMENTS OF INQUIRY IN THE NATIONAL CURRICULUM IN TURKEY; LS IS LOWER SECONDARY CURRICULUM, US IS UPPER SECONDARY CURRICULUM

Statements supporting inquiry from the curriculum for primary and lower secondary

In the Science Curriculum, learning environments that keep students active and teachers as a guide (problem, project, argumentation, collaboration, etc. based learning) form the basis for planning and application of courses. To help students learn meaningfully with long term retention in sciences, learning environments (in and out of school) are to be designed with an inquiry based learning strategy. For this purpose, informal learning environments (science, art, and archaeology museums, zoos, natural environments, etc.) are to be utilized. Inquiry should not be considered only as "discovery and experimentation" but also as "explanation and argumentation." Inquiry based learning is a learning approach in which students express curiosity about everything, explain the natural and physical world around them with strong evidence and argumentation, feel excited about science. In short, it is a hands on, minds on, student centred learning approach that help students construct knowledge in their minds like scientists. In this approach, teachers help students to take part in dialogs with their peers in which they express their ideas freely, support their ideas with various evidence and refute their friends' claims with counter arguments. Teachers act as guides and mediators in written and spoken discussions in which students offer evidence based claims and counter arguments. (Turkish Ministry of Education (MEB), 2013, p.III).

Statements supporting inquiry from the curriculum for upper secondary

<u>Physics</u>

The targeted objectives of the physics course were prepared based on the processes followed in producing scientific knowledge. One of the first priorities of the physics curriculum is to develop students' science process skills. A scientific process is a process in which analytical and critical thinking skills are shaped. Science process skills are separated into two categories: basic skills and integrated process skills. The main basic skills are: observe, measure, classify, infer, predict and share. The physics curriculum necessitates the use of these skills, while at the same time it aims to develop following integrated skills in students (MEB, 2013, p. II):

- Determine a problem
- Develop a hypothesis
- Determine variables
- Determine variables' functions
- Design research
- Conduct experiments
- Collect data
- Organize data into tables and graphical representations
- Analyse data
- Evaluate the research process

- Define the relationships among variables
- Define causal relationships
- Develop models

Biology

One of the main purposes of science education and a prerequisite to understanding science is to understand the process of developing scientific knowledge and develop related skills. Because of this, one of the main purposes of the biology curriculum is to develop students' understanding and skills of scientific thinking and inquiry.

Based on this aim, the objectives of the curriculum are based on developing students' skills of scientific inquiry and science process skills such as: determining a problem, suggesting solutions to a problem, determining an appropriate method to solve a problem, applying a solution appropriately and safely, classifying data obtained from experiments and observations using tables, graphs, statistical and mathematical operations, sorting and analysing data, providing explanations based on evidence and comparing results with other scientific findings, reporting and presenting ideas. Teachers are expected to provide opportunities for students to do "inquiry and investigation" about a subject, to "analyse data" and "to do evaluations" and follow their progress in developing these skills and support them (MEB, 2013, p. III).

Chemistry

Science process skill objectives (MEB, 2013, p.2).:

- Use the analytical and critical thinking skills that were developed in the chemistry courses to understand phenomena.
- State the results of observations, experiments and inquiry mathematically and verbally.
- Make predictions based on experience, observations, and findings.
- Set up a hypothesis, design experiments to test hypothesis.
- Obtain data by doing experiments, provide inferences by using experimental data, evaluate and make generalizations.
- State measurable quantities with appropriate units.
- State experimental results with visuals such as tables and graphs.
- Interpret tables and graphs

3.12 United Kingdom

Diagnosing problems		Critiquing experiments		Distinguishing alternatives		Planning Investigations		Researching conjectures	
LS	US	LS	US	LS	US	LS	US	LS	US
✓		✓		✓		✓		✓	
Searching for information		Constructing models		Debating with peers		Forming coherent arguments			
LS	US	LS	US	LS	US	LS	US		
✓						✓			

TABLE 17 ELEMENTS OF INQUIRY IN THE NATIONAL CURRICULUM IN ENGLAND; LS IS LOWER SECONDARY CURRICULUM, US IS UPPER SECONDARY CURRICULUM

Statements supporting inquiry from the curriculum for lower secondary
There are four separate target areas within the science curriculum

1) science, teaching of science and social implications of science,
2) physics,
3) chemistry
4) biology.

The curriculum defines attainment levels that students should reach at different key stage – age 7, 11, 14 and 16.

For example at age 14, students should be able to do the following:
Planning

- use scientific knowledge and understanding to turn ideas into a form that can be investigated, and to decide on an appropriate approach
- decide whether to use evidence from first-hand experience or secondary sources
- carry out preliminary work and to make predictions, where appropriate
- consider key factors that need to be taken into account when collecting evidence, and how evidence may be collected in contexts [for example, fieldwork, surveys] in which the variables cannot readily be controlled
- decide the extent and range of data to be collected and the techniques, equipment and materials to use [for example, appropriate sample size for biological work]

Obtaining and presenting evidence

- use a range of equipment and materials appropriately and take action to control risks to themselves and to others
- make observations and measurements, including the use of ICT for datalogging [for example, variables changing over time] to an appropriate degree of precision
- make sufficient relevant observations and measurements to reduce error and obtain reliable evidence
- use a wide range of methods, including diagrams, tables, charts, graphs and ICT, to represent and communicate qualitative and quantitative data

Considering evidence

- use diagrams, tables, charts and graphs, including lines of best fit, to identify and describe patterns or relationships in data
- use observations, measurements and other data to draw conclusions l decide to what extent these conclusions support a prediction or enable further predictions to be made
- use their scientific knowledge and understanding to explain and interpret observations, measurements or other data, and conclusions

Evaluating

- consider anomalies in observations or measurements and try to explain them
- consider whether the evidence is sufficient to support any conclusions or interpretations made
- suggest improvements to the methods used, where appropriate.

At 16, pupils should be taught to also:

- judge the level of uncertainty in observations and measurements [for example, by using the variation in repeat measurements to judge the likely accuracy of the average measured value]
- present the results of calculations to an appropriate degree of accuracy
- explain to what extent these conclusions support any prediction made, and enable further predictions to be made
- consider anomalous data giving reasons for rejecting or accepting them, and consider the reliability of data in terms of the uncertainty of measurements and observations
- suggest further investigations.

3.13 Finland

Diagnosing problems		Critiquing experiments		Distinguishing alternatives		Planning Investigations		Researching conjectures	
LS	US	LS	US	LS	US	LS	US	LS	US
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Searching for information		Constructing models		Debating with peers		Forming coherent arguments			
LS	US	LS	US	LS	US	LS	US		
✓	✓	✓	✓	✓	✓	✓	✓		

4 TABLE ELEMENTS OF INQUIRY IN THE NATIONAL CURRICULUM IN FINLAND; LS IS LOWER SECONDARY CURRICULUM, US IS UPPER SECONDARY CURRICULUM

Statements supporting inquiry in compulsory education
The statements reflecting achievement levels for Grades 5 to 9 (Finnish National Board of Education, 2004) were reviewed as these correspond to the targeted age-group 12-15.

Biology
Instruction must be given through inquiry based learning. At grade 6, students will be able to observe and investigate nature and describe simple investigations that they have performed and explain results. During grades 7- 9, students will learn to use concepts and methods of information acquisition that are characteristic of biology and carry out small-scale investigations independently.

Physics and chemistry
Students will learn to:

- Make observations and measurements, look for information and assess the reliability of this information
- Make conclusions about their observations and measurements and recognise the causal relationships associated with the properties of natural phenomena and objects
- Carry out simple scientific experiments clarifying the properties of phenomena, organisms, substances, and objects, as well as the correlations between them
- Use scientific knowledge in describing, comparing, and classifying concepts from the field of physics and chemistry

Good performance at the end of sixth grade is indicated by the student being able to make observations and measurements, draw conclusions from their own observations/measurements, presenting findings, perform simple experiments, gather and assess information.

For chemistry grade 7-9, pupils will:

- Learn scientific skills such as the formulation of questions
- Make, compare and classify observations, measurements and conclusions; present and test a hypothesis; and to process, present and interpret results
- Learn to plan and carry out an investigation, control variables and determine correlations between variables
- Formulate and use simple models, make generalisations and evaluate reliability of experiments and results
- Evaluate the reliability of information gathered

Good achievement for chemistry (grades 7-9) means that students can carry out simple investigations and present and interpret results of experiments

Statements supporting inquiry in the upper secondary school

Upper secondary education (Finnish National Board of Education, 2003) students have compulsory courses in biology, geography, physics and chemistry, but they can choose optional specialisation courses as well. Inquiry statements relating to the compulsory courses in Physics, Chemistry and Biology are listed below.

Biology

The objectives of instruction in biology are for students to

• familiarise themselves with biological information acquisition and research methods and be able to critically assess biological information obtained from different sources;

• know how to plan and implement a simple biological experiment and interpret its results;

Physics

Students will learn to plan experiments in groups and to discuss information or material acquired through experimentation, its processing and modelling and the assessment of its reliability.

The objectives of instruction in physics are for students to

• acquire and process information together with other students in the same way as expert communities;

• plan and take simple measurements and be capable of interpreting, assessing and applying the results;

• make use of various sources to acquire information and be capable of presenting and publishing information in a diverse manner, also using technical aids

Chemistry

The objectives of instruction in chemistry are for students to

• be able to seek and process information about chemical phenomena and properties of substances important in terms of life and the environment by means of experimentation and other active information acquisition methods and to assess the reliability and importance of such information;

• learn how to plan and carry out experiments concerning different phenomena, taking safety considerations into account;

• be able to interpret, assess, present and discuss information that they have acquired through experimentation or by other means;

• familiarise themselves with the opportunities provided by information and communications technologies as tools for information acquisition and modelling;

• know how to use their chemical knowledge as consumers in order to promote health and sustainable development and in discussions and decision-making processes concerning nature, the environment and technology;

3.14 Australia

Diagnosing problems		Critiquing experiments		Distinguishing alternatives		Planning Investigations		Researching conjectures	
LS	US	LS	US	LS	US	LS	US	LS	US
✓	✓	✓	✓	✓	✓	✓	✓	✓	
Searching for information		**Constructing models**		**Debating with peers**		**Forming coherent arguments**			
LS	US	LS	US	LS	US	LS	US		
✓	✓	✓	✓	✓	✓	✓	✓		

TABLE ELEMENTS OF INQUIRY IN THE NATIONAL CURRICULUM IN AUSTRALIA; LS IS LOWER SECONDARY CURRICULUM, US IS UPPER SECONDARY CURRICULUM

Statements supporting inquiry from the curriculum for lower secondary

The position of inquiry in the curriculum seems to be very high. The curriculum for science is divided into three strands that should be addressed together. Strand 1 is Science Understanding and covers four areas: biological science, chemical sciences, earth and space sciences, and physical science. Strand 2 is Science as a Human Endeavour and covers topics such as the nature and development of science and the use and influence of science. Strand 3 covers science inquiry skills. The particular inquiry skills mentioned are:

- Questioning and predicting
- Planning and conducting
- Processing and analysing data and information
- Evaluating
- Communicating

Standards of achievement for these skills are described by grade. For example, shows the progression of skills from Grade 7 to 10 relating to "planning and conducting" investigations.

<table>
<tr><th></th><th>Grade 7</th><th>Grade 8</th><th>Grade 9</th><th>Grade 10</th></tr>
<tr><td rowspan="5">Planning and conducting</td><td colspan="2">Collaboratively and individually plan and conduct a range of investigation types, including fieldwork and experiments, ensuring safety and ethical guidelines are followed</td><td colspan="2">Plan, select and use appropriate investigation methods, including field work and laboratory experimentation, to collect reliable data; assess risk and address ethical issues associated with these methods</td></tr>
<tr><td colspan="2">working collaboratively to decide how to approach an investigation</td><td>explaining the choice of variables to be controlled, changed and measured in an investigation</td><td>considering possible confounding variables or effects and ensuring these are controlled</td></tr>
<tr><td>learning and applying specific skills and rules relating to the safe use of scientific equipment</td><td>identifying any ethical considerations that may apply to the investigation</td><td colspan="2">identifying the potential hazards of chemicals or biological materials used in experimental investigations</td></tr>
<tr><td>identifying whether the use of their own observations and experiments or the use of other research materials is appropriate for their investigation</td><td>taking into consideration all aspects of fair testing, available equipment and safe investigation when planning investigations</td><td>ensuring that any investigation involving or impacting on animals is justified, humane and considerate of each animal's needs</td><td>identifying safety risks and impacts on animal welfare and ensuring these are effectively managed within the investigation</td></tr>
<tr><td>developing strategies</td><td></td><td colspan="2">using modelling and simulations, including using</td></tr>
</table>

	and techniques for effective research using secondary sources, including use of the internet		digital technology to investigate situations and events	
	In fair tests, measure and control variables, and select equipment to collect data with accuracy appropriate to the task		combining research using primary and secondary sources with students' own experimental investigation	
	recognising the differences between controlled, dependent and independent variables	identifying and explaining the differences between controlled, dependent and independent variables	considering how investigation methods and equipment may influence the reliability of collected data	Deciding how much data are needed to produce reliable measurements
	using a digital camera to record observations and compare images using information technologies		**Select and use appropriate equipment, including digital technologies, to systematically and accurately collect and record data**	
	using specialised equipment to increase the accuracy of measurement within an investigation		using probes and data loggers to record information	
			applying specific skills for the use of scientific instruments	
			identifying where human error can influence the reliability of data	

Statements supporting inquiry from the curriculum for upper secondary

ACARA has published curricula for subjects under the heading English, Mathematics, Science and History for the upper secondary school curriculum. Science subjects include biology, chemistry, earth and environmental science, and physics. Learning outcomes as well as content descriptions are provided for each unit. The content description is broken down, as in the lower secondary curriculum, into the three strands: inquiry skills, science as a human endeavour and science understanding.

Inquiry skills across the four science subjects include the ability to:

1. Identify, research, construct and refine questions for investigation; propose hypotheses; and predict possible outcomes
2. Design investigations, including the procedure/s to be followed, the type and amount of primary and/or secondary data to be collected; conduct risk assessments; and consider research ethics
3. Conduct investigations safely, competently and methodically for the collection of valid and reliable data
4. Represent data in meaningful and useful ways; organise and analyse data to identify trends, patterns and relationships; identify sources of random and systematic error and estimate their effect on measurement results; synthesise and use evidence to make and justify conclusions
5. Interpret a range of scientific and media texts, and evaluate processes, claims and conclusions by considering the quality of available evidence; and use reasoning to construct scientific arguments
6. Select, construct and use appropriate representations to communicate conceptual understanding, solve problems and make predictions
7. Communicate to specific audiences and for specific purposes using appropriate language, nomenclature, genres and modes, including scientific reports

3.15 CANADA

In a drive to promote scientific literacy and its place in the curriculum of each province/territory, the Canadian Council of Ministers of Education (1997) agreed on a Common Framework of science learning outcomes. This document established four foundation statements that expressed key aspects of student's scientific literacy including four skill areas where students should show development throughout their education. These skills are:

- **Initiating and planning**: These are the skills of questioning, identifying problems, and developing preliminary ideas and plans.
- **Performing and recording**: These are the skills of carrying out a plan of action, which involves gathering evidence by observation and, in most cases, manipulating materials and equipment.
- **Analysing and interpreting**: These are the skills of examining information and evidence, of processing and presenting data so that it can be interpreted, and of interpreting, evaluating, and applying the results.
- **Communication and teamwork**: In science, as in other areas, communication skills are essential at every stage where ideas are being developed, tested, interpreted, debated, and agreed upon. Teamwork skills are also important, since the development and application of science ideas is a collaborative process both in society and in the classroom.

The case of Ontario

As each province/territory is responsible for determining the local curriculum and assessment practices, the situation in the state of Ontario is described in greater detail. To gain a high school diploma in Ontario, students must gain a minimum of 30 credits, of which at least two credits should be in a science subject. One credit courses typically last a year.

Lower secondary school

Ontario has a curriculum for each year of secondary schooling and students may choose to study applied or academic science. Applied courses seem to be more geared towards a general science education for literacy rather than for training for future scientists, with an emphasis on hands-on applications, while academic courses are more theoretical are more theoretical in nature.

Inquiry is emphasised in the curriculum in Ontario at lower secondary school. The expectations for students in all Grade 9 and 10 courses are organized in five strands, the first focusing on scientific investigation skills and the remaining four representing the major content areas in the science curriculum. The five strands are as follows:

A. Scientific Investigation Skills and Career Exploration
B. Biology
C. Chemistry
D. Earth and Space Science
E. Physics

The Ontario curriculum has implemented the Common Framework of science learning outcomes. It further elaborates the inquiry skills as:

- *Initiating and planning* skills include formulating questions or hypotheses or making predictions about ideas, issues, problems, or the relationships between observable variables, and planning investigations to answer those questions or test those hypotheses.
- *Performing and recording* skills include conducting research by gathering, organizing, and recording information, and safely conducting inquiries to make observations and to collect, organize, and record data.

- *Analysing and interpreting* skills include evaluating the adequacy of the data from inquiries or the information from research sources, and analysing the data or information in order to draw and justify conclusions.
- *Communication* skills include using appropriate linguistic, numeric, symbolic, and graphic modes of representation, and a variety of forms, to communicate ideas, procedures, and results.

Within the scientific content descriptions, opportunities for applying particular inquiry skills are highlighted. For example:
C2.3 plan and conduct an inquiry into the properties of common substances found in the laboratory or used in everyday life (e.g. starch, table salt, wax, toothpaste), and distinguish the substances by their physical and chemical properties should provide students opportunities to develop skills in the areas of initiating and planning, performing and recording, and analysing and interpreting.

Upper secondary
In grades 11 and 12, science courses are offered to prepare students for their postsecondary destinations, i.e. University/College/Workplace. The same skills are listed for each science course and in the inquiry four key skills are described as:
Initiating and Planning [IP]
A1.1 formulate relevant scientific questions about observed relationships, ideas, problems, or issues, make informed predictions, and/or formulate educated hypotheses to focus inquiries or research
A1.2 select appropriate instruments and materials and identify appropriate methods, techniques, and procedures, for each inquiry
A1.3 identify and locate a variety of print and electronic sources that enable them to address research topics fully and appropriately

Performing and Recording [PR]
A1.5 conduct inquiries, controlling relevant variables, adapting or extending procedures as required, and using appropriate materials and equipment safely, accurately, and effectively, to collect observations and data
A1.6 compile accurate data from laboratory and other sources, and organize and record the data, using appropriate formats, including tables, flow charts, graphs, and/or diagrams
A1.7 select, organize, and record relevant information on research topics from a variety of appropriate sources, including electronic, print, and/or human sources, using suitable formats and an accepted form of academic documentation

Analysing and Interpreting [AI]
A1.8 synthesize, analyse, interpret, and evaluate qualitative and/or quantitative data to determine whether the evidence supports or refutes the initial prediction or hypothesis and whether it is consistent with scientific theory; identify sources of bias and/or error; and suggest improvements to the inquiry to reduce the likelihood of error
A1.9 analyse the information gathered from research sources for logic, accuracy, reliability, adequacy, and bias
A1.10 draw conclusions based on inquiry results and research findings, and justify their conclusions with reference to scientific knowledge

Communicating [C]
A1.11 communicate ideas, plans, procedures, results, and conclusions orally, in writing, and/or in electronic presentations, using appropriate language and a variety of formats (e.g., data tables, laboratory reports, presentations, debates, simulations, models).

3.16 USA

The National Research Council (NRC) has developed a framework for K-12 Science Education (National Academy of Science, 2012). From this, a team consisting of twenty-six states and partners across US have developed Next Generation Science Standards (NGSS) that students should reach at each stage of the education process from kindergarten to year-12 of high school. The focus is on helping students become more intelligent science consumers by learning how scientific work is done: how ideas are developed and tested, what counts as strong or weak evidence, and how insights from many disciplines fit together into a coherent picture of the world. The decision to adopt the standards and make them consistent between states will lie in the hands of the states themselves. The NGSS are composed of the three dimensions from the NRC Framework, depicted in the Figure 15.

FIGURE 16 NATIONAL RESEARCH COUNCIL'S FRAMEWORK

Dimension 1 of this framework contains inquiry goals and implies that students will engage in the practices of science and engineering. The practice of science highlighted by the framework are:

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analysing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

In 1996, the NRC had set out standards for what students should know, understand and be able to do at different grade levels in order to achieve scientific literacy. The standards promote the use of inquiry. In order to increase scientific literacy, changes need to be made to the way science is taught and assessed, the professional development of teachers, education programmes and education systems. The standards define inquiry as: *"Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyse, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations."*

Standards of achievement/knowledge that should be met over Grades Kindergarten-4, Grades 5-8 and Grades 8-12 are presented under the following categories:

- Unifying concepts and processes in science.
- Science as inquiry.
- Physical science.
- Life science.
- Earth and space science.
- Science and technology.

- Science in personal and social perspectives.
- History and nature of science.

For Grades 9 -12, for example, in order to reach the standard for the category science as inquiry, students should be able to:

- identify questions and concepts that guide scientific investigations.
- design and conduct scientific investigations.
- use technology and mathematics to improve investigations and communications.
- formulate and revise scientific explanations and models using logic and evidence.
- recognize and analyse alternative explanations and models.
- communicate and defend a scientific argument.

In addition, the Benchmarks for Science Literacy (American Association for Advancement of Science, 1993) described what all Americans should know in order to be considered to be scientifically literate. These benchmarks cover the nature of science, mathematics, and technology; basic knowledge of science content; the history and development of science, and skills and attitudes to science. This report concluded that effective teaching and learning should be consistent with the nature of scientific inquiry and that students should have the opportunity to take measurements, analyse results and work together in groups.

4. Inquiry in national assessment

As outlined in Sections 2 and 3, national policies generally promote the use of inquiry methodologies. However, there is a gap between what is stated in the curriculum in each country and what is assessed by teachers and national examinations. We believe that one important reason for this gap between policy and practice is the mismatch between assessment and desired classroom practice. Teachers are wary of investing time in a methodology unless there is a corresponding value attached to this learning in the assessment of their students. The main aim of SAILS is to address this issue and narrow or close this gap.

4.1 Belgium

In secondary education, the class council acts as the central assessment body (Jo De Ro,2008). The class councils consist of the School Head or his representative and all the members of the teaching staff who teach a particular pupil in a particular grade (all these persons are entitled to vote). They may be assisted by the deputy principal, the technical advisor (coordinator), support staff and/or the members of staff providing the pupils of the school in question with psycho-social or pedagogical counselling (these people have an advisory voice).

Diagnosing problems		Critiquing experiments		Distinguishing alternatives		Planning Investigations		Researching conjectures	
LS	US	LS	US	LS	US	LS	US	LS	US
✓	✓		✓		✓	✓	✓	✓	✓
Searching for information		Constructing models		Debating with peers		Forming coherent arguments			
LS	US	LS	US	LS	US	LS	US		
✓	✓				✓		✓		

TABLE 18 INQUIRY IN NATIONAL ASSESSMENT IN FLANDERS FOR LOWER SECONDARY (LS) AND UPPER SECONDARY (US)

The terms LS and US where interpreted following the Grades in the Flemish Educational System:
LS = Lower Secondary = Grade 1(year 1 &2 Secondary Education)
US = Upper Secondary = Grade 2 + 3 (year 3,4,5,6 in Secondary Education)

An important note to make is that assessment policy in school in Flanders is part of the autonomy of the school. The end terms do describe what competences and knowledge the students should achieve at the end of a grade. Table 19 is filled in following the advice of a Board member of VeleWe (Flemish Science Teachers Association) which has years of experience in the science education field in Flanders. It is important to note that the level of inquiry in assessment can vary very much from school to school, because of the autonomy schools have for this part.

Inquiry and information competences are mainly developed during "leerproeven" classroom experiments) and "informatie opdrachten" (information assignments. The results of these assignments are being used to make the final evaluation mark of the student. But during the theoretical exams, the assessment of inquiry – and information competences are of a very low level.

Examples of National Examinations:

3 Examples of Assessment questions used in Flanders

10) When you hang a mass on a spoke as in Figure 1, the spoke will bend. A tape measure is attached to the right side of the wooden board. You can make use of all materials in the picture plus a chronometer.
Describe 2 different methods to determine the elastic constant of this spoke (for a spring we would call this the spring constant).
(Tip: we sometimes speak about the static and dynamic method)

Write this out in the same format as you would do in the "method" part of an instruction sheet of the lab.

This includes the formulas used, the measurement that will be performed, the table with variables and units.

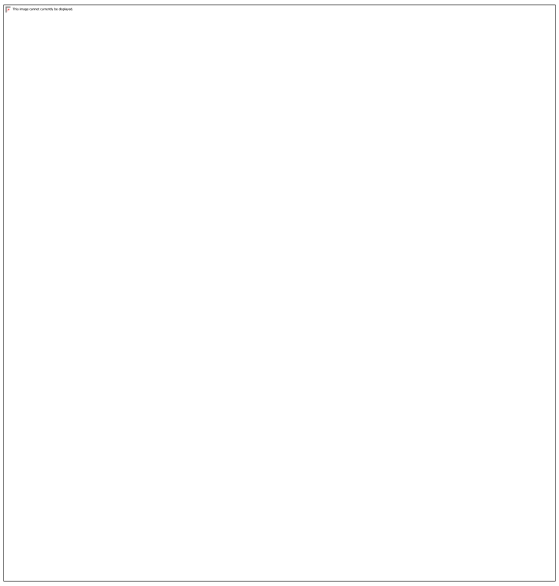


FIGURE 17

11) A ball is thrown up vertically. With an advanced photo camera we take pictures of the ball at fixed intervals. Which of the images below gives the best impression of the resulting photo?

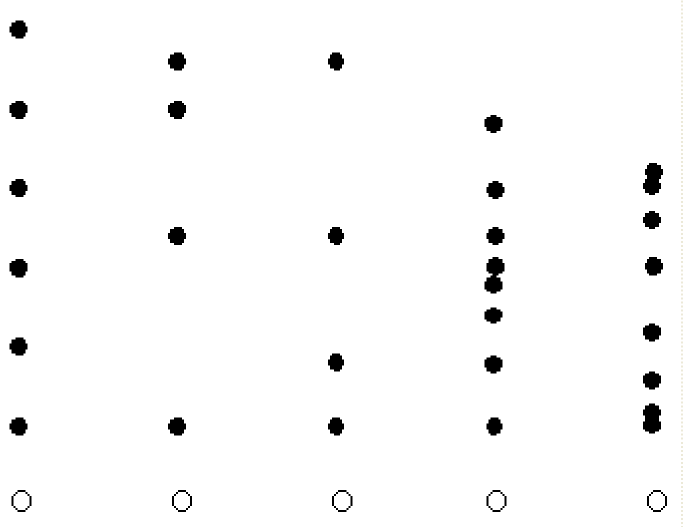
Tick the right box, and explain your choice.

………………………………………

………………………………………

………………………………………

………………………………………



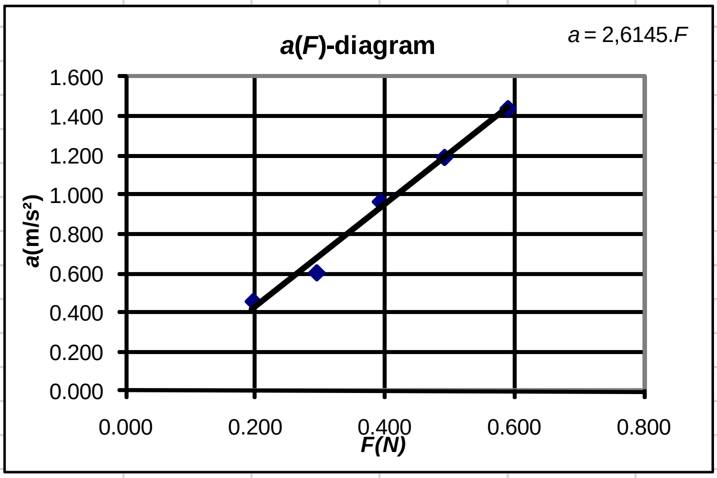
12) On the next page you find 2 tables with corresponding graphs.

a) Specify the method and materials used to make the measurements in the table.

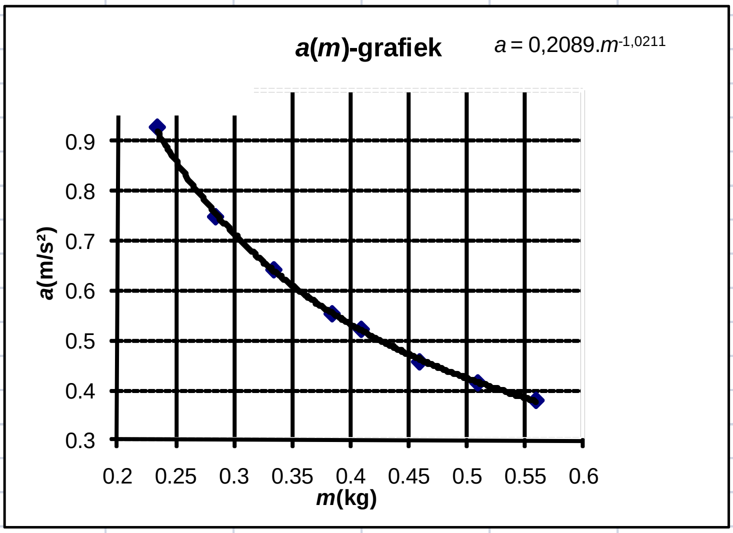
b) Make a decision for every situation.

c) Summarise both decisions in one single conclusion.

F (N)	*a* (m/s²)
0.196	0.453
0.294	0.600
0.392	0.964
0.491	1.192
0.589	1.442



m (kg)	*a* (m/s²)
0.234	0.927
0.284	0.748
0.334	0.642
0.384	0.554
0.409	0.523
0.459	0.458
0.509	0.416
0.559	0.381



4.2 DENMARK

Diagnosing problems		Critiquing experiments		Distinguishing alternatives		Planning Investigations		Researching conjectures	
LS	US	LS	US	LS	US	LS	US	LS	US
				✓	✓				
Searching for information		Constructing models		Debating with peers		Forming coherent arguments			
LS	US	LS	US	LS	US	LS	US		
						✓	✓		

TABLE 19 INQUIRY IN NATIONAL ASSESSMENT IN DENMARK FOR LOWER SECONDARY (LS) AND UPPER SECONDARY (US)

Assessment in lower secondary school
On completion of form levels 9 and 10, Folkeskole students take school-leaving examinations. This is compulsory on completion of form level 9 but voluntary on completion of level 10. The examinations after the 10th form level place higher academic demands on the students than the examinations after form level 9. Standard rules have been developed for all the examinations with a view to ensuring uniformity throughout the country. For the same reason, the written examination questions are set and marked at central level.

Students must take examinations in a total of seven subjects. Five of the subjects are compulsory for all students: written and oral examinations in Danish, a written examination in mathematics and oral examinations in English and physics/chemistry. Each student must take two additional examinations that are drawn at random at least 4 weeks before the exam takes place: one from the humanities group, which includes written English as well as French or German, history, social studies and Christian studies, and one from the science group, which consists of earth science or biology.

The method for assessment in biology/earth science and physics/chemistry is very different. In biology and earth science the assessment is an on-line multiple choice written test of half an hour. In physics/chemistry, there is a two hour practical test, where the students perform experiments and prepare examples and explanations of a given topic.

At the 9th and 10th form levels, a mandatory project assignment gives students the opportunity to complete and present an interdisciplinary project. The project assignment is assessed in a written statement on the content, working process and presentation of the final result. The written statement affords a broader and more detailed assessment of the student's ability.

Assessment in upper secondary school
All students studying a science subject undertake an oral examination lasting between 24 and 30 minutes depending on the level that students are studying the subject. At C level (1 year course), the students draw a question at random and get 24 minutes of preparation and then 24 minutes of examination.

At B (2-year course) – and A (3-year course) level, the students draw a topic and have 24 hours for preparation and 30 minutes for examination. This oral examination involves completing an assignment which takes as its starting point one or more issues that have a connection with one or more of the themes of the education. The assignment contains a thorough assignment text as well as known and unknown appendixes in the form of articles, experimental work and/or other materials. For Physics students, there is also an experimental component to the oral examination which lasts two hours and involves conducting an experiment and discussing the associated theory and data processing with the examiner.

For chemistry, students and schools may choose between the following types of examination for the oral component: a 30 minute assignment that has both theoretical and experimental components that relate to a common topic or a two-hour assignment with unrelated experimental and theoretical components.

Taking biology as an example, the assessment criteria for students are listed below.

- Express themselves correctly and with a precise use of biological terminology
- Be able to structure and communicate biological material on the basis of the examination question handed out
- Understand and evaluate biological data
- Include methods and results from experimental work
- Explain models which describe biological correlations
- Put unknown material in relation to known biological issues
- Put their biological knowledge into perspective and relate to issues with biological content.

Level A students also complete a written exam. An emphasis is put on the examinee's ability to:

- Be able to structure and communicate the material with a confident use of terminology
- Show academic insight and overview
- Include relevant academic elements in a given issue
- Understand biological issues
- Put unknown material in relation to known biological issues
- Analyse and evaluate biological data.

Examples of National Examinations:

- **Example 1 Lower Secondary Final Exam 2013 Biology**

Task 11: Ecological farmers are not allowed to use mineral fertiliser. Instead they use organic fertiliser like slurry or compost. The organic fertiliser has to be broken down and transformed to nutrient ions before the corn can use it.

Spreading of organic fertiliser *Photo: Keld Nørgaard*

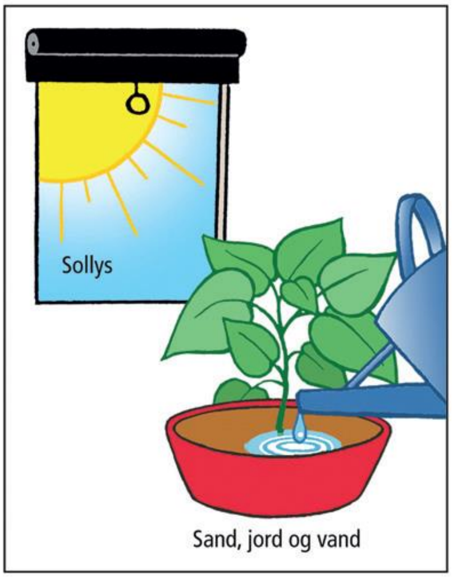
Make 1 X in each line

	The root system of the corn	Decomposing organisms	Plant nucleus'	Atmospheric CO_2	Groundwater
Nutrient ions can be washed out to					
Nutrient ions be released by					
Nutrient ions can be taken up through					

Task 4: Through genetic splicing we can have crops that are more resistant to herbicides. In genetic splicing one or more genes are artificially transferred in to an alien organism.
What is true about genes and genetic splicing?

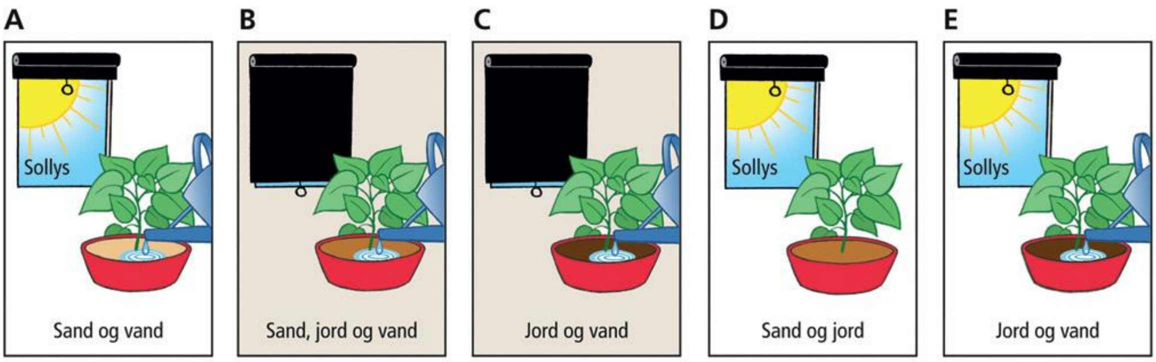
- Transferring a gene from one species DNA to another species DNA is called genetic splicing
- The farmer himself can make genetic splicing on his animals in his own laboratory
- Only animals and fungus can be genetically spliced
- A gene is a small part of the DNA string
- The DNA string consists only of sugars
- A protein is made from the code of a single gene
- Respiration creates many genes in the organism
- Genes are placed at the offshoots of nerve cells

Task 2: Enhancement of the cultivation soil
A farmer has gotten the idea that his potatoes will grow better in the field if the cultivation soil contains extra sand. To test his idea he uses tow large pots with potato plants. One of the pots is seen on the picture below.



What should he put in the other pot and where should it be placed?

Make 1 X



Sollys = sun light; Sand = sand; Jord = soil; Vand = water

4.3 Germany

Diagnosing problems		Critiquing experiments		Distinguishing alternatives		Planning Investigations		Researching conjectures	
LS	US	LS	US	LS	US	LS	US	LS	US
✓	✓	✓	✓	✓	✓				
Searching for information		Constructing models		Debating with peers		Forming coherent arguments			
LS	US	LS	US	LS	US	LS	US		
✓	✓		✓	✓	✓	✓	✓		

TABLE 20 INQUIRY IN NATIONAL ASSESSMENT IN GERMANY FOR LOWER SECONDARY (LS) AND UPPER SECONDARY (US)

Assessment for upper / lower secondary school
In Germany the teachers at the school are in general responsible for assessing their students' progress. There are a few exceptions. For example, in many federal states some of the schools leaving examinations at the end of upper-secondary school are the same for all students in this state, i.e. in these states, a commission of experienced teachers prepares the examination for all students.

In general, the learning success is assessed with the use of examination tests and by evaluation of the work during the lessons. There are some general statements concerning examination tests like how to formulate tasks and subtasks, the competencies that have to be assessed or the degree of difficulty ("Anforderungsbereiche") of the tasks.

The mark of the students consists in general of a number of partial marks. One general rule is that the overall mark is dominated by the sum of partial marks given for the work during the lessons. However, there are some special rules in addition. The "Abitur" mark, that means the final mark of the school leaving certificate after upper-secondary school, consists of a) a high number of partial marks given in the two school years before in different subjects and b) a number of marks given in the final examinations. The subjects cover a broad spectrum. The final examinations are mostly written examinations and at least one is an oral examination.

The curricula in the state Lower-Saxony provide some guidelines on assessment. Some of these assessment "methods" are strongly correlated with inquiry-based learning activities. In lower-secondary and upper-secondary schools almost all elements of inquiry are covered in the assessment (see table above). However, not all elements are assessed in each test or assessed to the same extent.

Example of assessment items:
- the evaluation of oral statements of the students (e.g. recognition of scientific questions, development of scientific questions)
- documentation of the lessons (e.g. protocols, portfolio, project work)
- application of subject-related methods (e.g. planning, conduction and evaluation of experiments)
- collecting relevant data (e.g. seeking for relevant information, classifying and reviewing information, investigation in different sources)
- presentation (e.g. speech, placard, model, video)
- working in teams (e.g. planning, reflecting)

Examples of National Examinations:

- **Upper secondary school final Physics exam 2010**

Three tasks used in one final examinations 2010 in physics in upper-secondary school covering elements of inquiry (Raecke, D. 2011):

- Build up an experiment to measure Planck‘s constant h using a red, green, blue and UV-LED.
- Describe your execution of the experiment with a sketch of the experimental set-up and minute your data.
- Use an appropriate diagram to determine Planck‘s constant and estimate the bias in the measurement.

4.4 GREECE

Diagnosing problems		Critiquing experiments		Distinguishing alternatives		Planning Investigations		Researching conjectures	
LS	US	LS	US	LS	US	LS	US	LS	US
Searching for information		Constructing models		Debating with peers		Forming coherent arguments			
LS	US	LS	US	LS	US	LS	US		

TABLE 21 INQUIRY IN NATIONAL ASSESSMENT IN GREECE FOR LOWER SECONDARY (LS) AND UPPER SECONDARY (US)

Assessment in Primary Education
Practical activities are not formally assessed. Typically, after carrying out the experiment, students fill the work sheets (in which knowledge or skills are assessed) but mainly implement self-assessment procedures. Alternatively, students may be assessed via projects (e.g. the ability to use maps or information search), or other creative activities (such as research, constructions, playing games etc.).

Assessment in lower secondary school
Practical activities are not formally assessed. Typically, after carrying out the experiment, teachers lead a plenary discussion in which findings are discussed and evaluated and considerations about the procedure that was followed are also pointed out.

Assessment in upper secondary school
As in the case of lower secondary school, practical activities are not formally assessed either. The informal assessment carried out is as in the case of lower secondary school.

National exams are taken at the end of the third class of upper secondary school (lyceum). Students participating in these exams are those who aim at continuing at tertiary education. The exams are set by a central committee formed by university professors and secondary school teachers.

Students take exams in the subjects of their direction respectively and select either Biology or Physics of General Education as a nationally tested subject as well. Most students select Biology.

The format of the exam is essentially similar across science subjects. The first exam question tests mainly recall of information and the second requires the justification of students' response and usually takes certain calculations. The other two exam questions require application of the theory and use of mathematical calculations. The fourth question is of increased difficulty and may contain an element of extension.

Examples of National Examinations:

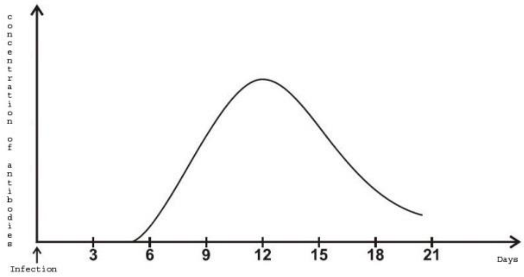
Example 1: Physics, C class USS, General education - National exams 2013, (part of) Exam question 1
State whether the following propositions are right (R) or wrong (W).
a) As the electromagnetic wave propagates through the vacuum, the intensity of the electric field E and the magnetic field B also propagate at the same velocity.
b) The radiation whose wavelength through the vacuum is 800 nm belongs to the infrared.
c) The human bone absorbs X-rays less than other tissues.
d) The strong force among nuclei is stronger than the repulsion force among the protons of a stable nucleus.

Example 2: Chemistry, C class USS, Science direction - National exams 2013, (part of) Exam question 2

A. How many elements are there in the 2nd period of the periodic table? Justify your response.
B. To which section, which period and which group does the element with atomic number Z=27 belong? Justify your response.

Example 3: Biology, C class USS, General education - National exams 2013, Exam question 3

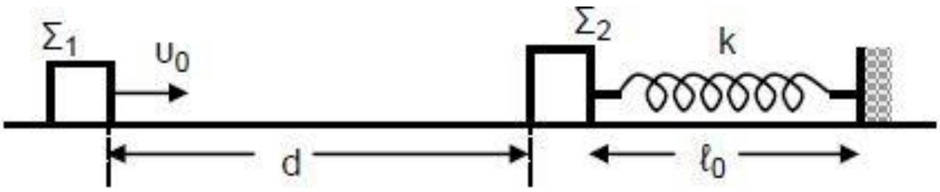
One person is infected by certain bacteria. The diagram below shows the change with time in the concentration of antibodies produced so as to neutralise the bacteria.



A. Explain the type of mmuno-biological response that is taking place based on the diagram shown above.
B. Explain the processes which take place in this immuno-biological response, from the time the T-lymphocytes are activated until the production and excretion of a large number of antibodies.
C. Describe the processes responsible for the increase of the concentration of ammonia in the soil.
D. Describe possible human interventions which can lead to reduction in the concentration of oxygen dissolved in water.

Example 4: Physics, C class USS, Science and technological direction - National exams 2013, Exam question 3

A body Σ_1 of mass m_1 is moving along a horizontal plane, sliding towards another body Σ_2 of mass m_2=2 m_1, which is motionless initially. Let v_0 be the initial velocity of Σ_1 at time t_0=0, when body Σ_1 is at a distance of d=1m from Σ_2. Σ_2 is fixed to an ideal spring of negligible mass, which initially has its natural length l_0. The spring constant is k. The other end of the spring is tied to a rigid wall, as shown in the diagram:



Exactly after the head-on elastic collision, the velocity Σ_1 acquires is $v_1'=\sqrt{10}$ m/s and of the opposite direction to its initial velocity.

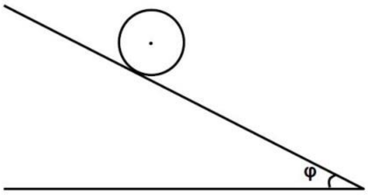
The coefficient of friction between the two bodies and the horizontal plane is μ=0.5 and the acceleration of gravity is g=10m/s^2.

A. Calculate the initial velocity v_0 of body Σ_1.
B. Calculate the proportion of the kinetic energy which was transferred from body Σ_1 to body Σ_2 during the collision.
C. Calculate the total duration of movement of body Σ_1, from the initial moment t_0 up to when the body stops.
   ($\sqrt{10} \approx 3.2$)
D. Calculate the maximum compression of the spring, if m_2=1kg and k=105 N/m.

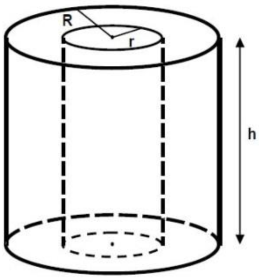
Consider that the duration of the collision is negligible and that the two bodies collide only once.

Example 5: Physics, C class USS, Science and technological direction - National exams 2013, Exam question 4

Consider a solid, homogeneous cylinder of mass M and radius R. The cylinder is let to roll without sliding, under the effect of gravity, down an inclined plane of angle ϕ, as shown in the following diagram:



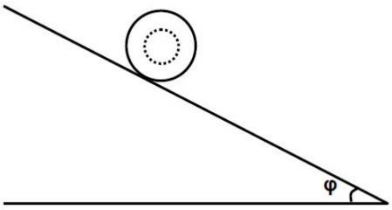
A. Calculate the acceleration of the centre of mass of the cylinder. The axis of the cylinder remains horizontal.
B. From the inner part of this cylinder, whose height is h, we remove a co-axial cylinder of radius r, where r < R, as shown in the diagram below:



Show that the moment of inertia of the hollow cylinder about its axis, once the inner cylinder is removed is:

$$I_{hol} = \frac{1}{2} M R^2 \left(1 - \frac{r^4}{R^4}\right)$$

Then, we lubricate the cylindrical section we removed previously and replace it at its initial position, so that it fits perfectly with the hollow cylinder, without any friction being exerted. The new system is let to roll without sliding, under the effect of gravity, down the same inclined plane, as shown in the diagram below:



C. Calculate the acceleration of the centre of mass of the system.
D. When r=R/2, calculate at any instant of the rolling down the plane, the ratio between the translational and the rotational kinetic energy of the system.

The axis of the system remains horizontal.

Note that:
The moment of inertia I of a solid homogeneous cylinder of mass M and radius R, about its axis is $I=1/2MR^2$.
The volume of a solid cylinder of radius R and height h is $V=\pi R^2 h$.

4.5 HUNGARY

Diagnosing problems		Critiquing experiments		Distinguishing alternatives		Planning Investigations		Researching conjectures	
LS	US	LS	US	LS	US	LS	US	LS	US
✓	✓					✓	✓	✓	✓
Searching for information		**Constructing models**		**Debating with peers**		**Forming coherent arguments**			
LS	US	LS	US	LS	US	LS	US		
						✓	✓		

TABLE 22 INQUIRY IN NATIONAL ASSESSMENT IN HUNGARY FOR LOWER SECONDARY (LS) AND UPPER SECONDARY (US)

The National Assessment of Competences has been assessing the reading and mathematical knowledge of students in 6th, 8th and 10th grades since 2001. The assessment takes place in all Hungarian elementary and secondary schools at the same time, under same circumstances, and it assesses that to what extent the students are able to utilize their knowledge acquired in school to solve tasks taken from real-life situations. The tests are followed by background questionnaires that collect background information about the students' family background and their schools' features in order to evaluate the students' assessed achievements.

In the near future the assessment of competences is going to be expanded to the field of sciences as well. The Hungarian National Office of Education within the framework of the EU-financed TÁMOP 3.1.8 project entitled Overall Quality Development in Public Education has prepared the content framework of the assessment which establishes the formation of tests which are suitable to assess the scientific literacy of students in 6th, 8th and 10th grades. The content framework covers the fields of biology, chemistry, physics and geography, and it examines the knowledge in three groups of competences: (1) the knowledge of scientific notions and principles; (2) the interpretation of phenomena and problem solving; (3) the examination of phenomena of nature. IBL skills (formulation of questions, formulation of hypotheses based on observations, planning examinations and evaluation of examination plans, operations with assessment data, interpretation of data and information, assessment, drawing conclusions based on proofs) are primarily assessed within the third group of competences. The structure and features of the planned tasks are similar to that of the PISA assessments. The first tasks are going to be piloted in 2013.

Beside the preparatory works of the National Assessment of Science Competences within the framework of the EU-financed TÁMOP 3.1.9-08/1-2009-0001 entitled Developing Diagnostic Assessments the Center for Research on Learning and Instruction of the University of Szeged has worked out the content frameworks of diagnostic assessments for grades 1-6 in the field of science. In the second phase of the project online tasks are being worked out to assess the students' scientific literacy in three dimensions (disciplinary, reasoning and application). The diagnostic system may provide regular feedback in these three dimensions, helping the students to develop their skills more effectively and be able to apply their knowledge more widely, as well as more thoroughly and intensively acquiring the content of the curriculum.

At the end of secondary education students have to take the high-school graduation exam of Hungarian literature and grammar, Mathematics, History, one foreign language and one subject of the student's choice (this can be anything that they have learned before). Consequently, not every students have to choose a subject from the field of science. Those who finally decided to take the graduation exam in biology, physics or chemistry, may choose from two levels of the exam: middle or advanced level. Biology proved to be the most popular science subject; about one sixth of the examinees chose in 2012. Physics and chemistry were chosen by less than one tenth of the examinees.

Inquiry skills can be found both in the middle and the advanced levels of the graduation exam requirements. The biology exam contains the next competencies:

Middle level:
- knowledge of biological facts
- recognition of connections between phenomena
- interpreting biological observations and experiments
- interpreting professional texts and figures

Advanced level:
- knowledge of biological facts
- understanding and interpreting data, recognizing rules (graphs and tables)
- comprehension and analysing texts
- solution of tasks
- problem-solving (the validity of the problem and the methods, analysis and recognition of the results and the mistakes)
- classification (with definite marking of the apportionment's logical bases), and the inverse of these
- ranking, completing and explaining pictures

Examples of National Examinations:

The following examples show how inquiry skills are elicited in different domains in the high-school graduation exam tasks.

Example 1 – High-school graduation exam in Biology 2012 - middle level

Malaria is one of the Earth's most common diseases, which is nowadays responsible for the death of 1.5 million people annually. Formerly it used to appear in Europe and in the United States as well. Originally the word means „bad evaporation", because it was considered for a long time that it was spread by the bad air of the swamps. However the Italian medical researcher's, Giovanni Grassi's (1854-1925) suspicion was shifted to the malaria mosquitos, because its larvae live in the water, and its infection is transmitted by the female mosquitos by their bites – according to the theory of Grassi. In 1900, Capaccio Grassi equipped the railway company's 10 houses with mosquito nets in a malaria striken territory. The 112 inhabitants were not allowed to leave their houses in the hours of twilight - which was the most active time of the mosquitos. No one was infected with malaria among them. On the other 415 neighbouring houses there weren't any mosquito nets. They became sick, almost without exception. After that, Grassi returned to Rome – where there was no malaria – and in the Holy Spirit Hospital he made a healthy volunteer infected by 10 mosquitos, which he took from the malaria striken territory.

The candidate became infected with malaria. The results of the experiments are shown in table.

Occurance of malaria (+)	Dry air (Rome)	Swamp humidity (Capaccio)
Exposed to mosquito bites	+ (1 person)	+ (415 people)
Without mosquito bites	- There is no occurance	- (112 people)

Questions

1. Justify the malaria name by the fact that this disease occurs only in marshy areas! What is the explanation for this phenomenon?

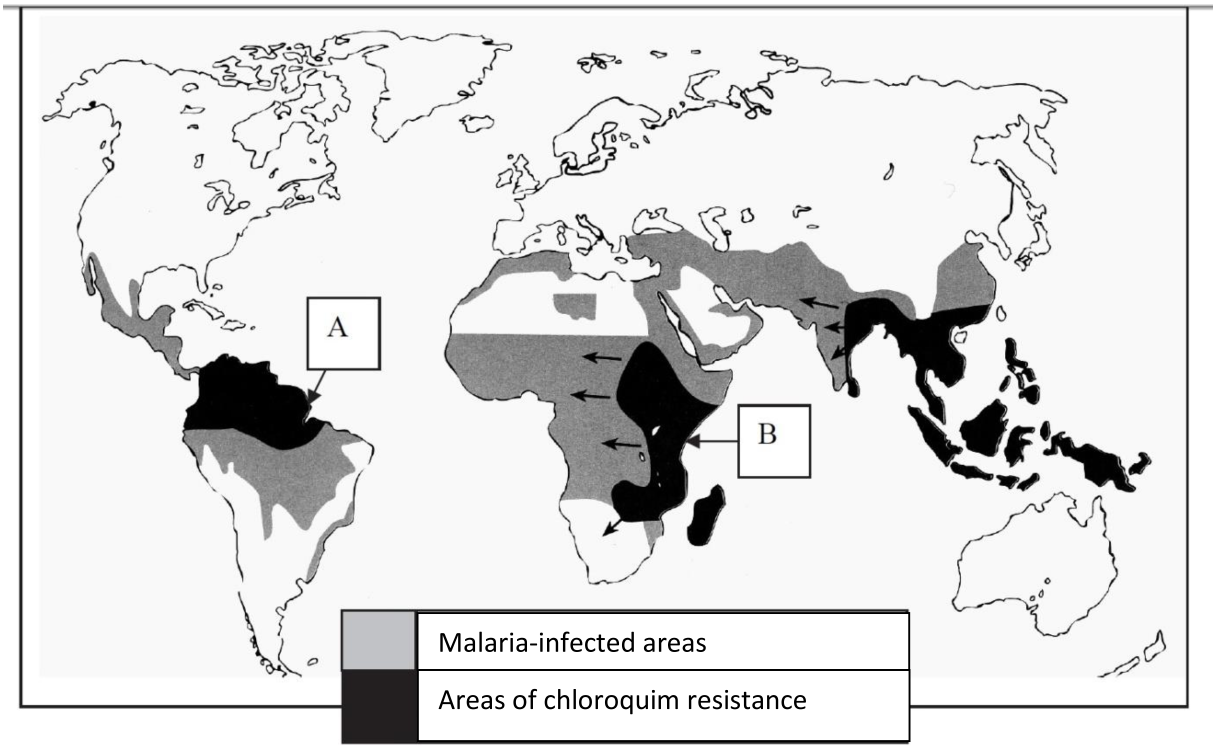
2. Why was the experiment required in the Holy Spirit Hospital?

3. Grassi's investigations were partly observations, partly experiments. Draw up an important difference between the two research methods!

4. The causative agents of malaria are the plasmodiums which are unicellular eukaryotes developing inside the red blood cells. Explain why that time's antibiotics were not effective against malaria!

5. One of the most important remedy of malaria is the extracted quinine from the bark of cinchona, which tree is a native one in Peru, or a drug called chloroquine with a similar structure. The attached map shows, that the malaria which is resistant to quinine or to chloroquinne spreads quickly. With the usage of the concept of mutation and selection explain what could be the reason of the phenomenon!

6. Why could the malaria return back from the territories of Europe and the USA? Give a possible explanation!



7. Do the plasmodiums belong to the same population genetically on the A and B labelled territories on the map? Justify the statement!

Example 2 – High-school graduation exam in Chemistry 2012 - middle level

Sodium and its compounds
a) How do we store sodium in the laboratories, and what is the reason of it?
b) We make sodium react with other liquids. In experiment A) we put it in water, in experiment B) we put it in ethyl alcohol.
You have to decide for which experiment the following statements are true! (Write the correct experiment(s)'s letter sign after the statement!)
The densities: ρ(sodium) = 0,970 g/cm^3, ρ(water) = 1,00 g/cm^3, ρ(alcohol) = 0,789 g/cm^3.

- The experiment can be done in safety in test-tubes as well:
- During the experiment the sodium is floating on top of the liquid.:
- During the experiment a redox reaction takes place:
- Colourless and odourless gas has developed:

c) There is solid sodium chloride in one test-tube, and solid sodium carbonate in the other one. We dissolve both of them in water. What is the pH value of the received solution? You have to justify those which are different from neutral with an ion equation, too.

d) We can prepare from the sodium chloride HCl gas with a suitable concentration of sulfuric acid.

- We can develope gas from sodium carbonate with sulfuric acid.
- Which gas can be developed from the sodium carbonate?
- Write down an equation of the production of a gas.
- Is it possible to distinguish two gases with the followings? Prove it.
  -according to its colour:
  -according to its odour:
  -by leading it into lime-water:

Example 3 – High-school graduation exam in Physics 2012 - advanced level

There are more lines of cars on a straight motorway. The cars are passing steadily by 120km/h in each lane and the distance between the cars is 70 meters.
But due to a heavy downpour all the cars slow down exactly at the same time to 60 km/h with the same retardation.
How will the distance change between them?

A) The distance will increase.
B) The distance will reduce.
C) The distance remains the same.

Requirements of the high-school graduation exams can be found at:
http://www.oktatas.hu/kozneveles/erettsegi/vizsgatargyak/

The tasks of high-school graduation exams can be found at:
http://www.oktatas.hu/kozneveles/erettsegi/vizsgatargyak/

4.6 IRELAND

Diagnosing problems		Critiquing experiments		Distinguishing alternatives		Planning Investigations		Researching conjectures	
LS	US	LS	US	LS	US	LS	US	LS	US
						✓	✓		
Searching for information		Constructing models		Debating with peers		Forming coherent arguments			
LS	US	LS	US	LS	US	LS	US		
						✓	✓		

TABLE 23 INQUIRY IN NATIONAL ASSESSMENT IN IRELAND FOR LOWER SECONDARY (LS) AND UPPER SECONDARY (US)

Assessment in lower secondary

During the Junior Cycle Programme, students are assessed by teachers. At the end of the three year programme, students sit a final exam which is set by the State Examination Committee and corrected by external examiners. Students choose between ordinary and higher level. At each level the examination paper will consist of three sections. These will assess students' knowledge and skills in relation to syllabus material and learning outcomes in the areas of biology, chemistry and physics.
65% of the marks go toward the final written exam, while 10% of marks are awarded for completion of the 30 mandatory experiments and 25% for completion of specified investigations, set by the examining authority, in the third year

COURSEWORK A – MANDATORY EXPERIMENTS AND INVESTIGATIONS (10%)
Students must complete the mandatory experiments and investigations specified in the syllabus. Over the three years of the course each student is also required to maintain a laboratory notebook, in which a record of these experiments and investigations is kept according to specified criteria. This record must be available for inspection. As part of the assessment, marks will be awarded on a pro rata basis for the satisfactory completion of this required coursework.

COURSEWORK B – ADDITIONAL STUDENT INVESTIGATIONS (25%)
This section is perhaps the most relevant to inquiry.
Each student is required to undertake two specified investigations in the third year and to submit a pro forma report on these for assessment. These additional investigations, based on the topics and learning outcomes in the syllabus, are set by the examining body and vary from year to year. Instead of the set assignments, students may substitute an investigation of their own choice that meets required criteria. The number of candidates who presented an investigation of their own choice was very small, at 0.6%.

In practice, the time allocated to the development of inquiry skills and the degree of freedom given to students varies widely from school to school. It is possible to have students write up mandatory experiments without ever having done them; it is not uncommon for teachers to demonstrate the mandatory experiments and for students to write reports on the demonstration. In some schools the inquiry skills are left to year 3, and teachers more or less determine how students carry out the investigation. On the other end of the spectrum, in some schools the spirit of the curriculum is adhered to much more closely and students are given much more freedom to explore and devise their own experimental methods.

Assessment in upper secondary

Assessment in science for upper secondary school takes the form of a written exam only. Inquiry skills are not assessed at present, but it appears that this may change if the proposed new curriculum is introduced.

Examples of National Examinations:

- **Example 1: End of Lower Secondary (Junior Cycle) Science Examination 2012, Higher Level**

Q4 (*c*) Water had been flowing through the pipe shown in the photograph for some time. The pipe originally had no internal deposit. Give a possible reason for the formation of the deposit. What do you think the deposit is?
Reason ___________________________________
____
Deposit ___________________________________

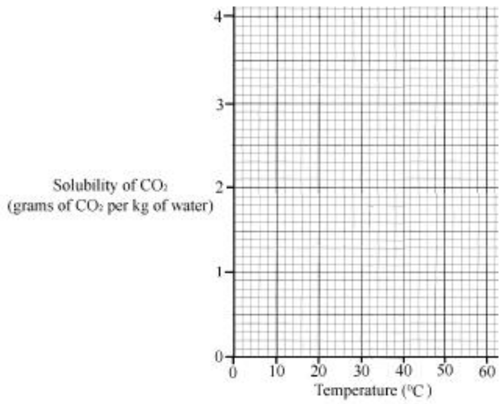
Q5 (*a*) An experiment was performed to investigate the effect of temperature on the solubility of carbon dioxide in water. The data obtained from this experiment is given in the table below.

Solubility of CO2 (grams of CO2 per kg of water)	3.4	2.5	1.7	1.4	1.0	0.8	0.6
Temperature (oC)	0	10	20	30	40	50	60

(*i*) Draw a graph of solubility against temperature in the grid below using the data from the table. A smooth curve is required. (9)

(*ii*) Usually the solubility of a solid increases with increasing temperature. The solubility of a gas decreases as the temperature increases. Suggest a reason why this decrease happens. (3)
Suggest_____________________________________
____

(*iii*) From the graph estimate the temperature at which the solubility of CO2 is 2 g per kg of water. (3)
____

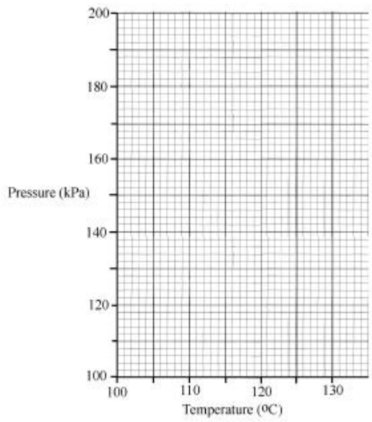


Q7 (*e*) The damage to the railway tracks shown in this image was caused by an environmental factor. Name the factor and explain how it caused the damage.
Name ____________________________________
Explain ___________________________________
____

Q8 An experiment was performed to investigate the effect of pressure on the boiling point of water. The data from the experiment is given in the table below.

Pressure (kPa)	100	120	140	160	180	200
Temperature (°C)	100	105	109	114	119	124

Draw a graph of pressure against temperature using the grid (9)



(*ii*) What two pieces of information can be drawn from the graph about the relationship between the boiling point of water and pressure. (6)

1 ____

2____

(*iii*) What effect would reducing the pressure on water below normal atmospheric pressure, about 100 kPa, have on its boiling point? (3)

What?

____

- **Example 2: End of Lower Secondary (Junior Cycle) Examination 2013**
  New Science Syllabus - Investigation Titles for Coursework B

Biology

Compare by means of investigation the vitamin C content of a number of commercial and fresh fruit juices.

Chemistry

Compare by means of investigation methanol, propan-1-ol and candle wax in terms of their effectiveness as fuels.

Physics

Investigate any two factors that affect the output from a solar cell when light is shone on it.

- **Example 3: End of Lower Secondary (Junior Cycle) Examination 2012**
  New Science Syllabus - Investigation Titles for Coursework B

Biology

Investigate named seeds, chosen by you, to examine the effects of (a) placing the seeds in a fridge for a few days before sowing, (b) placing the seeds in a hot press for a few days before sowing on (i) the percentage of seeds that germinate, (ii) the speed of germination of the seeds.

Chemistry

Investigate the effects on the amount of carbon dioxide dissolved in a fizzy drink when it is stored in (a) an open container, (b) a closed container, at different conditions of (i) temperature, (ii) stirring or shaking, (iii) time elapsed.

Physics

Investigate the factors that determine the rate at which heat is lost from different types of drinking cups that contain hot liquid.

4.7 POLAND

Diagnosing problems		Critiquing experiments		Distinguishing alternatives		Planning Investigations		Researching conjectures	
LS	US	LS	US	LS	US	LS	US	LS	US
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Searching for information		Constructing models		Debating with peers		Forming coherent arguments			
LS	US	LS	US	LS	US	LS	US		
✓	✓					✓	✓		

TABLE 24 INQUIRY IN NATIONAL ASSESSMENT* IN POLAND FOR LOWER SECONDARY (LS) AND UPPER SECONDARY (US)

*NOTE: There is no official document describing directly competences or knowledge that must be checked obligatory in the national exams. Instead, it is stated that curriculum serves as the base for the examination standards. Thus the table above refers to the IBSE requirements present in the core curriculum.

Elements of IBSE assessment are present especially in the national final exam for lower secondary school, organized by the Central Examination Committee – that's a competence test in science – and in the last two school years we could see some aspects of inquiry in this test, and probably there will be more of them in the next years. Since the reform did not enter the final grade in upper secondary school, the final national exam (allowing to enter the higher education) based on a new curriculum has not been introduced yet. However, some examples of inquiry tasks are already present in the national upper-secondary exams, see examples below.
For example:

(1) A chemical experiment is described and an appropriate drawing is included; students are asked to draw the conclusions about possible the result of the experiment or to choose the true/false statements.
(2) A biological experiment is described and the student is asked to design a control group
(3) A table with blood pressure results of several people is provided; a student decides who should consult a doctor.
(4) A physical experiment is described and experimental data provided; student is asked to draw the conclusions on the basis of the experiment and the results; etc., see examples below.

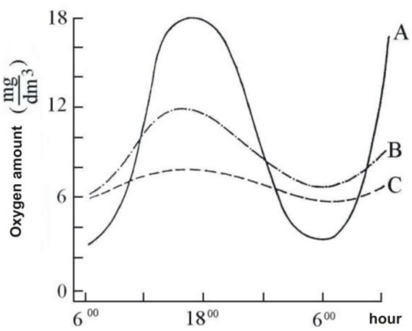
Examples of National Examinations:

- **Example 1 - External exam (2012) at the end of Lower Secondary School, age 16.**

Note: This exam consists of four sections: biology (6 problems), chemistry (6 problems), physics (6 problems), geography (6 problems).

BIOLOGY

1. Unicellular algae living in a pond use solar radiation for photosynthesis. Amount of oxygen produced by algae depends on their population and light intensity. The figure shows the results of the early Spring research on a daily amount of oxygen dissolved in the layer of surface water (0-0,5 m) in three adjacent ponds (with similar population of algae): A, B and C



From: K. Bieniarz, A. Kownacki, P. Epler, *Biologia stawów rybnych*, Olsztyn 2003.

Does the analysis of figure and text presented above confirm the truth of the following statements? Choose Y (yes), if the statement is justified or N (no) – if the statement is not justified.

The greatest daily amount of oxygen is produced in pond C.	Y	N
The ponds contain the greatest amount of oxygen at the end of the day	Y	N

2. Choose below the line with diseases correctly attributed to the given categories

	cancer	**genetic**
A	malaria	hemophilia
B	skin cancer	cystic fibrosis
C	AIDS	skin cancer
D	lung cancer	herpes simplex

<u>Information to be used for tasks 3-5</u>

The fur of a small herbivorous mouse, living in Costa Rica forest, a dozen or so beetles can be found constantly. The insects hook with their strong mandibles to its ears and neck. The beetles can be rarely found anywhere else in mouse fur. The rodent travelling all the time with a group of “passengers” does not show any sign of weakness or anemia. On the contrary, it exudes health. The beetles start to feed off only during the day, when their host stays in a burrow. At that time they leave the fur and prey on blood-sucking fleas, quite popular in a mouse nest.

Based on D. Attenborough, *The Trials of Life*

3. A diagram below refers to the food chain described in the text.

I ⟶ II ⟶ III ⟶ IV

Complete the sentence so as to give a true one.

In the food chain diagram a mouse and a beetle are labelled respectively by:

A. II and IV
B. I and II
C. III and IV
D. III and II

4. Choose Y (yes), if information is true or N (no) if information is false

In relationship described in text a flea is:

a parasite.	Y	N
a victim.	Y	N

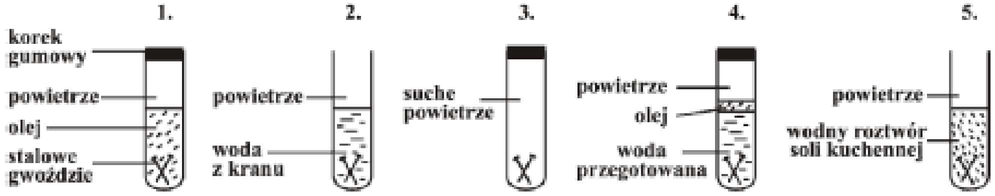
5. Relationship between mouse and beetles, described in the text above may be called

A. symbiosis.
B. parasitism.
C. competition.
D. predation.

CHEMISTRY

Information to be used for tasks 1-2.

A Student planned the experiment with the use of identical steel nails. The experiment is illustrated by the student:



(korek gumowy=rubber stopper; powietrze=air, olej-oil; stalowe gwoździe=steel nails; woda z kranu=tap water; suche powietrze=dry air; woda przegotowana=boiled water; wodny roztwór soli kuchennej=aqueous sodium chlorite solution)

After a several days the Student wrote down the following results of observation.

Test-tube	result
1.	No rust
2.	Rust present
3.	No rust
4.	No rust
5.	A lot of rust present

1. Mark Y (yes) if, according to the performed experiment, justification is correct or N (no) if justification is incorrect.
   The Student poured boiled water into test-tube 4, because

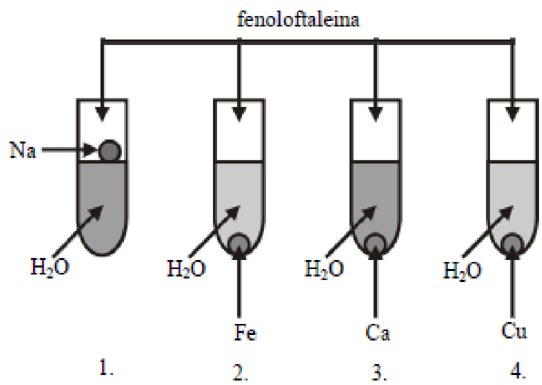
boiling kills bacteria and microorganisms.	Y	N
boiling removes air dissolved in water.	Y	N

2. Which of the following sentences <u>is not the conclusion</u> from Student's experiment. Choose from the statements below.
   A. Steel gets rusts quicker if there is salt dissolved in water.
   B. Stainless steel is more resistant to corrosion that ordinary steel.
   C. Water and air are the major factor causing corrosion.
   D. Lack of water or air stops the corrosion.

3. A Pupil performed the experiment following the steps depicted in the picture.

Phenolphtalein stained in test-tube 1 and 3.

(fenoloftaleina=phenolphthalein)



Which of the following conclusions from the conducted experiment are correct? Choose from the statements below.

A. By reaction of any metal with water , a base is formed.
B. By reaction of sodium and calcium with water, an acid is formed.
C. By reaction of reaction of sodium and calcium with water, a base is formed.
D. By reaction of iron and copper with water, an acid is formed.

4. On the package of product for unblocking pipes, containing solid sodium hydroxide the following sentences can be found: *Warning! Under no circumstances, do not pour water into container! Failure to follow this warning may cause burning by spattering liquid.*

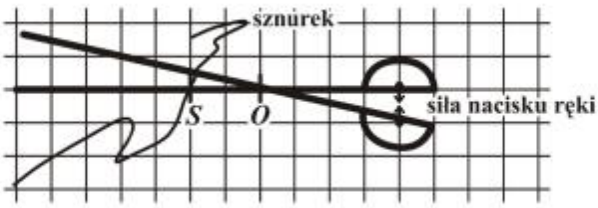
   From the statements below choose <u>the best explanation</u> of that warning.
   A. Sodium hydroxide is rapidly degraded, while heated, that is why the liquid spatters.
   B. Sodium hydroxide is corrosive and it should not be dissolved in water, because in such case it spatters.
   C. During dissolving of sodium hydroxide in water a great amount of heating is produced and that causes liquid boiling and spattering.
   D. Sodium hydroxide rapidly intakes water, that is why the liquid spatters.

PHYSICS

1. Along the main roads small, red-white piles are distributed at equal distance (every 100 m). Tom, travelling with his father noticed that for some time they'd been passing them exactly every 5s. At some point a car speed started to decrease gradually. Tom, continuing the observation, got two subsequent results.

   Which of the following results (written down chronologically) Tom was able to receive?
   A. 4 s and 3 s B. 3 s and 4 s C. 6 s and 7 s D. 7 s and 6 s

2. In the picture the act of cutting the thread in point S with use of scissors is shown.

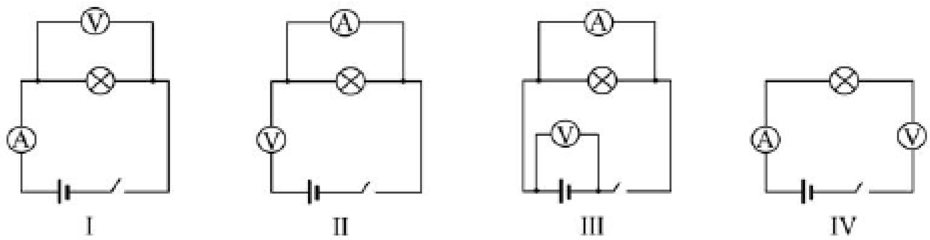


(sznurek-thread; siła nacisku ręki=the force of hand)

In the following sentences choose T (true) if the sentence is true or N (no) if the sentence is false.

In order to increase a cutting force, the thread should be moved towards point O.	Y	N
Work done by cutting force is greater that work done by pressing force	Y	N

3. Students divided into four groups (I-IV), got the task to determine the wattage of a bulb. In order to do so, they build the following electric circuits.

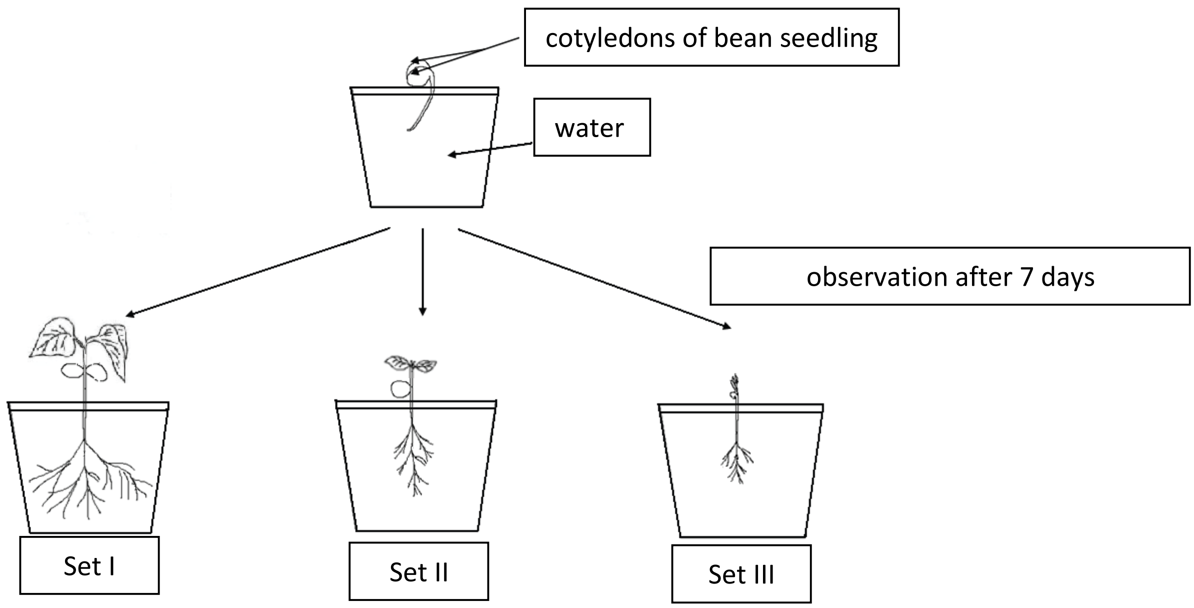


Which group completed the task correctly to perform measurements? Choose from below.
A. I B. II C. III D. IV

- **Example 2 – Upper secondary school final Biology exam 2013 - advanced level.**

An experiment was conducted to investigate the role of the cotyledons in the growth and development of plants. 30 bean seeds germinated (seedlings having a root length of several millimeters) were placed in a separate vessels of tap water. Seedlings were divided into three sets (I-III) of 10 pieces:

I - seedlings, which have both cotyledons
II - seedlings, which removed one cotyledon,
III - seedlings, which removed two cotyledons.

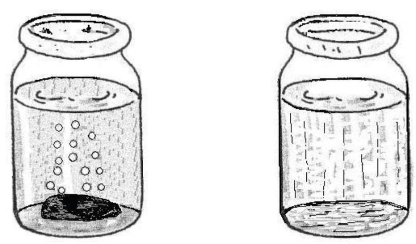


All sets were placed in the same conditions of temperature and lighting. During the experiment a plant growth was observed and after one week the length of their leaves, stems and roots were measured. The figure shows the progress and results of the experiment.

a) Indicate the control set in this experiment. Justify your answer.
   ....
b) Formulate a conclusion containing the function of the cotyledons in the growth and development of seedlings.
   ....

- **Example 3 – Upper secondary school final exam in Biology 2012 - advanced level.**

Q8. Harmful to the cell, hydrogen peroxide (H_2O_2) is produced in many cells. The neutralization is done by a specific enzyme - catalase. An experiment was performed in which an equal amount of a 3% solution of H_2O_2 (hydrogen peroxide) was poured into two jars. To one of the jars, a piece of fresh raw bovine liver was placed. The figure shows the results of this experiment.

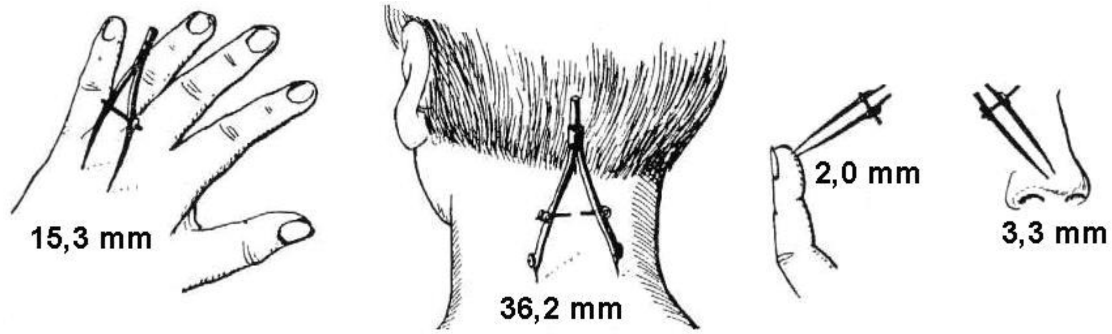


On the basis of: J. Chisholm, D. Beeson, Biologia, Wyd. Penta, Warszawa 1991.

a) Formulate a research problem to that experience.
   ....

b) Specify, how does the neutralization of hydrogen peroxide by mammalian liver cells run?
   ....

Q14. Observations to determine the distribution of touch receptors in various areas of human skin were performed. To stimulate the touch receptors calipers were used, which touched the skin at the same time two of his arms. The moment that both callipers arms were felt at the same time meant stimulation of the two adjacent receptors. That showed the distance between them. The following figures show the average results of the observations collected from several trials.

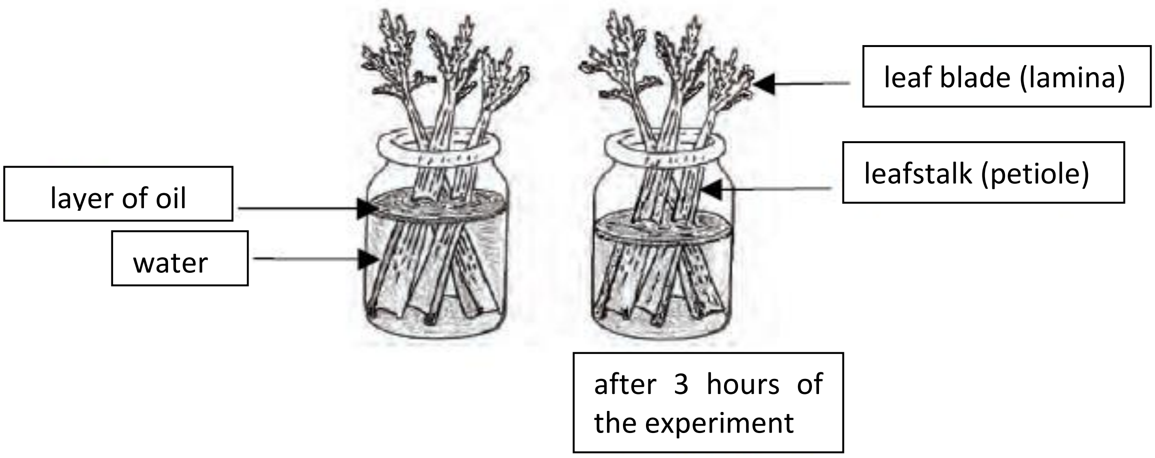


On the basis of: J. Chlebińska, *Anatomia i fizjologia człowieka*, WSiP, Warszawa 1981.

Mark the correct conclusion that is based on the analysis of the results of observations.

A. The density of the touch receptors in the skin of various parts of the human body is the same everywhere.
B. Touch receptors are present in different locations of the human body and are evenly distributed on the surface.
C. Touch receptors are not evenly distributed in the skin in different parts of the body, and in some places there is more than in others.
D. The greater the distance between points on irritated skin, the more tactile receptors located between them.

Q23. An experiment to investigate the role of the process of transpiration in a water transport in plants was made. A few leaves of celery were placed in a jar with water. A thin layer of oil was applied on the surface of the water and the water level was marked. The jar was placed in a warm room. After three hours it was observed that the water level dropped (illustrated in the figure below).



On the basis of: J. Chisholm, D. Beeson. *Biologia*. Wyd. Penta, Warszawa 1991.

a) Formulate a research hypothesis confirmed by the result of the experiment. ....

b) Explain the importance of the oil layer on the water surface in this experiment. ....

Q27. The aim of the experiment was to determine whether metabolic processes occur in seeds during germination. A thermos was filled with germinating seeds (grains) of wheat and sealed with a stopper. The thermometer was placed in the stopper in a way that allowed the temperature reading. The temperature measurements were recorded every three hours during a 24-hour experiment. It was found a gradual increase in temperature in the sample test.

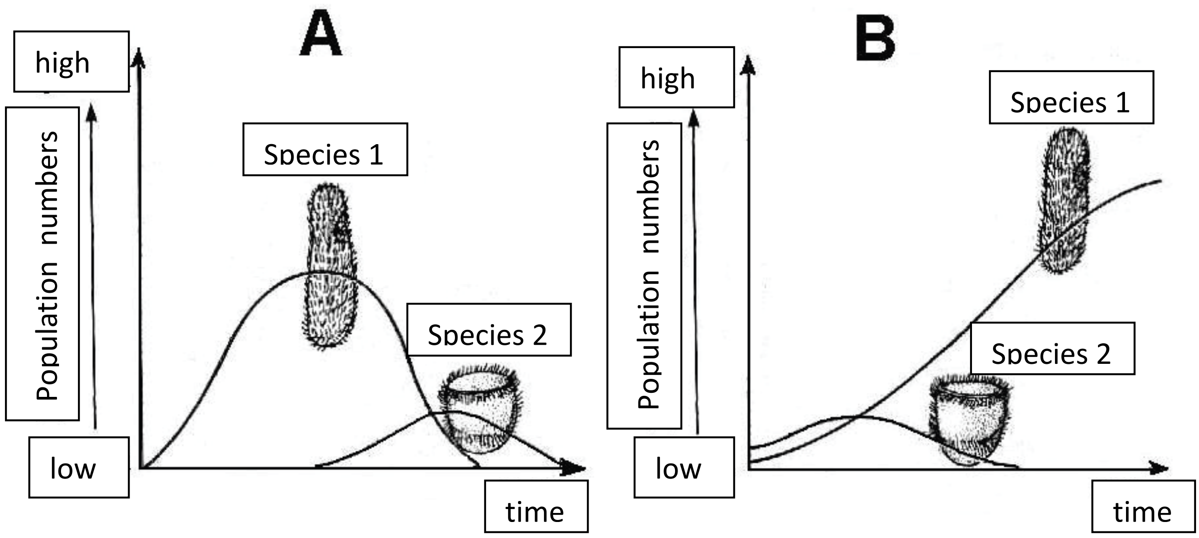
a) Specify a control sample in this experiment.

....

b) Mark a misinterpretation of the results of this experiment.

A. A heat production increases during germination.
B. The intensity of respiration increases during germination.
C. The intensity of the anabolic processes increases during germination.

Q35. Experiment on the relations between the populations of two species of ciliates (species 1 and species 2) was carried out. Ciliates of the species 2 hunted ciliates of the species 1. Two types of experiments were used (culture A and culture B) in which changes in the populations of both species were observed, depending on whether the victim may find shelter or not. The figures show the results of two variants of the described experiment.



On the basis of: J.H. Postlethwait, J.H. Hopson, R.C. Vernes, *Biology. Bringing science to life*, Oxford 1991.

Describe changes in the populations of predatory ciliates only in this experiment, in which the victims didn't find hiding places. Take into account the causes and consequences of these changes.

- **Example 4 –Upper secondary school final exam in Biology 2012 - basic level**

Heart rate (pulse) corresponds to the frequency of heart contractions. Observation of the pulse is important in assessing the functioning of the cardiovascular system.

a) Specify where in the body, and how you can measure your heart rate.

Place of measurement ………………………………………………………………………………………………….

The measurement method ………………………………………………………………………………………

b) Plan how to carry out observation which shows that physical activity has an effect on the heart rate.

....

4.8 PORTUGAL

Diagnosing problems		Critiquing experiments		Distinguishing alternatives		Planning Investigations		Researching conjectures	
LS	US	LS	US	LS	US	LS	US	LS	US
✓	✓	✓	✓	✓	✓	✓	✓		
Searching for information		Constructing models		Debating with peers		Forming coherent arguments			
LS	US	LS	US	LS	US	LS	US		
✓	✓			✓	✓	✓	✓		

TABLE 25 INQUIRY IN NATIONAL ASSESSMENT IN PORTUGAL FOR LOWER SECONDARY (LS) AND UPPER SECONDARY (US)

There are no national standardized examinations for science at the end of lower secondary (third cycle). Students are submitted to science exams in the terminal year of secondary that can correspond to 11^{th} or 12^{th}. At the end of each cycle students are submitted to external assessment. The national exams report only to the subjects of Portuguese and Mathematics.

This school year, the Ministry of Education and Science established an assessment program that allows schools to conduct intermediate national tests. Participation in this program is a school decision. These tests are intermediate assessment tools, provided to schools throughout the school year. According to the Ministry of Education, the main purpose of these tests is to allow each teacher to assess the performance of their pupils by reference to national standards, to help students develop a better awareness of the progression of their learning and, in addition, contribute, where applicable, to their gradual familiarization with instruments of the external evaluation process that they will be subject to at the end of cycles of basic education, or terminal year of secondary school subjects.

The organization of intermediate tests in the present school year, involves the subjects indicated below, according to the teaching cycle to which belong:

Basic Education		**Secondary Education**
1st Cycle	**3rd Cycle**	**Secondary**
Portuguese	Physics and Chemistry	Biology and Geology
Mathematics	Natural Science	Philosophy
	Geography	Physics and Chemistry
	History	Mathematics
	English	Portuguese
	Portuguese	
	Mathematics	

The Portuguese science curriculum values the following competencies that can be developed through inquiry:

- Knowledge (substantive knowledge, process knowledge, epistemological knowledge)
- Reasoning (critical thinking, problem solving, decision making)
- Communication (different types of scientific data representation, argumentation, oral and written scientific explanation)
- Attitudes (curiosity, respect for others and for nature, perseverance)

The curriculum provides examples of questions that teachers can ask in order for the students to develop some research trying to find a way or different ways to solve it.
The competencies described in the curriculum for secondary education are listed below.

- Knowledge – the acquisition, understanding and use of data, concepts, models and theories.

- Reasoning and communication – the development of learning and reasoning skills (such as researching, analysing, organising, critically evaluating, understanding and communicating information, interpreting, critically discussing, judging, deciding and responsibly acting upon the surrounding reality).
- Attitudes – the adoption of attitudes and values relating to personal and social awareness and informed decision making (concerning problems that involve interactions between science, technology, society and the environment) aimed at an education for citizenship (for instance, attitudes and values pertaining to the nature of science and its social implications; rigour, curiosity, humbleness, scepticism, critical analysis, reflection, responsibility, cooperation and solidarity)

Examples of Examination and Midterm-test Exercises:

- **Example 1- Physics and Chemistry (10th grade – Key Stage 4) Midterm Test 2012**

Ozone, O3, is in the stratosphere, forming the ozone layer, which extends for several kilometers in altitude. In the stratosphere, the interaction of the ultraviolet B radiation (UV-B) with oxygen molecules leads to the formation of free radicals (atoms) of oxygen. These radicals react with other oxygen molecules in the stratosphere, producing ozone. Meanwhile, ozone molecules also interact with the UV-B radiation in the stratosphere, getting dissociated. If there was no interference with other chemical species present in the stratosphere, ozone concentration in this layer of the atmosphere would remain approximately constant - the formation and decomposition of the gas would occur at the same rate. However, some free radicals also present in the stratosphere, particularly free radicals (atoms) of chlorine, react with ozone and starts decomposing at a greater speed than the speed of its formation. As a result of the action of these free radicals, there is a reduction in the concentration of ozone in the stratosphere, a phenomenon which is commonly called "ozone hole".

Maria Teresa Escoval,
A Ação da Química na Nossa Vida (Chemistry´s action in our life),
Editorial Presença, 2010 (adapted)

1. Explain why the molecules of oxygen and ozone form UV-B radiation filters in the stratosphere.

2. CFCs (chlorofluorocarbons) are compounds which, interacting with UV-B, become the major source of free radicals of chlorine in the stratosphere. The weaker C-Cl bonds of the CFCs molecules that reach the stratosphere break, but not the stronger C-F bonds.

Explain why the breaking of the C-F bonds does not occur.

- **Example 2- Biology and Geology (10th/11th grade – Key Stage 5) - Exam**

Production of β-carotene in large scale by unicellular algae
Dunaliella salina is a unicellular alga that accumulates high concentrations of β-carotene, in response to severe stress conditions of salt, light and nutrients. Numerous oil droplets that accumulate in chloroplast play a critical role in capturing light and protect the algae from photo-oxidative damage. Aiming to promote the production of β-carotene in large scale through the use of *D. saline*, the researchers studied the influence of various factors, including the hypersaline shock, nutrient availability and light intensity.

For studying these issues researchers performed the following experiment:
1. For several weeks a strain *D. saline* was cultivated at a temperature of 23 ° C and an illumination of 120 mol m-2 s-1, in two culture medium, one with a NaCl concentration adjusted to 4% and another culture medium with NaCl concentration adjusted to 9%.
2. In order to study the response of *D. saline* to a sudden increase in the NaCl concentration, growing cells pre-adapted in a culture medium containing 4% NaCl were transferred to the fresh culture medium containing 4% NaCl, 9%, 18% and 27%. The accumulation of carotenoids was measured over 15 days (Graphic 1A).
3. To observe whether acclimation to high salinity would decrease susceptibility of these microalgae to severe salt stress, cells of D. saline pre-adapted to 9% were transferred to a fresh medium containing NaCl 9%, 18% and 27%. The accumulation of carotenoids was measured over 15 days (Graphic 1B).
4. The influence of nutrient supplements and light on cell growth and accumulation of carotenoids is represented respectively, in the graphics 2A and 2B.

(***+ Nutrients*** = with nutrient supplements; ***– Nutrients*** = without nutrient supplements; BL = low illumination of 65 µmol m–2 s–1; AL = high illumination of 150 µmol m–2 s–1).

Results: The results of the observations are recorded in the graphics below.

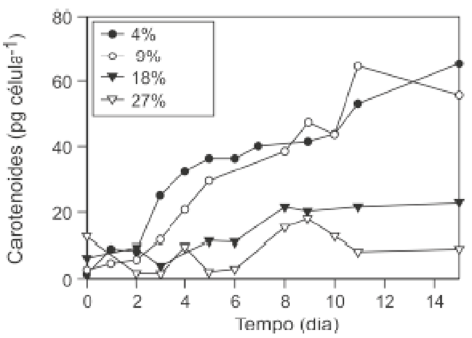


Gráfico 1A

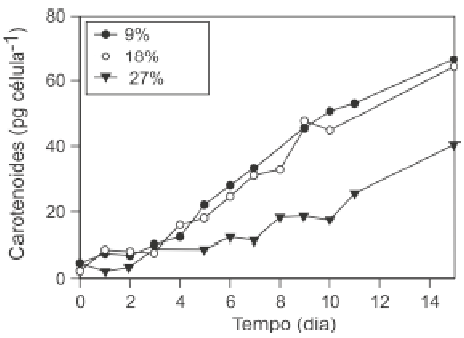


Gráfico 1B

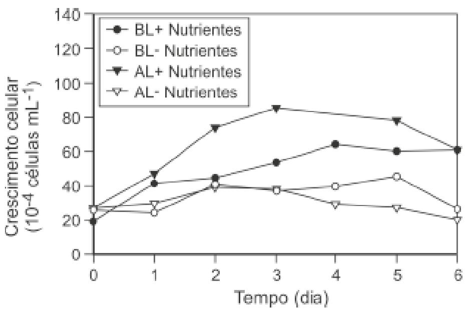


Gráfico 2A

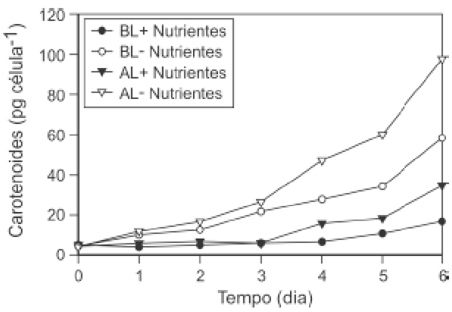


Gráfico 2B

Adapted from: Baumgartner, A. C., et.al., «Nutrient limitation is the main regulatory factor for carotenoid accumulation and for Psy and Pds steady state transcript levels in Dunaliella salina (Chlorophyta) exposed to high light and salt stress», Marine Biotechnology, 2008.

In response to the items 1. to 5., select the only option to get a correct statement. Write the answer in the response sheet, with the item number and the letter that identifies the selected option.

1. In the experiment, which results are portrayed in Graphic 1A, control contains cells pre-adjusted to NaCl 4% that were transferred to a culture medium with
    (A) NaCl at 4%.
    (B) NaCl at 9%.
    (C) NaCl at 18%.
    (D) NaCl at 27%.
2. Cells that respond best to hypersaline shock, accumulating carotenoids, are cells pre-adapted to
    (A) NaCl at 4% that were transferred to a culture medium with NaCl at 18%.
    (B) NaCl at 4% that were transferred to a culture medium with NaCl at 27%.
    (C) NaCl at 9% that were transferred to a culture medium with NaCl at 18%.
    (D) NaCl at 9% that were transferred to a culture medium with NaCl at 27%.
3. Regarding the growth of algae and accumulation of carotenoids (Graphics 2A and 2B), the analysis of the results allows us to conclude
    (A) in both cases, the limiting factor is the low luminous intensity.
    (B) the limiting factors are, respectively, the low luminous intensity and high luminous intensity.
    (C) in both cases, the limiting factor is the culture medium without nutrient supplements.
    (D) the limiting factors are, respectively, the culture medium without nutrient supplements and the culture medium with nutrient supplements.
4. During photosynthesis, on the phase directly dependent of the light, occurs
    (A) NADP+ oxidation.
    (B) ADP phosphorylation.
    (C) decarboxylation of organic compounds.
    (D) CO2 reduction.
5. In *Dunaliella salina*, protection against photo-oxidative damage requires the mobilization in chloroplasts of carbon dioxide in
    (A) catabolic processes through the accumulation of lipid droplets.
    (B) catabolic processes through the accumulation of starch granules.
    (C) anabolic processes through the accumulation of lipid droplets.
    (D) anabolic processes through the accumulation of starch granules.
6. Arrange in proper sequence the letters from A to E, in order to reconstruct the chronological sequence of events during a cell cycle.
    A. chromosomes alignment on the equatorial plate.
    B. DNA replication.
    C. achromatic spindle formation.
    D. nucleolus reappearance.
    E. Polar rise of sister chromatids.
7. During the investigation, it was difficult to match the increase in biomass (algae growth) with the accumulation of carotenoids, which was overcome by separating the increase biomass phase from β-carotene production phase.

Based on the results represented into graphs 2A and 2B, explain which conditions must be created at each stage of the process to optimize the production of β-carotene in large scale.

4.9 SLOVAKIA

Diagnosing problems		Critiquing experiments		Distinguishing alternatives		Planning Investigations		Researching conjectures	
LS	US	LS	US	LS	US	LS	US	LS	US
				✓	✓				
Searching for information		Constructing models		Debating with peers		Forming coherent arguments			
LS	US	LS	US	LS	US	LS	US		
✓	✓	✓	✓			✓	✓		

TABLE 26 INQUIRY IN NATIONAL ASSESSMENT IN SLOVAKIA FOR LOWER SECONDARY (LS) AND UPPER SECONDARY (US)

The National Institute for Certified Educational Measurements (NUCEM) is a state budget organization with a legal personality, founded by the Ministry of Education of the Slovak Republic. The basic mission of NUCEM includes: providing external part and written form of internal part of school leaving examination assigned by the Ministry of Education, providing external testing of pupils at primary schools Testing 9, preparation of international measurements in accordance with programmes where the Slovak Republic participates according to their rules.

In 2008, a new Education Act was adopted to define national educational evaluation and bring some changes into curriculum administrative. External testing of pupils of 9th grade at primary schools is carried out each year in order to detect individual level of pupils´ knowledge of Mathematics and national language. The results of the testing can be used by headmasters of secondary schools as one of the criteria for accepting pupils to study at secondary schools.

The Maturita exam consists of two parts - external and internal. The external part of Maturita exam includes tests prepared and evaluated externally. It is NUCEM wherein these tests are being prepared. The internal part consists of an essay to be written in mother and/or foreign language, and an oral exam processed by individual schools. The essay themes are announced by NUCEM. Both parts are obligatory for all students. In sciences there are only internal parts of Maturita exams.

Classification of the learning outputs in science subjects is carried out in line with curriculum and educational standards.

The following items are assessed:

(a) quality of thinking, in particular, logical thinking, independence and creativity,
(b) quality and extent of acquired competencies to carry out required intellectual and practical activities within experimentation,
(c) ability to express opinion and apply gained knowledge and skills to solve theoretical and practical assignments, to explain and evaluate natural phenomena and laws or theories,
(d) ability to use and generalize experience and knowledge gained during the practical activities within experimentation,
(e) compatibility, accuracy, durability of gained knowledge, facts, concepts, definitions, laws and relations, theories,
(f) proactive approach to activities, interest and positive attitude towards the activities,
(g) accuracy, scientific and language correctness of the oral and written presentation,
(h) quality of the activity results,
(i) adoption of effective methods of independent active learning and ability of self-learning.

For example, the oral form of the school-leaving exam in biology consists of three different character tasks:

1. **Presenting and understanding of a given topic –** pupils have to show the ability to present acquired knowledge in their own words. They also have to know facts and biological terms, be able to learn the essence, causes and connections among biological phenomena and processes.
   In this task pupil's monologue prevails in combination with answering the complementary questions of the commission.

2. **Applying the acquired knowledge -** pupils have to show the ability to evaluate biological phenomena and processes and their significance for the nature and practical life of people. They are able to solve given problems, analyse causes, and make conclusions.
   In this task pupil's dialogue with the commission prevails.

3. **Implementation –** pupils are familiar with empirical and theoretical methods of gathering information about nature, they can process it. They are capable of interpreting and discussing observed phenomena and processes/experiment. They can work with information, identify a problem, suggest their own solution, and defend their opinion.
   In this task pupil's dialogue with the commission prevails.

Examples of National Examinations:

For inquiry skills assessment there are no official examinations. There is some use of skills oriented questions; problem solving or argumentation tools testing questions within the non-standard tests, created mostly by teachers themselves. However the creation and evaluation of standard assessment tools are currently under development through a new national grant supported by Ministry of Education.

4.10 SWEDEN

Diagnosing problems		Critiquing experiments		Distinguishing alternatives		Planning Investigations		Researching conjectures	
LS	US	LS	US	LS	US	LS	US	LS	US
		✓	✓			✓	✓		
Searching for information		Constructing models		Debating with peers		Forming coherent arguments			
LS	US	LS	US	LS	US	LS	US		
						✓	✓		

TABLE 27 INQUIRY IN NATIONAL ASSESSMENT IN SWEDEN FOR LOWER SECONDARY (LS) AND UPPER SECONDARY (US)

National assessment in lower secondary school

Mandatory national subject tests are held at the end of compulsory school to assess student progress in biology, chemistry, and physics. However, each individual student is only tested in one of the subjects. As of 2013, national tests in biology, chemistry, and physics will also be held in grade 6. The national tests are supposed to assess the national performance standards, including the IBSE standards exemplified in section 3.10 above, but for practical reasons the national science tests in Sweden are basically paper-and-pencil based. However, the tests often include a single task requiring students to plan and perform a simple investigation.

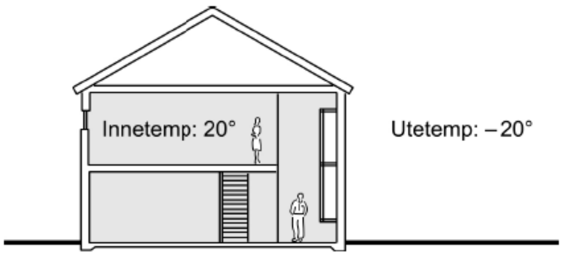
National assessment in upper secondary school

There are no mandatory national subject tests in science. There are, however, voluntary course tests in biology, chemistry, and physics, which are developed by order of the Swedish National Agency for Education. Just as the test in compulsory school, these tests are paper-and-pencil test, but also include tasks requiring students to plan and perform an investigation.

Examples of Examination and Midterm-test Exercises:

A systematic investigation in physics: Insulation

Your task is to plan an investigation that you can carry out and evaluate later.
When building a house, different insulating materials are used (such as glass wool) to keep the house warm. Insulating materials can also be used to keep liquids warm.



1. Planning (time 30 min)

Your task is to plan an investigation in order to find out which of the materials cotton cloth, corrugated cardboard, or soft plastic that best keep water warm in a beaker.

Method

Describe step by step how to carry out your investigation. The description must be so detailed that someone else could use it.

Equipment

Make a list of the equipment needed in order to carry out your investigation.

2. Investigation (time 30 min)

Your task is to carry out an investigation in order to find out which of the materials cotton cloth, corrugated cardboard, or soft plastic that best keep water warm in a beaker. When carrying out your investigation you must:

- follow your planning.
- follow the safety regulations provided by your teacher.
- document your results.

4.11 TURKEY

Diagnosing problems		Critiquing experiments		Distinguishing alternatives		Planning Investigations		Researching conjectures	
LS	US	LS	US	LS	US	LS	US	LS	US
Searching for information		Constructing models		Debating with peers		Forming coherent arguments			
LS	US	LS	US	LS	US	LS	US		

TABLE 28 INQUIRY IN NATIONAL ASSESSMENT IN TURKEY FOR LOWER SECONDARY (LS) AND UPPER SECONDARY (US)

In Turkey, the curriculum was changed in March 2013, and will be implemented in primary schools from autumn 2013 and following that in lower secondary and in upper secondary schools.

The new science curriculum aims to track students' performance throughout the learning process, guide the students, probe their learning difficulties and try to remedy them and to provide continuous feedback for meaningful learning. The main approach for the assessment is to evaluate the process and the product. Traditional assessment tools would not be sufficient to assess the process; therefore, formative assessment tools and strategies are suggested in the new science curriculum. In summary, the new science curriculum emphasizes the importance of both summative and formative assessment and offers guidelines to teachers on the use of these strategies in their classroom practice. (MEB, 2013, p. IV)

The curriculum uses alternative assessment tools, and also formative assessment along with other kinds of assessments. But the teachers are under pressure because parents ask teachers to use other kinds of assessment tools that are more aligned with the exams the student will take. Therefore teachers prefer to use summative assessment rather than other assessment tools.

Examples of National Examinations:

No specific assessment examples have been made available yet following the recent change in curriculum.

4.12 United Kingdom

Diagnosing problems		Critiquing experiments		Distinguishing alternatives		Planning Investigations		Researching conjectures	
LS	US	LS	US	LS	US	LS	US	LS	US
✓						✓		✓	
Searching for information		Constructing models		Debating with peers		Forming coherent arguments			
LS	US	LS	US	LS	US	LS	US		
✓						✓			

TABLE 29 INQUIRY IN NATIONAL ASSESSMENT IN ENGLAND FOR LOWER SECONDARY (LS) AND UPPER SECONDARY (US)

There is a component in science of coursework assessment, which is meant to be based on teachers' own assessment but it is heavily controlled and moderated from outside.

There are competing providers of the exams. There are inquiry based open questions on the written exams. There is not much reliance on multiple choice; there are a lot of short answer questions and some more open questions. The prevalence of these varies between different providers.

Level 5 (Typical age: 14).
Pupils describe how experimental evidence and creative thinking have been combined to provide a scientific explanation [for example, Jenner's work on vaccination at key stage 2, Lavoisier's work on burning at key stage 3]. When they try to answer a scientific question, they identify an appropriate approach. They select from a range of sources of information. When the investigation involves a fair test, they identify key factors to be considered. Where appropriate, they make predictions based on their scientific knowledge and understanding. They select apparatus for a range of tasks and plan to use it effectively. They make a series of observations, comparisons or measurements with precision appropriate to the task. They begin to repeat observations and measurements and to offer simple explanations for any differences they encounter. They record observations and measurements systematically and, where appropriate, present data as line graphs. They draw conclusions that are consistent with the evidence and begin to relate these to scientific knowledge and understanding. They make practical suggestions about how their working methods could be improved. They use appropriate scientific language and conventions to communicate quantitative and qualitative data.

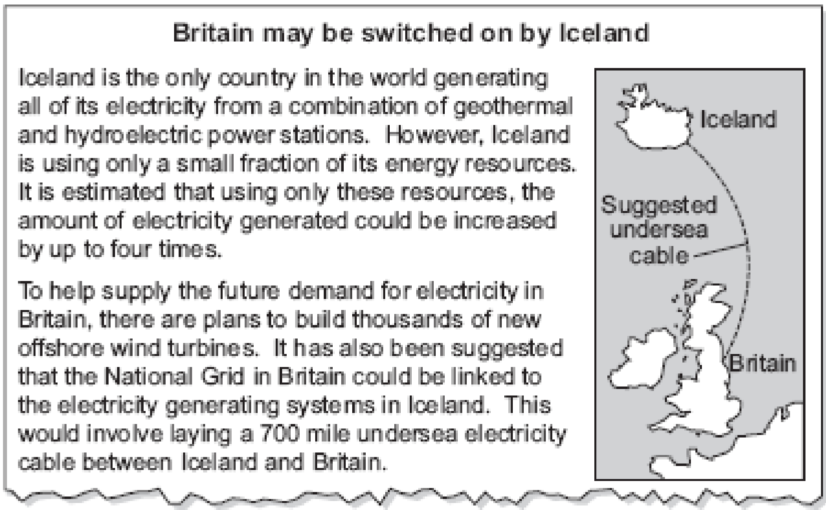
Exceptional performance
Pupils give examples of scientific explanations and models that have been challenged by subsequent experiments and explain the significance of the evidence in modifying scientific theories. They evaluate and synthesise data from a range of sources. They recognise that investigating different kinds of scientific questions requires different strategies, and use scientific knowledge and understanding to select an appropriate strategy in their own work. They make records of relevant observations and comparisons, clearly identifying points of particular significance. They decide the level of precision needed in measurements and collect data that satisfy these requirements. They use their data to test relationships between variables. They identify and explain anomalous observations and measurements, allowing for these when they draw graphs. They use scientific knowledge and understanding to interpret trends and patterns and to draw conclusions from their evidence. They consider graphs and tables of results critically and give reasoned accounts of how they could collect additional evidence. They communicate findings and arguments using appropriate scientific language and conventions, showing their awareness of the degree of uncertainty and a range of alternative views.

Examples of National Examinations:

Example 1: General Certificate of Secondary Education, Higher Tier Physics 2012

Q3 (b) *In this question you will be assessed on using good English, organising information clearly and using specialist terms where appropriate*.

Read the following extract from a newspaper.



Britain may be switched on by Iceland

Iceland is the only country in the world generating all of its electricity from a combination of geothermal and hydroelectric power stations. However, Iceland is using only a small fraction of its energy resources. It is estimated that using only these resources, the amount of electricity generated could be increased by up to four times.

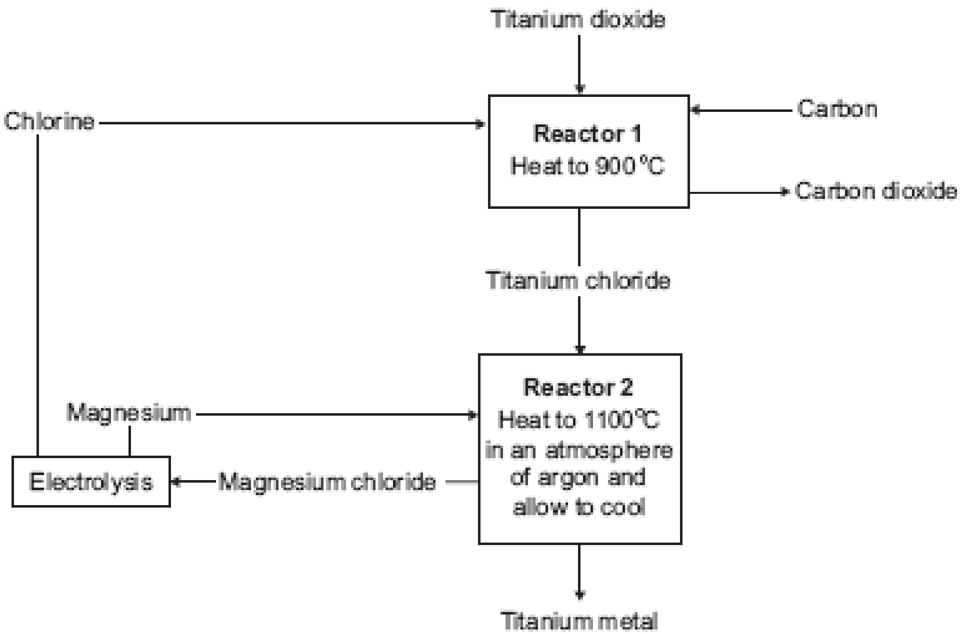
To help supply the future demand for electricity in Britain, there are plans to build thousands of new offshore wind turbines. It has also been suggested that the National Grid in Britain could be linked to the electricity generating systems in Iceland. This would involve laying a 700 mile undersea electricity cable between Iceland and Britain.

Discuss the advantages and disadvantages of the plan to build thousands of offshore wind turbines around Britain **and** the suggested electricity power link between Britain and Iceland.

Example 2: General Certificate of Secondary Education, Higher Tier Chemistry 2012

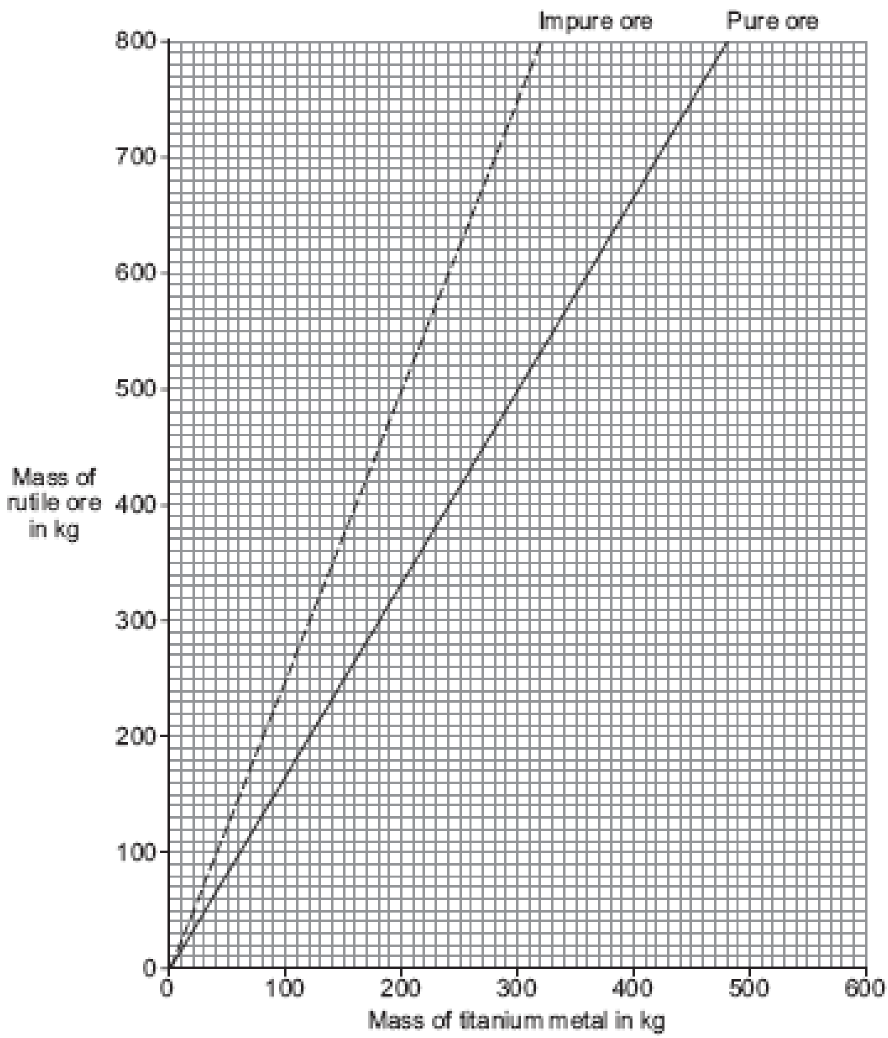
Q2 Rutile is an ore of titanium. Rutile contains titanium dioxide.

The flow chart shows how titanium metal is extracted from titanium dioxide.



2 (a) Titanium is much more expensive than iron.
Give **one** reason why. *(1 mark)*
2 (b) Name the only waste product shown on the flow chart. *(1 mark)*
2 (c) Describe the example of recycling shown on the flow chart. *(2 marks)*
2 (d) The air is removed from **Reactor 2**. An atmosphere of argon is used for the reaction between titanium chloride and magnesium metal. Explain why. (2 marks)
2 (e) Titanium metal is produced by reacting titanium chloride with magnesium. 950 kg of titanium chloride was mixed with 240 kg of magnesium metal. The mixture was heated and produced 950 kg of magnesium chloride. Calculate the mass of titanium metal produced.
Mass = ... kg *(1 mark)*

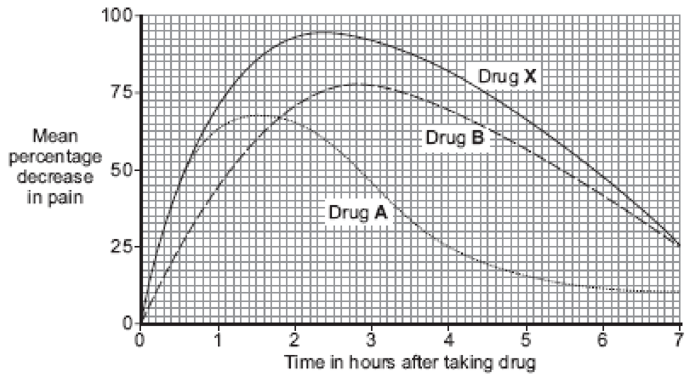
2 (f) The graph shows the mass of titanium metal produced from a pure rutile ore and from an impure rutile ore.



The difference between the two lines represents the amount of waste rock in the impure ore.
300 kg of titanium metal was produced from the impure ore. Calculate the mass of waste rock in the impure ore.
Mass = ... kg *(1 mark)*

Example 3: General Certificate of Secondary Education, Higher Tier Biology 2012

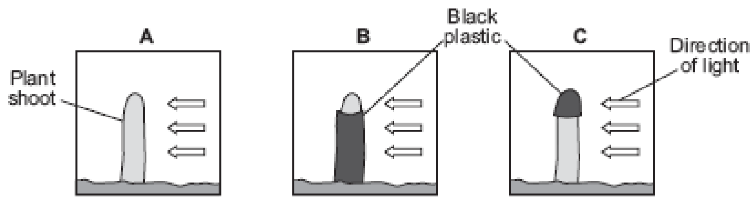
1 (c) The graph shows the results of the investigation.



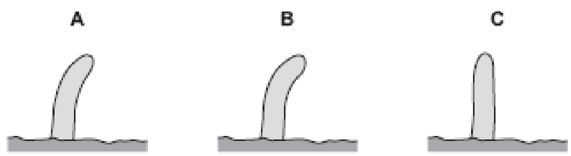
1 (c) (i) How much pain did the volunteers still feel, four hours after taking drug **A**?
.... percent *(1 mark)*
1 (c) (ii) Give **one** advantage of taking drug **A** and **not** drug **B**.
.... *(1 mark)*
1 (c) (iii) Give **two** advantages of taking drug **B** and **not** drug **A**. *(2 marks)*
1 (d) Drug **X** is much more expensive than both drug **A** and drug **B**.
A pharmacist advised a customer that it would be just as good to take drug **A** and drug **B** together instead of drug **X**. Do you agree with the pharmacist's advice?
Give reasons for your answer. *(3 marks)*

4 Charles Darwin investigated tropisms in plants. Some students did an investigation similar to Darwin's investigation. The students:
- grew seeds until short shoots had grown
- used black plastic to cover parts of some of the shoots
- put the shoots in light coming from one direction
- put boxes over the shoots to keep out other light.

The diagrams show how the investigation was set up.



Two days later the students took off the black plastic covers and looked at the shoots.
The diagrams show the results.



4 (a) Give **two** variables that the students should control in this investigation.
4 (b) Shoot **A** bent towards the light as it grew. Explain how. *(4 marks)*
4 (c) What conclusions can be drawn from the results about:
4 (c) (i) the detection of the light stimulus *(1 mark)*
4 (c) (ii) where in the shoot the response to the light takes place. *(1 mark)*

4.13 Finland

Pupil assessment is divided between in-class assessment and final assessment for some subjects. Final assessment is required for the core subjects which include physics, chemistry and biology. A certificate is issued at the end of compulsory education if performance in all graded subjects is adequate.

Assessment in upper secondary school

Physics

Assessment in physics will focus on achievement of course-specific physics skills as set out in the National Core Curriculum and of their application skills, using mathematical models in particular. The targets of assessment will also include development of students' information processing skills, experimental skills and other skills supporting their studies, such as the ability to analyse physical problem-solving processes.

Chemistry

Assessment in chemistry will focus on students' abilities to understand and apply chemical knowledge. In addition, assessment must pay attention to development of experimental information acquisition skills and information processing skills, including

- making observations, planning and implementation of measurements and experiments;
- presentation of results both orally and in writing;
- interpretation, modelling and assessment of results;
- drawing conclusions and applying them.

The assessment methods used in chemistry will include course tests, monitoring of the degree of active participation, experimental work, work reports, projects, presentations or research papers. In addition, the development of students' conceptual and methodological skills and knowledge will be monitored on a continuous basis.

Biology

Assessment in biology will focus on students' abilities to master and use key biological concepts and to apply biological knowledge. Assessment will pay attention to students' understanding of the laws of natural science and causal relationships, insight into the significance of interdependencies and perception of extensive wholes. Skills assessment will place emphasis on students' aptitude for scientific work, team behaviour and their ability to use different sources for the acquisition of biological information and to assess information critically.

4.14 AUSTRALIA

Assessment of Australian students takes the form of:

- ongoing formative assessment within classrooms for the purposes of monitoring learning and providing feedback, to teachers to inform their teaching and for students to inform their learning
- summative assessment for the purposes of twice yearly reporting by schools to parents and carers on the progress and achievement of students
- annual testing of Years 3, 5, 7 and 9 students' levels of achievement in aspects of literacy and numeracy, conducted as part of the National Assessment Program – Literacy and Numeracy (NAPLAN) since 2008
- periodic sample testing of specific learning areas, e.g. scientific literacy (Year 6), civics and citizenship (Years 6 and 10), and information and communications technology (Years 6 and 10), within the Australian Curriculum as part of the National Assessment Program (NAP).
- State-wide testing at different stages

The NAP — Science Literacy assessment at Year 6 measures scientific literacy. This is the application of broad conceptual understandings of science to make sense of the world, understanding natural phenomena and interpreting media reports about scientific issues. This assessment also includes asking investigable questions, conducting investigations, collecting and interpreting data and making decisions. As the curriculum and assessment varies in each state, the assessment practices in two states are considered.

The case of Queensland

The Queensland Comparable Assessment Tasks (QCATs, 2012a) are taken by students in Years 4, 6 and 9. The tasks are designed to

- engage students in solving meaningful problems that value higher-order thinking skills
- provide evidence of students' understanding and skills in relation to the Australian Curriculum content descriptions and achievement standards in English, Maths and Science
- support teachers in making consistent judgments about student work, using moderation processes
- provide teachers with information about student achievement with a focus for future teaching and learning.

Students are assessed on how their performance matches selected statements from the National Curriculum. For example, in 2012, the following was assessed for Year 9 students (QCAT, 2012b).

Science Understanding

- The theory of plate tectonics explains global patterns of geological activity and continental movement

Science as a Human Endeavour

- Advances in scientific understanding often rely on developments in technology and technological advances are often linked to scientific discoveries

Science Inquiry Skills

- Questioning and predicting: Formulate questions or hypotheses that can be investigated scientifically
- Processing and analysing data and information: Analyse patterns and trends in data, including describing relationships between variables and identifying inconsistencies and use knowledge of scientific concepts to draw conclusions that are consistent with evidence
- Communicating: Communicate scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations

The case of New South Wales

The New South Wales Essential Secondary Science Assessment (ESSA, 2012) is a mandatory test for students in government schools who have completed two years of secondary schooling and learning in science (optional for students in non-governmental schools). It is a diagnostic test which is used to support teaching and learning. In these tests, students are asked to demonstrate their

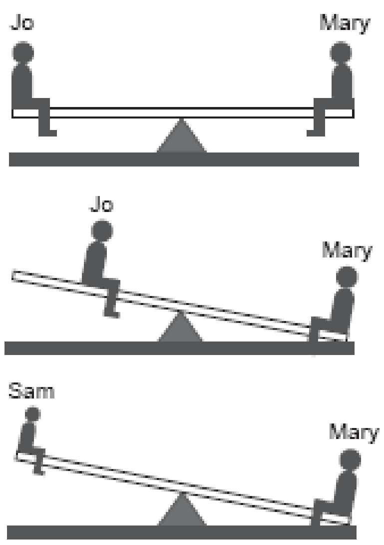
- knowledge and understanding in science
- skills in planning and conducting investigations, including a simulated experiment
- skills in understanding and responding to a range of scientific information in a variety of media (including video, audio, animation graphics and text)
- skills in critical thinking and problem solving.

Example from NAP – SCIENCE LITERACY 2009

LIFTING WEIGHTS

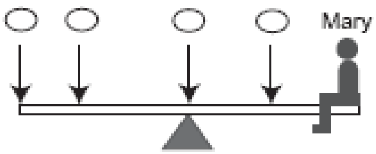
Mary, Jo and Jo's little sister Sam investigated balancing on a seesaw. Both Jo and Mary each weighed 40 kg. Sam weighed 20 kg.

The diagrams show the observations the children made during their investigation. When no one is sitting on the seesaw, it is balanced.



Q5 In the diagram below Mary is sitting at one end of the bar of the seesaw.

If Sam sat on Jo's lap, where should they sit to balance the seesaw?



SEPARATING MIXTURE

Jan investigated how a mixture could be separated into its parts.

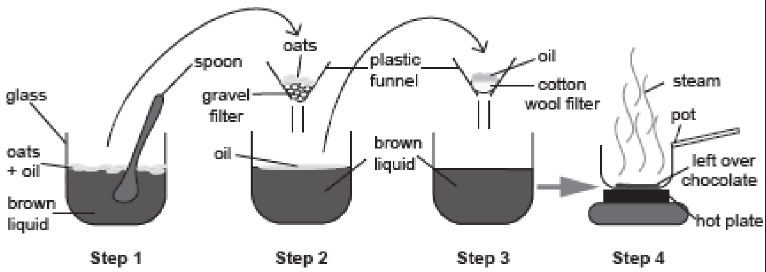
She mixed the following substances together in a glass:

100 mL water
1 teaspoon olive oil
1 teaspoon rolled oats
1 teaspoon powdered drinking chocolate.

She used the following steps in her investigation:

1. Stir the mixture with a spoon.
2. Pour the mixture through a gravel filter and collect what passes through in a glass.
3. Pour the contents collected in the glass in **Step 2** through a cotton wool filter and collect what passes through in another glass.
4. Place the contents of the glass collected in **Step 3** into a pot and boil it.

The diagram shows Jan's observations of the steps taken in her investigation.



Q7 Jan wanted to collect the water that had been separated from the mixture in her investigation.

How could she best achieve this?

- ◯ Collect the contents of the glass in **Step 3**, which is water only.
- ◯ Put the mixture through **Step 3** a second time.
- ◯ Allow the pot in **Step 4** to cool leaving water only.
- ◯ Collect the steam from **Step 4** and cool it to a liquid.

Three methods for separating mixtures into their parts are:		
Dissolving	Using a magnet	Filtering

Which method should Jan use to separate the mixtures listed below into their parts?

Q8 Separate sand and iron filings (tiny pieces of iron):

____

Q9 Separate mud in water from water:

____

Q10 Which two methods should Jan use to separate the mixture listed below into its parts?

Separate sand and salt:

____

4.15 CANADA

In 2003, the Council of Ministers of Education (CMEC) recognized that a new pan-Canadian assessment program was needed to reflect changes in curriculum, integrate the increased jurisdictional emphasis on international assessments, and allow for the testing of the core subjects of mathematics, reading, and science. Pan-Canadian Assessment Program (PCAP) responds to these goals. In addition, during each test one subject is the focus of the assessment and the majority of the students write the test on this subject. However, the other two subjects are also tested, with a smaller number of students writing the tests in those subjects. In this way, PCAP provides results in all three subjects.

An understanding of science is important for young people to be able to participate in and understand that science and technology affects their lives both in the present and in the future. Scientific literacy is developed when students are engaged in demonstrating the competencies of science inquiry, problem solving, and scientific reasoning. PCAP Science places a priority on being able to assess these competencies. For each competency, students will be assessed on their understanding and ability to critique the practices and processes related to these competencies.

Science inquiry: Understanding how inquiries are conducted in science to provide evidence-based explanations of natural phenomena

Science inquiry requires students to address or develop questions about the nature of things, involving broad explorations as well as focused investigations (CMEC, 1997a). It is from the perspective of the student in that they focus on the "why" and "how" of science.
The PCAP assessment of students' ability to use scientific practices provides evidence that they can:

- formulate hypotheses;
- make observations;
- design and conduct investigations;
- organize and communicate information;
- analyze and interpret data (e.g., using graphs and tables);
- apply the results of scientific investigations;
- select alternative conclusions in relation to the evidence presented;
- provide reasons for conclusions based on the evidence provided;
- identify assumptions made in reaching the conclusion.

Problem solving: Using scientific knowledge and skills to solve problems in social and environmental contexts

Problem solving requires students to seek answers to practical problems requiring the application of their science knowledge in new ways (CMEC, 1997a). Students demonstrate this competency by applying their knowledge of science, their skills, and their understanding of the nature of science to solve science-related problems. It is part of the problem process that includes problem finding and problem shaping where problem is defined as the state of desire to reach a definite goal.
The PCAP assessment of students' ability to solve problems provides evidence that they can:

- define the problem;
- formulate questions;
- communicate the goals related to the problem;
- solve problems by recognizing scientific ideas;
- select appropriate solutions in relation to an identified problem;
- verify and interpret results (communicate, reflect);

- generalize solutions (recognize and apply science in contexts not typically thought of as scientific);
- provide reasons for the solution and how it meets the criteria to solve the problem;
- identify assumptions made in solving the problem;
- show an awareness of sustainable development and stewardship when addressing problems.

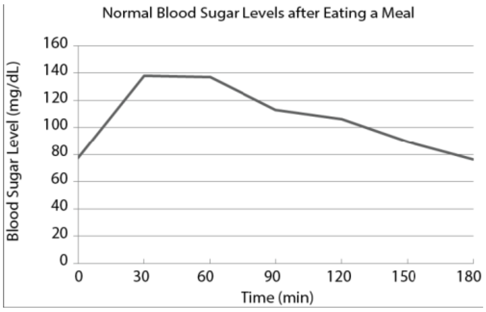
Scientific reasoning: Being able to reason scientifically and make connections by applying scientific knowledge and skills to make decisions and address issues involving science, technology, society, and the environment

Scientific reasoning involves a comparison, rationalization, or reasoning from the student in relation to an existing theory or frame of reference. Students demonstrate this competency by applying their knowledge of science, their skills, and their understanding of the nature of science to make informed, evidence-based decisions. They draw conclusions or make comparisons to an existing frame of reference or perspective. Students identify questions or issues and pursue science knowledge that will inform the question or issue.
The PCAP assessment of students' ability to reason scientifically provides evidence that they can:

- recognize patterns;
- develop plausible arguments;
- verify conclusions;
- judge the validity of arguments;
- construct valid arguments and explanations from evidence;
- connect scientific ideas and thereby build one on another to produce a coherent whole;
- use reasoning in order to make an informed decision for a particular issue in relation to the evidence;
- use reasoning in order to understand a science-related issue;
- provide reasons for the decision based on the evidence provided;
- identify assumptions and limitations of the chosen decision for that issue;
- develop and use models;
- show respect and support for evidence-based knowledge;
- display an interest and awareness in science-related issues.

Example from PCAP Science Assessment Framework
Sample Unit D:

Q2. After eating a meal, blood sugar levels in a healthy person slowly increase as food is broken down and then decrease as the cells of the body use the sugar, as shown below.



Nutritionists recommend eating three meals a day in addition to small snacks in the middle of the morning and afternoon. **Sketch a diagram below to represent the blood sugar levels of a non-diabetic person who follows this eating pattern for 24 hours. Include a title and labels for the axes on the lines given.**

Q3. Explain how your sketch would look different if the person eating the meals were a diabetic.

Q4. The best diet for a person with diabetes is the same healthy diet that is good for everyone. A healthy meal includes a combination of fats, proteins, and carbohydrates, but not in equal proportions. Analyze the two nutrition labels below. Identify which one you think is a healthier choice and explain why.

The healthier food choice is: Sample 1 or Sample 2
Explain your answer.

Sample 1	
Nutrition Facts **Valeur nutritive** Per 1 cup / Pour 1 tasse (250 mL)	
Amount Quantité	% Daily value % valeur quotidienne
Calories / Calories 260	
Fat / Lipides 13 g	20%
Saturated / Saturés 3 g Trans / Trans 2 g	25%
Cholesterol / Cholestérol 30 mg	
Sodium / Sodium 660 mg	28%
Carbohydrate / Glucides 31 g	10%
Fibre / Fibres 0 g Sugars / Sucres 5 g	0%
Protein / Protéines 5 g	
Vitamin A / Vitamine A	4%
Vitamin C / Vitamine C	2%
Calcium / Calcium	15%
Iron / Fer	4%

Sample 2	
Nutrition Facts **Valeur nutritive** Per 1 cup / Pour 1 tasse (250 mL)	
Amount Quantité	% Daily value % valeur quotidienne
Calories / Calories 130	
Fat / Lipides 5 g	8%
Saturated / Saturés 3 g Trans / Trans 0 g	21%
Cholesterol / Cholestérol 0 mg	
Sodium / Sodium 15 mg	1%
Carbohydrate / Glucides 17 g	6%
Fibre / Fibres 2 g Sugars / Sucres 16 g	4%
Protein / Protéines 2 g	
Vitamin A / Vitamine A	0%
Vitamin C / Vitamine C	0%
Calcium / Calcium	4%
Iron / Fer	2%

5. Conclusions

This report details the educational structures in each SAILS beneficiary country and outlines the position of science education in secondary level education in the participating countries as well as in four international contexts. In the SAILS beneficiary countires general education is compulsory from at least ages 7 to 15 years but there is wide variation in educational structures at lower secondary level across the 16 countries discussed. While science education is compulsory in 15 of these national situations at lower secondary there is wide variation in science subject/content included, e.g. Integrated science, life science. The educational structures at upper secondary level are also quite varied from general to vocational and pre-university structures. Science subjects offered at this level are divided into specific disciplines of Physics, Chemistry and Biology/Geology.

It is clear that from recent international reports such as the 2012 report of the Working Group (WG) on science education of the ALLEA (ALL European Academies) federation that there are key factors to be considered in science education. “In order to renew science education throughout Europe, the report mainly pleads for IBSE extension and for a strong effort in the sphere of science teacher training (pre- and in-service), through better interaction at the level of the national education systems and between the scientific community and stakeholders in politics, society and the corporate sector.” (Allea 2012) The importance of teachers in reforming education is strongly presented in the National Centre on Education and the Economy 2011 report , Standing on the Shoulders of Giants: An American Agenda for Education Reform. This report defines the agenda for education reform in the USA informed by reviewing specific strategies pursued by Canada (focusing on Ontario), China (focusing on Shanghai), Finland, Japan and Singapore, through developing a world-class teaching force. In particular it advocates the Finnish model where teachers undergo a rigorous recruitment process and only one out of ten applicants for entry into teachers colleges are admitted. A very high value is placed in Finland on having teachers who have really mastered the subjects they will teach, and also on giving teachers the skills they will need to teach those subjects well once they arrive in the classroom, National Centre on Education and the Economy (2011).

These recent findings support the key focus of the SAILS project in supporting the use of inquiry based science education (IBSE) in the science classroom though teacher education at both in-service and pre-service level. However, this focus must also be informed by the specific contexts in each country. Therefore it was necessary to conduct a review of the relevant curricula and assessment statements in each SAILS beneficiary country and to consider the situation in four international contexts.

In Finland, science is compulsory in both basic and upper secondary education. A national curriculum has been set out and schools must implement a local curriculum that complies with the stipulations of the core curriculum but recently specifications have been readdressed in an effort to find the right balance between specificity and flexibility for teachers. Pupil assessment is divided between in-class teacher assessment and final assessment for the core subjects which include physics, chemistry and biology.

An Australian national curriculum has been developed and made available in 2011. Each state is responsible for implementing this curriculum in their state. Assessment practices vary state-by-state but are largely teacher-led with some state and national diagnostic testing. Year-12 final assessment generally has a state-wide written examination component which along with in-school assessment tasks is required to obtain a high school diploma.

A common framework for science learning outcomes was developed by the Canadian Council of Ministers of Education in 1997. The content of inquiry in this framework was analysed and the state of Ontario, was chosen for a deeper consideration of how inquiry in incorporated in the curriculum and assessment as this state has the highest population of all of the Canadian provinces and territories.

In the USA, curriculum and assessment strategies are determined by the Education Department in each state, but several national policies promoting wider use of inquiry in schools have been developed by institutions such as the National Research council and the American Association for the Advancement of Science and these have, at least in part, been implemented within state policies.

Tables 31 and 32 presents an overview of the role of the inquiry as "*the intentional process of diagnosing problems, critiquing experiments, and distinguishing alternatives, planning investigations, researching conjectures, searching for information, constructing models, discussing with peers and forming coherent argument."* in each SAILS national context. In particular , *constructing models* is the aspect least included in national curricula - only in 4 countries at lower secondary and in 8 at upper secondary. For the eight other elements there is a very strong inclusion, at least in 9 national curriculum, at both lower and upper levels, across the twelve countries. In terms of assessment of these elements, *constructing models, discussing with peers and researching conjectures* are present in only 3/4 national strategies while *planning investigations* and *forming coherent argument* are included more widespread, in around 8/9 countries.

One important aspect of this report is the inclusion of specific examples of inquiry assessment from national examinations in eleven of the SAILS countries and Canada and Australia, that will be used to inform the development of SAILS assessment items. In the case of Turkey such examples were not available as new curricula and assessment are currently being implemented. Indeed in many of the SAILS beneficiary countries, new curricula to promote inquiry and such approaches have been irolled out in recent years.

This review of national contexts indicates that although inquiry and its associated skills and competencies are valued in the national curriculum in all countries, it is not reflected in the assessment used in most of the participating countries. We feel that this highlights a need for assessment instruments and tools that measure the inquiry skills of students. If these skills are not being assessed, it is difficult for teachers and students to realise the value of inquiry based methodologies.

In essence, these are the main objectives of the SAILS project, to identify the key inquiry skills and competencies and develop assessment instruments and tools that can measure these in students and to support teachers in developing the competency and confidence in not only to teach using inquiry but also to assess using inquiry.

Country	Diagnosing problems		Critiquing experiments		Distinguishing alternatives		Planning Investigations		Researching conjectures		Searching for information		Constructing models		Debating with peers		Forming coherent arguments	
	LS	US	LS	US	LS	US	LS	US	LS	US	LS	US	LS	US	LS	US	LS	US
Belgium	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓				✓		✓
Denmark	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
Germany	✓	✓	✓	✓	✓	✓					✓	✓		✓	✓	✓	✓	✓
Greece	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
Hungary	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓		✓	✓	✓		✓
Ireland			✓	✓			✓	✓			✓	✓			✓	✓	✓	✓
Poland	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		+	✓	✓	✓	✓
Portugal	✓	✓		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓
Slovakia	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Sweden	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Turkey	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
UK	✓		✓		✓		✓		✓		✓						✓	

TABLE 30 INQUIRY IN NATIONAL CURRICULUM IN TWELVE SAILS BENEFICARY COUNTRIES FOR LOWER SECONDARY (LS) AND UPPER SECONDARY (US)

Country	Diagnosing problems		Critiquing experiments		Distinguishing alternatives		Planning Investigations		Researching conjectures		Searching for information		Constructing models		Debating with peers		Forming coherent arguments	
	LS	US	LS	US	LS	US	LS	US	LS	US	LS	US	LS	US	LS	US	LS	US
Belgium	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓				✓		✓
Denmark					✓	✓											✓	✓
Germany	✓	✓	✓	✓	✓	✓					✓	✓		✓	✓	✓	✓	✓
Greece																		
Hungary	✓	✓					✓	✓	✓	✓							✓	✓
Ireland							✓	✓									✓	✓
Poland	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓					✓	✓
Portugal	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓			✓	✓	✓	✓
Slovakia					✓	✓					✓	✓	✓	✓			✓	✓
Sweden			✓	✓			✓	✓									✓	✓
Turkey																		
UK	✓						✓		✓		✓						✓	

TABLE 312 INQUIRY IN NATIONAL ASSESSMENT IN TWELVE SAILS BENEFICARY COUNTRIES FOR LOWER SECONDARY (LS) AND UPPER SECONDARY (US)

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