VOLUME 1

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Science Teaching and Labwork Practice in Several European Countries

Volume 1: Description of Science Teaching at Secondary Level

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Contents of volume 1

Volume 1

General Description of Science Teaching

at Secondary Level

In this volume our perspective is to stick as close as possible to the reality of science teaching in classrooms at the upper secondary level. Consequently, we first present the global aspects of science teaching showing the main similarities and differences according to the countries (Part A). Then, a specific description is done by country, including the labwork practices (Part B).

The countries involved in this study are :
Denmark, England, France, Germany, Greece, Italy, Spain.

PART A GENERAL DESCRIPTION OF SCIENCE TEACHING

Science teaching may start at a very early stage of education. To get a better understanding of science teaching at upper secondary school, it is helpful to know, even at a general level, how science is taught in primary and lower secondary schools. This information is therefore presented in the first section. We then give a more detailed description of science teaching in upper secondary schools.

1 Science teaching before upper secondary school

In all of our countries compulsory education begins between ages 4 and 6, and ends between ages 14 and 16. Most of the countries have two main types of schools between these ages which we will refer to as primary and lower secondary schools (in Germany grade 5 and 6 are a third type called “Orientierungsstufe”). Primary education starts between ages 5 and 6, and continues for 4 to 6 years. Lower secondary school follows, lasting for 3 to 6 years until age 14 or 16. In all countries, around 90% of a given age group will continue schooling until 16 years old.

1.1. The case of primary schools

From the point of view of science teaching, we have a *common situation at the primary level* in all countries. Usually, the primary teacher teaches all disciplines. In general, we note that the official curricula include science, most of the time as integrated sciences. However, science, whatever as integrated or by disciplines, is much less taught in practice than in the official requirements. Moreover, the initial background of a great majority of the primary teachers is mainly arts and humanities and their scientific background is very limited. Currently, some countries are trying through different activities (such as in-service teaching and the creation of new teaching material) to help primary teachers in introducing more science activities in their teaching.

1.2. Science teaching in lower secondary schools

The curriculum disciplinary organisation, the duration of this teaching and the teachers’ background in science is rather different in each country.

All the countries have an official curriculum at a national or regional level. Nevertheless an important difference exists in curriculum disciplinary organisation: in Great Britain, in Italy and in Spain for the first three years, *the curriculum refers to "science"*, whereas in Denmark, France, Germany and Greece, the curriculum specifically refers to *different subject disciplines.* These subject disciplines - chemistry, biology, geology, physics - are combined in different ways in each country, and taught by the same or by different teachers. In Denmark, physics/chemistry is one and the two disciplines are taught together by the same teacher, while biology and geography (containing geology) are taught separately. In France, physics and chemistry are taught by the same teacher, as are biology and geology. During the

first year of lower secondary school, biology and geology are taught (by the same teacher) and not chemistry and physics. Let us note that in the academic year 1997 - 98, physics and chemistry are again introduced at the second year of lower secondary school. In Greece, in the first class, only biology and geography are taught, in second class physics, chemistry and geography and in the third physics, chemistry and biology. Every discipline can be taught by any science teacher. In fact, in large schools, one teaches his/her discipline preferably. In Germany, there is no subject geology, geology is in geography and in general all three subject disciplines are taught by different teachers. In the "Orientierungsstufe", sometimes "science" is taught by one teacher. The same holds for the "Hauptschule".
In Spain, in the first two years of lower secondary school, there is a general science course (*Ciencias de la Naturaleza)* which is a combination of physics, chemistry, biology and geology. This subject is taught by one teacher. In the third year, there is still one science course, but it is taught by two teachers. One teacher is in charge of the part of the subject having to do with physics and chemistry, while another is in charge of biology and geology. There is a final exam for the whole course. In the fourth year, however, there are two different science courses: physics-chemistry and biology-geology. These subjects are taught by different teachers and are optional.

The Table 1 gives the approximate duration of science teaching.

		Duration of science teaching				
	subject matter	1st year	2nd year	3rd year	4th year	5th year
Denmark	Phys/Chem (7-9grade) Biology (7-8 grade) Geography (7-8 grade)	80 H[1] 80H 80H	80H[1] 80H 80H	80H[1]		
France	Physics + Chemistry (grade 6 to 9) Biology + Geology	0 45 - 50H	45 - 50H[2] 45 - 50H	45 - 50H[2] 45 - 50H	45 - 50H[2] 45 - 50H	
Germany	Physics and/or Chemistry and/or Biology	480 H for B + Ch + Ph altogether in grade 7 to 10 (4 lessons a week)				
England	Integrated science	10-15%[3] 2h30-3h45[5] 97h30-146h15[6]	10-15%[3] 2h30-3h45[5] 97h30-146h15[6]	15%[3] 3h45[5] 142h30[7]	10% or 20%[4] 2h30 or 5h[3] 97h30-195h[6]	10% or 20%[4] 2h30 or 5h[3] 77h30-155h[8]
Italy	Physics, Chemistry, biology, mathematics ("science")	230H 6H/week	230H 6H/week	230H 6H/week		
Greece	Physics Chemistry Biology/Geography	- - B2+G2=4/35	2/35 (hours a week)[9] 1/35 G=2/35	2/35 1/35 B=2/35		
Spain	Integrated science Phys-Chem + Bio-Geo Phys-Chem Bio-Geo	3 h/week	3 h/week	2 + 2 h/week	3 h/week 3 h/week	

Table 1: Duration of science teaching at lower secondary school
grade 1 is the first class of primary school

1 In Denmark the teaching duration is officially 199 days a year

2 In France at this level of teaching, the teaching duration is about 36 weeks a year, including the examination period. Currently there is a modification of physics and chemistry teaching: in the academic year of 1998/99 for each year it will be compulsory to teach these disciplines by distributing teaching time over the three years (2nd to 4th year). The total duration of this teaching must be between 4 and 6 hours for the 2nd, 3rd, and 4th years together. This interval (4 - 6 hours) leads to about 1h 30 a week for each year. Before 1998, physics and chemistry were not taught at the 1st and 2nd years of lower secondary school.

3 Percentage of total curriculum time, though there is considerable variation between schools; average values given.

4 Percentage of curriculum time, students choosing to study either ‘single option’ or ‘double option’ science. Although there is some variation between schools, 10% and 20% curriculum time is recommended.

5 Per week, based on an average week of 25 hours’ teaching time.

6 Per year, based on 39 teaching weeks.

7 Per year, based on 38 teaching weeks (1 week lost to compulsory testing)

8 Per year, based on 31 teaching weeks (the remaining weeks being lost to examinations and preparation)`

9 In Greece, there is 35 teaching hours a week (6 hours a day). The total number of weeks a year is 35 (around)

In this table the time is given in different forms. Depending on the countries the basis is different. In some countries this is the duration a year, another basis is also used: percentage of curriculum time or hours per week. In fact no duration whatever the basis gives a complete information. If we take the duration by year, the comparison does not take into account the balance with the other disciplines; if the percentage is taken, then according to the countries some disciplines are taught or not (music, or others) and the 100% does not correspond to the same thing. Therefore the comparison needs to take into account the contexts in which teaching is done. This context is given in part B which includes the presentations by countries.

From our previous description and the table 1, *a great variety appears at lower secondary school level according to the country*. This variety corresponds to several aspects:

- The teaching content: integrated science or several subject disciplines; these disciplines can be different from one country to another.
- The regularity of science teaching from one year to the next. England seems the most regular and homogeneous science teaching over five consecutive years. All students do science for about 12.5% of curriculum time between ages 11 and 14, and between 14 and 16 they do either 10 or 20% science. In some other countries, a certain discontinuity appears concerning the organization of the curriculum: an important teaching duration of a discipline one year and much less, even nothing, the year after.
- The duration of science teaching for a given year from 120 hours to 80 hours.
- The variety of teachers, in some countries the same teacher teaches science whereas in others different teachers intervene and the disciplines are put together in different ways according to the countries or even the school.

This situation leads to rise the question if, in most of the countries involved in this study, there is a coherent view of science teaching at lower secondary school level in several countries.

The importance of the experimental aspect in science teaching varies from one country to the next. If the assessment of the role of labwork is considered as significant, the experimental aspect is particularly important in England and Wales (in Scotland too) and in Denmark. In England and Wales, for instance, in the assessment related to the stage from 11 to 14 years old (KS3), the weighting for the "attainment target: Experimental and investigative science" counts for 25% of the whole assessment. Obviously, this assessment reinforces the role of labwork in science education. In Denmark labwork is an essential part of all Science disciplines and the (optional) assessment for the Leaving Certificat in Physice/Chemistry is based on an experiment. In Germany, France, Italy, and Spain, this aspect is not assessed. The kind and amount of labwork in lower secondary in Germany depends on the teacher's decisions. In the case of Greece no labwork is carried out by students, though teacher demonstrations are used during science lessons (in each discipline).

Science teachers have various initial backgrounds in each country. In Denmark and Germany, teachers in lower secondary schools have a different background from those at upper secondary schools. In all the other countries, teachers' backgrounds are identical for both lower and upper secondary schools. In France and Spain, a given teacher in lower secondary schools teaches either physics and chemistry or biology and geology according to his/her initial background. In Great Britain and in Greece, as soon as teachers are qualified in one scientific discipline (physics, chemistry, biology), they can teach any of these domains at the lower secondary level, though in practice they often teach a discipline corresponding to their background discipline. In Italy, lower secondary school teachers have a degree in a scientific discipline, i. e. Mathematics, Physics, Biology, etc. (4-5 years of university).

2. Science teaching at the upper secondary school

2.1 Organisation of routes

In the following, we consider only academic routes and not the case of vocational routes which is more diverse.

To give an idea of the science teaching organisation we selected three aspects: the possible choices available to students to attend science teaching, the existence of a curriculum, the duration of science teaching according to the routes if any.

2.1 Possible choices available to students to attend science teaching

A basic aspect of science teaching organisation consists of the possible choices that the student can make during the upper secondary school concerning the teaching content. Depending on the country, the type of choices is different, two cases can happen :
- choice of disciplines;
- choice of a whole set of an organised curriculum emphasising an orientation in science, literature, languages for example, in the following we call it "route". In a given route, sub choices can be possible among some disciplines.

In the first case, it is possible to choose or not a discipline, biology, chemistry, physics courses for example. England and Wales are in this case; students may select one to four (or, in exceptional cases, five) subjects at the upper secondary level. Some students take mixed combinations of upper secondary level courses, and retakes of courses failed at lower secondary level (e.g. 1 'A'-level and some retakes of GCSEs previously failed, or 1 'A'-level and 2 'AS'-levels[1], GCSE being the exam at the end of the lower secondary school and A level at the end of upper secondary school). Typically, students take 3 subjects at 'A'-level, 'A'-levels being the most commonly-studied courses at upper secondary level.

In the second case the teaching content of sciences can be adapted depending on the route. In the countries, where the students have to choose an orientation, these are the following:
- The Danish Gymnasium has two orientations - a Language orientation and a Mathematical orientation. The Language orientation contains compulsory Physics/Chemistry/Mathematics taught together (not necessarily integrated), Biology and Geography. In addition the same disciplines can be chosen at 2 higher levels (intermediate and high). The Mathematical orientation contains compulsory Physics, Chemistry and Biology and the same disciplines can be chosen at higher level. In Denmark at least two of the Science subjects physics, chemistry, biology and geography (including geology) are compulsory.
- In France, the first year of the upper secondary school has no orientation, all students follow the same type of courses. Chemistry, biology, geology, physics is compulsory during the first year of lyceum. In the second and third years, two main orientations are offered a scientific and a literacy one with sub-choices in each.
- In Germany a student (in larger cities) has a choice of different schools offering a different spectrum of possible advanced courses. At least one of the sciences (except geology) is compulsory as a basic course (three lessons a week). Each student selects two subjects out of the whole range of possible subjects as advanced course (with five lessons a week for at least two years). S/he may select two, one or none of the sciences as advanced course.
- In Italy there are three branches in secondary school education which give access to University:

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[1] In recent years, a growing number of students take 'Advanced supplementary level' courses ('AS'-levels). These courses are of 'A'-level standard, but on a narrower range of syllabus content equal to about half an 'A'-level. Students might therefore take two 'A'-levels and two 'AS'-levels. The number of students taking 'A'-levels is still far greater than the number taking 'AS'-levels.

- “classical” education, which lasts five years and is chosen by about 33% students. It comprises classical lyceum, which gives a highly academic education based on Latin and Greek; scientific lyceum which is more based on mathematics and science; istituti magistrali, schools which prepare teachers for primary schools; art schools; language schools;
- “technical” education (istituti tecnici), which lasts five years and is chosen by 47% students. The curriculum depends very much on the kind of specialisation chosen: chemical, industrial, mechanical, as accountant, as land surveyor, and so on;
- “professional” education (istituti professionali) which lasts three years and is chosen by about 20% students. The curriculum varies according to the kind of training. After the first three years, there are courses for two more years which must be followed if one wants to go to University.

- In Greece, there is no orientation in the first and the second classes of Lycei. All students are taught the same subjects. During the first and second years of general lycei and only during the first year in MDL (Multi Disciplinary Lycei or Integrated) and TPL (Technical and Professional or Vocational Lycei), biology, chemistry, geology, physics are compulsory.
- In Spain, a student of one orientation can choose an optional subject from any of the other orientations. Then, science is taught in two of the four possible orientations open to secondary school students: the scientific and biomedical orientations. In the first year, physics-chemistry and biology-geology are compulsory. In the second year, the four subjects are taught separately. Physics is obligatory in the scientific orientation, whereas chemistry and biology are obligatory in the biomedical orientation. The other subjects are optional.

Thus depending on the type of organisation, physics, chemistry, biology, geology are or are not taught to all students, the teaching content can or cannot be adapted to the students' orientation. At upper secondary school, for the scientific route in the countries where routes exist and in England and Wales, science is taught by separate subjects, biology, geology, chemistry, physics. In other routes, if any, it can be taught as integrated science.

2.2 Existence of a curriculum

Concerning the curriculum, we consider three groups of countries :
1 - Denmark, Greece and France where there is an official curriculum which specifies time duration for each subject;
2 - Germany and England where some criteria of assessment or some compulsory topics for each subject are given by a national body. In Germany, this plan is different in all the 16 different states, however a more general plan is equal for all states (EPA: Einheitliche Prüfungsanforderungen).
3 - Italy and Spain as an intermediate situation.

2.3 Duration of science teaching

The time duration for physics, chemistry and biology teaching may depend on the orientation if any. It is officially given for each orientation in some countries (Denmark, France, Greece, Germany). In England and Wales there is no official recommendation about time. In Germany the time duration for science may vary from 3 to 13 lessons per week (10% to 40% of teaching time). The Table 2 gives indication on the duration of teaching.

	Duration of science teaching subject matter	Hours per week			
		1st year	2nd year	3rd year	
Denmark compulsory (optional) ***see note 1***	*Math route* Physics Chemistry Biology Geography(Geology)	 3 3 3	 3 (5 optional) (5 optional) 3	 (5 optional) (5 optional) (5 optional) (5 optional)	
England	***see note 2***				
France	 Physics + Chemistry Biology / Geology	*no orientation* 3,5 =2 + (1,5) 2 = 0,5 + (1,5) ***see note 3***	*Scientific route* 4 =2,5 + (1,5) 3= 1,5 + (1,5) ***see note 3***	*Scientific route* 5 = 3,5 + 3 = 1,5 + ***see note 4***	*optional* [1,5] [1,5]
Germany	Physics or Chemistry or Biology ***see note 5***	3 or 5	3 or 5	3 or 5	
Greece	 Physics Chemistry Biology/Geology/Astro	*no orientation* 3 1 1Geology	*no orientation* 3 1,5 1,5Bio+1Astr	*1st route* 5 3 0	*2nd route* 5 3 4
Italy	*see note 6*				
Spain	Physics + Chemistry Biology + Geology Phys/Chem/Bio/Geo	4 4	 4/4/4/4	***see note 7***	

Table 2: Duration per week of science teaching in the science route. Number of hours for labwork in parenthesis

see note 1: In Denmark, the total number of teaching days a year is 200

note 2: Different students will have quite different programmes. Students may be studying 3 'A'-levels in combinations such as physics, mathematics, chemistry; physics, chemistry, biology; maths, chemistry and biology; physics, mathematics, further mathematics; biology, geography, economics; etc.
Some students will study mixed combinations of 'A'-levels and 'AS'-levels or GCSEs.
A 'typical' student might study 'A'-levels in physics, chemistry and mathematics. Each subject would have 1/3 of teaching time allocated to it (about 4h40). Out of this, 1/4 of teaching time would be labwork, though this varies a lot between schools.

note 3 : the number between parenthesis gives the official time devoted to labwork;

note 4 : the time between [ ] is only for the students who choose special option in this discipline

note 5: 3 hours refers to the basic course ("Grundkurs"), 5 hours to the advanced course ("Leistungskurs")

note 6 : Time devoted to scientific subjects and labwork depends very much on the route chosen within the different schools (lyceums and technical institutes which both allow to enter University). From 3-4 hours a week to 24 hours a week with nearly half time devoted to laboratory in technical schools

note 7: in Spain, the upper secondary school has two cyles, the last one lasts for two years (see part B).

The allocation time for science teaching varies, but the strict comparison has not a real meaning since in some countries this teaching is for all students in the academic route

whereas in other countries it is only for those who choose to learn particularly science or a given scientific discipline. Even the percentage on the total teaching time allocated is difficult to compare because it also can vary in a same country according to the chosen route or sub-choices in a given route. However, it appears a large variety of educational organisation depending on the countries: roughly speaking according to the country and his/her choice a student at upper secondary school level can have between 0 and 16 hours a week of science teaching. In the scientific route (if any), at the last year of the secondary school, the duration can be between 8 and 16 hours a week.

3. Labwork in science teaching

Three different approaches to the use of labwork in science teaching can be identified between the countries:

1 - In Denmark, in England and Wales, and in France where labwork is regularly done during teaching by small groups of students (pairs or groups of three or four); we can consider that labwork is compulsory. Moreover, in England and Wales labwork is assessed, and in France, inspectors check the balance between lecture courses and labwork. The frequency of labwork is about once a week for each discipline.

2 - In Germany, labwork is possible, but is often not done. It is part of the general teaching time, no special time is devoted only for lab. To a large extent, it depends on the individual teachers' decision.

3 - In Italy, labwork varies extensively according to the kind of school chosen. Labwork is not compulsory in the 'classical education' stream and is carried out only in experimental teaching and depends on teachers' initiative. On the contrary for 'technical education' and 'professional education' streams, labwork is compulsory and the time devoted to it is prescribed. It can be as high as twelve hours per week for the whole year. In these cases school laboratories are usually well equipped.

4 - In Greece, labwork which is done by groups of 2 to 4 pupils is rare, only being found in experimental teaching. For example, in Greece labwork is carried out in the Lycei where special curricula have been adopted. Otherwise labwork depends on the teachers' initiative. In general, labwork rarely take place, because of shortage of equipment, lack of laboratories and overloaded curricula. In Italy, in classical or scientific lycei, labwork in class or in the lab is very rarely performed.
Spain is in an intermediate situation between 2 and 3.

In all countries where labwork is performed, the duration of the session is about 1 to 2.5 hours. The number of students in class, more often ranges from 20 to 35 (in Germany 6 to 25). The questionnaire confirms these data.

In academic route labwork assessment is included to the final examination grade in Great-Britain only. In the other countries, there is no formal assessment. In Germany however, there is a tradition in many schools to include demonstration experiments in the final examination

("Abitur"), e.g. in physics. In France, the assessment of labwork activity is currently being experimented. The questionnaire gives more information about the assessment done by the teacher all along the year.

In all countries, the teachers themselves carry out experiments in front of their pupils during lessons. The frequency of these experiments is up to the teacher. The questionnaire inform us about this practice.

4. Teachers' training for labwork

At upper secondary school, all teachers hold a university degree in a science subject which at least involves three or four years at university (in Germany at least four).
In Germany, most universities have a special curriculum for prospective teachers, which includes courses in science education and special labs with school experiments. Moreover, in Denmark, France, Germany, Great-Britain future teachers have to enter a special institute for one or two years where, as future teacher, they are given a specific training. In this training future teachers have to give lessons in real classrooms under guidance of a teacher and/or a tutor from the institute. The development of their practice of labwork in teaching is not specified: choice is the responsibility of individual teacher trainers.
In Denmark, future teachers have to follow short courses on education and give lessons under guidance of an experienced teacher and in addition pass a course in School Science Experiments in each of their discipline.
In Italy, there are some "teaching oriented addresses" in some university curricula. In these addresses a course on "school labwork" is added to the "normal" laboratory courses which all students must follow in every case.
In Greece, anyone can teach who holds a university degree in the subject that they want to teach, after short initial compulsory training.
In Spain, the various university departments are in charge of the training of future secondary school teachers. The course takes one year. A fair amount of time is given to practice sessions in secondary schools under the guidance of a practicing teacher.

Specific training on how to use labwork in teaching is rarely done in all countries; it depends on the teacher trainers themselves.

PART B DESCRIPTION OF SCIENCE TEACHING BY COUNTRY AT SECONDARY SCHOOL LEVEL

The description of science teaching is presented for the following countries:
Denmark
England and Wales
France
Germany
Greece

Italy
Spain

A same structure is used for all countries. First a presentation of science teaching before to upper secondary school in order to know what a student can learn from the beginning of schooling in science. Then the situation at upper secondary school is developed on the following aspects: organisation of the different routes, the examination at the end of upper secondary school, the specific organisation of science teaching and the teacher training. At the end, example of labwork activities are presented for each subject discipline which can be different according to the countries.

SCIENCE TEACHING IN DENMARK

Science teaching previous to upper secondary school

Danish children enter "Folkeskolen" at the age of 6-7 (optional Pre-school or Kindergarten from age 5) for 9 years of compulsory schooling. About 90% of all children are in the public educational system, the rest attend private schools which are subsidized by the government. The "Folkeskole" is a comprehensive, compulsory school for age groups 7 - 16 (17) (grades 1-9 with an optional 10th grade).

The "Folkeskole" provides pupils with Primary and Lower Secondary Education in mixed ability groups that usually stay together for the entire 9 years. There is no streaming according to abilities or other reasons in the comprehensive, compulsory school and there is a deliberate policy for integrating pupils with special needs of physical or mental reasons.
The act on the "Folkeskole" prescribes 200 days/year of schooling and a weekly minimum number of 20 lessons up to the 2nd grade gradually raising to 28 lessons at the grades 8-10.

Science in curriculum and labwork practice.
Science in the common core takes up about 11% of the minimum recommended curriculum time during compulsory school. Over and above the common core there are science options in the grades 8-9(10).

At primary level Science (Nature/Technology) is integrated and includes the subjects Biology, Geography, Physics and Chemistry.

From the 6th grade on science is divided into separate disciplines.

Science in the common core of the compulsory school "Folkeskole":

1st-6th grade: Nature/Technology
7th-8th grade: Geography, Biology
7th-9th grade: Physics/Chemistry
10th grade: Physics/Chemistry

Science options:

8th-10th grade: Technology, needle-, wood- and metalwork, workshops for engine knowledge and possibilities for other workshops. The municipalities may approve that the pupils are offered other options in practical subjects e.g. prevocational training in industries, practical environmental studies etc.
Science teaching in Denmark has a long tradition of laboratory work, field studies in biology and geography, woodwork and other kinds of practical work. These activities are strongly recommended on all levels and mandatory for passing science at most Secondary courses. During the last years practical work has changed from consisting of very rigid teacher organized activities to project-like activities controlled by the pupils.

Evaluation and examination at the end of intermediate school.

Compared with most other countries Denmark has very few tests and examinations beyond continuous evaluation by the teacher. The teacher is the main key to standards.

The only Science Examination in the "Folkeskole" is an optional oral examination in Physics/Chemistry for the Leaving Certificate and for the Advanced Leaving Certificate. The examination is based on an experiment prepared by the pupil.

Upper Secondary School

Organisation of secondary schooling.

In the General Upper Secondary School, the "Gymnasium", there are 3 years of 200 days/year of schooling containing 32 weekly lessons and examinations.

The "Gymnasium" is divided into two lines: the languages line and the mathematics line. There is a marked gender division. In 1993/94 about 23% of applicants for the language line were male and 77% were female. Of the applicants for the mathematics line 54% were male and 46% female.

The two lines have a common core of obligatory subjects as well as subjects distinctive to each line. Some subjects are available at two or three levels, obligatory level, intermediate level and high level. Optional subjects are offered and vary from school to school. At least two and not more than three of all the offered high level options must be taken, and all students must write a major assignment.

Besides the "Gymnasium", the general Upper Secondary Educational system contains a two years course called the Higher Preparatory Examination (Danish abbreviation: HF) which is above all directed at young people and adults who have left the educational system and wish to return.

An account of the various vocational schools and the demands for qualifications by applicants would be beyond the terms of reference of this report.

Organisation of Science teaching in the gymnasium

Science is taught at various levels: a common core, an intermediate level option and a high level option.

The language line has a science curriculum (including mathematics) covering about 14% of the curriculum. Over and above the obligatory science curriculum there are science options.

The mathematics line has a science curriculum covering about 16% of the curriculum and a variety of science options.

The two lines of the General Upper Secondary School "Gymnasium" offer a variety of mainly discipline centred science courses, although the science curricula of the separate sciences contain thematic integrated approaches and include mandatory subjects like the History and Philosophy of Science, the Scientific Picture of the Universe, Technology and Society etc. in the Physics curriculum.

Courses in the "Gymnasium" are either mandatory or options at two levels.

The language line science courses:

Common core:

Science (Chemistry, Physics and Mathematics), Biology, Geography.

Intermediate level science options:

Geography, Biology, Chemistry, Technology, Physics, Computer Science.

High level science options:

Biology

The mathematics line science courses:

Common core:

Biology, Physics, Chemistry, Geography

Intermediate level science options:

Biology, Geography, Chemistry, Technology, Computer Science.

High level science options:

Biology, Physics, Chemistry.

Subject	language line grade			math.line grade		
	10	11	12	10	11	12
science	3	4				
geography		3			3	
biology	3			3		
physics				3	3	
chemistry				3		
optional		5	5		5	5
optional			5			5
optional			5			5

Table 3:Science lessons in the General Upper Secondary School, "Gymnasium".

options	courses		ratio %	ratio girls/boys
Intermediate level courses	biology		6	1.7:1
	chemistry		5	1.0:1
	geography		6	0.78:1
	physics		0	
	computer science		4	0.23:1
	design		2	3.5:1
	technology		0.3	0.34:1
high level courses	biology		11	2.0:1
	mathematical line only	chemistry	16*	0.72:1
		physics	20*	0.24:1

Table 4: The ratio of pupils in the 12th grade "Gymnasium" taking science courses in 1993/94 and the respective girls/boys ratio.(*The ratio of pupils attending from the mathematical line).

The national curriculum is a framework and Danish teachers are traditionally autonomous with respect to teaching methods and there is no state or other centralised approval of teaching materials.

The concepts of science are usually delivered in lecture form by the teacher. The extent of lecturing will depend very much on the subject and the teacher. This systematic approach will then be supported through exercises, problems and experimenting which are carried out in groups. High level courses in particular are influenced by the final written examinations. A fixed number of lessons are reserved for experimentation which is carried out in groups. Experimental projects and independent investigations are mandatory and encouraged. Homework for studying theory, doing exercises and problems and for writing reports is usual.

Examinations

For the General Upper Secondary Leaving Certificate national central written examinations in the High level Science Courses are mandatory. The problems for the examinations are produced by a national committee of science teachers and graded by nationally appointed science teachers. Oral examinations with nationally appointed external

examiners alternate between the subjects from year to year. 50% of the student's total result consists of marks given by the teachers at the end of a course.

Initial training of teachers, including degree requirements

Teachers are trained in separate institutions according to the level or type of schools in which they will be employed.

The 18 Colleges of Education offer general teacher training of 4 years duration for the Primary and Lower Secondary compulsory school. These teachers are allowed to teach across the curriculum for the whole 1-9(10) year compulsory school.

There are no reliable statistics showing the qualifications of science teachers in the compulsory schools. However, very few teachers have any training in science. Teachers at the primary level especially have no training for teaching Nature/Technology, a Science Subject which recently (1994) was implemented by the new curriculum.

Teachers for the general Upper Secondary Schools have graduated from one of the 5 Universities, usually with two subjects. Their university training of 5 years is not different from the training of researchers and does usually not include educational training. To be allowed to teach in the general Upper Secondary Schools they have to be Masters of Science and during their first year of service at about half time to take practical-pedagogical training and a short course of theoretical pedagogy administered by the Ministry of Education. Teachers in Science also have to take a course in experimental work in School Science administered by the universities.

Inservice, continuing training.

The Royal Danish School of Educational Studies is a national institution for in-service teacher training. The School has 8 divisions throughout the country and runs courses for qualifying teaching mainly in the Primary and Lower Secondary Schools. The Royal Danish School of Educational Studies is of considerable significance and the main source of continuous training for teachers.

However, the responsibility and the permission and any leave for attending in-service training courses rests with the municipalities.

In-service training for teachers in the Upper Secondary Schools depend on grants from the Ministry of Education. These grants often finance courses arranged by teacher associations established by groups of teachers. The responsibility and permission rests with the directors, the school committees and the counties.

Innovation, developmental work and in-service training are also initiated and financed at local level. Schools usually have a small budget for local courses.

In-service training of any kind does not contribute to the teacher's career or salary.

Selected quotations from the Danish curriculum for the gymnasium

Aims and content, included experimental work

Quotations from the curriculum are given in length from the Biology curriculum (except concerning examination) and may represent an example of a Danish curriculum. For the Chemistry and Physics curriculums only the relevant quotations concerning experimental work are given. For more extensive study of Danish curricula a reference list is provided.

BIOLOGY
High Level (2 year course.)

Aims:

The aims of instruction:

- The students should acquire a deeper and coherent understanding of biological methods and modes of thinking, as well as a broad knowledge of central biological areas.
- The students should gain skill in making precise descriptions and analyses of biological systems on the basis of experimental work.
- The students should learn to formulate and solve biological problems by means of scientific methods.
- The students should acquire a scientific basis for analysing and evaluating the possibilities of technological development and its consequences for nature, society and the individual.
- The students should learn to apply their knowledge of biology and its methods to forming an opinion about individual and social problems related to biology.

Syllabus:

The instruction alternates between work with topics and other teaching units. The choice of topics must ensure coverage of the following areas:

a. Biology as a Science.
b. Biological Production and Biotechnology.
c. Health and Disease.
d. Nature and the Environment.

The subject is experimental Qualitative and quantitative investigations and experiments are an integrate part of the instruction. The theoretical and experimental work should be organized in such a way that the students will gradually learn to plan and carry out studies and experiments on their own.
In connection with the experimental work the students should be trained in assessing possible risks and in taking the necessary safety precautions while working with equipment, chemicals and biological materials.
The students are trained in making critical appraisals of working methods and test results.
In connection with the instruction the students must learn to present biological information and understanding. This is done by oral presentation, by writing papers of a qualitative as well as a quantitative kind and by preparing reports. Other forms of presentation may also be included.
The students are to carry out experiments in about 60 lessons.

The syllabus comprises:

1. Genetics and Evolution.

The instruction must ensure a broad introduction to genetic theory and method, including human genetics, population genetics, the theory of evolution, and the application of genetics in research and production.

The molecular and cellular basis of genetics is included in the instruction. Furthermore, cell differentiation and embryology, hereditary patterns, the interaction between heredity and the environment, mutations, natural selection, improvement and genetic engineering must be studied.

2. Physiology.

Human physiology is elaborated upon, and examples of physiological factors in plants and animals are given.

In the instruction emphasis must be placed on the relationship of structure to function, the maintenance of balance and the interaction between the individual and the environment.

The molecular basis of physiological processes, as well as their basis in the biology of the cell and of tissues, is incorporated in the topics and other units studied.

When dealing with human physiology problems related to health promotion, the causes of disease, prophylaxis and treatment as well as the application of medical technology are included.

The following processes are to be elaborated on and treated in the instruction: absorption and transportation of matter, transformation of matter and energy, excretion, movement as well as biological regulation in connection with hormones, the nervous system and the immune system.

3. Ecology.

Ecological problems are elaborated upon within the following subareas: biological production, the utilization of resources, environmental pollution, and nature management. Taken as a whole, the topics must ensure insight into ecological theories, methods and models. Furthermore examples of the adaptation of plants and animals to the environment are included.

Gross and net production, cycles of elements and the transformation of energy, eco-toxicology, population biology, behaviourial biology, as well as the development and sustaining capacity of ecosystems are elaborated and studied in the instruction.

4. Biochemistry and Biophysics.

Biochemistry and biophysics form an integral part of the instruction within the topics and units selected.

The structure and function of carbohydrates, fats, proteins and nucleic acids are studied. Enzymology, molecular transport processes, chemosynthesis, photosynthesis, protein synthesis, intermediary metabolisms as well as methods of biochemical analysis are also included.

5. Microbiology.

Microbiology forms an integral part of the instruction in the topics and units selected. Microorganisms as the causes of disease, the function of microorganisms in the ecological systems, microbiological laboratory methods as well as the application in research and production of microorganisms are included.

6. Elective project work.

For a period of about 30 lessons the students are to work on projects of their own choice. This work is usually carried out in groups.

Examination.
There are one written and one oral examination"

In the curriculum more extended guidelines for the examinations are given. Experimental works are represented as follows:

"....The experimental work and the elective project must be included in the examination questions to an appropriate extent....."

CHEMISTRY
High level.(2 year course)

In the curriculum experimental work is represented as follows:

Concerning the *aims:*

".... - The student should acquire an understanding of the central concepts, the laws and the experimental methodology of chemistry..."

".....- The student should acquire practice in the use of laboratory equipment, including modern analytic equipment, extend their knowledge of how to handle chemicals, and become acquainted with sophistical laboratory equipment...."

Concerning the *syllabus:*

"....Experiments by students and demonstration experiments must be carried out, and a record of this work must be kept by the students. Experiments by the students take up about 50 lessons and are to be followed up by the writing of group reports. In the experimental part of the instruction the students must, in so far as possible, become acquainted with modern analytic equipment both in theory and practice, either at school or outside it...."

Concerning *examination:*

"There is an oral and a written examination..."

"...each oral examination takes about 30 minutes. Each candidate is given about 30 minutes for preparation..."

"...In addition 12 reports on experiments done by students are presented for the examination..."

"... In addition all reports on experiments carried out by students and records of the other experimental work should form a part of the examination...."

"...In the time allotted for preparation the candidates may use the following aids: books, compendia, tables, reports, records and other written material ....,as well as apparatus that is relevant to the experimental work selected..."

"...Relevant equipment must be available during the examination..."

PHYSICS
High level. (1 year course)

Concerning the *aims:*

"...- The student should become familiar with the methods and the way of thinking in the science of physics..."

"...- The students should gain understanding of central areas of classical and modern physics by working with physical theories and experiments..."

Concerning the *syllabus:*

"...The experimental work performed by the students themselves must amount to about 30 lessons. Of these, about 20 lessons are to be spent on student experiments, about which the students write individual reports, and about 10 lessons are devoted to an experimental project. This project work is done in small groups, each with its own assignment, and a group report is to be submitted on each project..."

Concerning the *examination:*

"There are an oral and a written examination"

"For the oral examination about 30 minutes' time is allotted for preparation..."

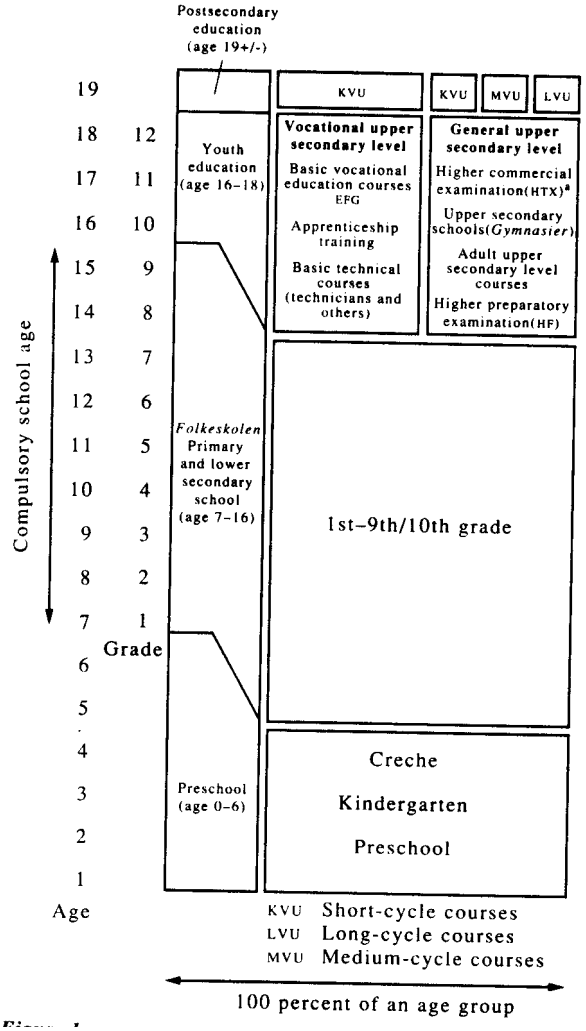
"...In addition, 10 experimental topics must be selected for use in the examination from the individual reports or from the group reports. An experimental topic may include one or more reports or extracts from one or more reports..."

"...The student is allowed to use the following aids during the time allotted for preparation: books, compendia, tables, assignments, reports and other written material...In addition, equipment relevant to the experimental work selected..."

"...The candidate is given two questions, one mainly theoretical and one mainly experimental. The two questions must be set on different subject areas..."

"...During the examination on the experimental question, the relevant equipment must, as a rule, be included...."

SCHEMA PRESENTING THE STRUCTURE OF THE DANISH EDUCATIONAL SYSTEMS



Schema from the "International Encyclopedia of National systems of Education". Second Edition
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SCIENCE TEACHING IN ENGLAND AND WALES

1 - Science teaching before upper secondary school

In Great Britain education is compulsory between 5 and 16 years of age. There are two types of school, primary and lower secondary. Primary school serves children between the ages of 5 and 11, lasting for six years. Lower secondary school lasts for 5 years, for students between the ages of 11 and 16 years.

1.1 - Science in the curriculum and labwork practice

The national curricula for England and Wales, Scotland and Northern Ireland are slightly different; This document refers to the National Curriculum for England and Wales, which was phased in to schools from September 1989. This curriculum spans the years 5 to 16, and refers to 'science' rather than the separate subject disciplines. The curriculum is organised into four Key Stages (KS). KS1 is from age 5 to age 7, KS2 from 7 - 11, KS3 from 11-14 and KS4 from 14-16. At each Key Stage, the curriculum is organised around four broad areas (called 'attainment targets'). These are:

- Experimental and investigative science (Sc1);
- Life processes and living things (Sc2);
- Materials and their properties (Sc3);
- Physical processes (Sc4).

Sc1 is primarily concerned with teaching pupils about scientific investigation, and laboratory work is the main teaching approach used. Labwork is also used to support the teaching of biological, chemical and physic concepts (Sc2, 3, 4).

Teachers in state schools are legally obliged to teach the national curriculum to all students. They are, however, allowed to decide *how* science teaching in their school is organised. At KS4, most schools offer a single subject called 'science', which incorporates physics, chemistry, biology and some astronomy and Earth science. In most cases, specialist physics, chemistry and biology teachers will teach their respective parts of the curriculum. Other schools offer separate science courses to students in physics, chemistry and biology.

There is no recommendation on timetable time for labwork. However, *assessment weightings* are given to Sc1, 2, 3 and 4. The weighting for Sc1 (experimental and investigative science) at KS4 is 25%.

Organisation of labwork at KS4 : Class sizes for science at KS4 vary; classes of 20 - 32 are common. Students are in the same class , with the same teacher, for both labwork and theoretical work. Consequently, labwork and other teaching activities are closely related (though see the comments on investigative work below). Some labwork is carried out by students themselves, usually working in groups of 2 - 4; in other cases, teachers will demonstrate to students. Some investigations may be carried out by students working alone. Schools are equipped with science teaching laboratories, though these vary in quality. The vast majority of science lessons (theory and labwork) are taught in laboratories. Teachers also use labwork in their teaching of biological, chemical and physical concepts. In many cases, labwork sessions are used to illustrate phenomena that may not be familiar for students. In other cases, the purpose of the labwork is to allow students to 'think through' some new concept in a 'real world' situation. Sc1 is given a 25% weighting in the assessment of KS4, and the award of General Certificate of Secondary Education (GCSE) grades in science at age 16.

1.2 - Assessment at the end of intermediate school

The GCSE examination is taken by most pupils at the end of lower secondary school. It consists of written papers covering all aspects of the national curriculum (including physics, chemistry, biology, Earth sciences and astronomy), as well as marks from continuous assessment of experimental and investigative science.

2 - Upper secondary school

Note: the curriculum at upper secondary school level in England and Wales is currently under review, and changes will be implemented at the beginning of the academic year 1998/9. This document refers to the curriculum as it exists at the time of writing (May 1997).

2.1 - Organisation of the different routes

Upper secondary schools serve students between 16 and 18/19 years old. The organisation of the curriculum is more complex. In the UK, courses in the different disciplines can be chosen or not chosen by students themselves.

In the years 16 to 18 a number of options are open to students. The most able students tend to select three or sometimes four 'A'-level courses which run over a period of two years. Traditionally, students select 3 or 4 science/maths courses, or 3 or 4 arts/social science courses. Recently, mixed packages of arts and sciences are selected, often involving combinations such as economics, geography and biology or mathematics, physics and economics. Our system forces specialisation upon students at a very early stage. The majority of university science students will take 'A'-level courses in one or more of the three

main sciences, particularly for pure science courses in the traditional universities. [There is now a 'double' 'A'-level course called 'Science' in addition to 'A'-level courses in physics, chemistry and biology.]

In recent years, a growing number of students take 'Advanced supplementary level' courses ('AS'-levels). These courses are of 'A'-level standard, but on a narrower range of syllabus content equal to about half an 'A'-level. Students might therefore take two 'A'-levels and two 'AS'-levels. The number of students taking 'A'-levels is still far greater than the number taking 'AS'-levels.

The 'vocational' strand of the 16-18 curriculum involves courses called GNVQs (General National Vocational Qualifications). These are in subjects like leisure and tourism, business studies etc. A GNVQ course in science started in 1994, though the uptake has been small so far. A growing number of university science students now come with GNVQ-type courses rather than 'A'-levels, especially in the case of applied science and technology courses in the newer universities. A major difference between GNVQ science and 'A'-level courses in the three main sciences is that the major aim of GNVQs is to promote students' competence in various scientific skills, whereas 'A'-level courses address subject matter content more strongly.

The training of groups such as nursery nurses and other health and caring professionals includes a small component on science, especially biology.

There are three different types of upper secondary school (table 1) :
- College of Further Education (FE colleges) ;
- grammar school 'sixth forms'. [The phrase 'sixth form' is commonly used to mean the part of a secondary school for students aged 16-19. Traditionally, the lower secondary school years were referred to as Forms 1 - 5, although this is less common now. Indeed, FE colleges were formally called 'Sixth Form Colleges'.]
- many comprehensive schools which have 'sixth forms'.

Grammar schools select students at age 11 by ability. Grammar school sixth forms typically offer 'A'-level courses in academic subjects. The same body of teachers teach students in the sixth form and lower down the school.

Comprehensive schools do not select students by ability at age 11 - all abilities are catered for. Some comprehensive schools only cater for students aged between 11 and 16. Students who want to continue with their education after the age of 16 must attend an FE college, or a sixth form in a different school. Other comprehensive schools cater for students between ages 11 and 18. Comprehensive school sixth forms vary a lot in the range of courses offered. Most offer 'A'-level courses in academic subjects, and many also offer GNVQ courses. [See below for details of these courses.] The same body of teachers teach students in the sixth form and lower down the comprehensive school. F.E. colleges offer much broader ranges of courses than school sixth forms. These include 'A'-levels, GNVQs, NVQs and non-award baring courses aimed at interested members of the public (e.g. conversational French, car maintenance). Also, classes in F.E. colleges often include 'mature' students returning to

study who are not aged 16-18. The teachers in F.E. colleges come from very different backgrounds and have very different qualifications according to the types of courses that they teach. At the age of 16, many students move from one sector to another [e.g. comprehensive school to FE college, comprehensive school to private school sixth form...].

The length of time spent by students in the Sixth Form or in FE colleges depends upon the types of courses being studied, and a number of options are open to students. The most able students tend to select three or sometimes four 'A'-level courses. Typically, students select 3 or 4 science/maths courses, or 3 or 4 arts/social science courses. Mixed packages of arts and sciences are becoming more common, often involving combinations such as economics, geography and biology or mathematics, physics and economics. The system forces specialisation upon students at a very early stage. The majority of university science students will take 'A'-level courses in one or more of the main science subjects [i.e. physics, chemistry and biology], particularly for pure science courses in the traditional universities. [There is now a 'double' 'A'-level course called 'Science' in addition to 'A'-level courses in physics, chemistry and biology[2].]

The 'vocational' strand of the 16-18 curriculum involves courses called GNVQs (General National Vocational Qualifications). These courses relate to broad areas of employment such as leisure and tourism, business studies etc. A GNVQ course in science started in 1994, though the uptake has been small so far. A growing number of university science students now come with GNVQ-type courses rather than 'A'-levels, especially in the case of applied science and technology courses in the newer universities. A major difference between GNVQ science and 'A'-level courses in the three main sciences is that the major aim of GNVQs is to promote students' competence in various scientific skills, whereas 'A'-level courses address subject matter content more strongly. NVQ course (National Vocational Qualifications) are normally studied on a part-time basis by people in employment. NVQs differ from GNVQs in that they are more specific to particular jobs rather than general areas of employment. The vast majority of NVQ students are above upper secondary school age.

The following data (table 1) relate to numbers of students in various educational sectors during the academic year 1992/3 for the whole of the U.K. (not just England):

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[2] In recent years, a growing number of students take 'Advanced supplementary level' courses ('AS'-levels). These courses are of 'A'-level standard, but on a narrower range of syllabus content equal to about half an 'A'-level. Students might therefore take two 'A'-levels and two 'AS'-levels. The number of students taking 'A'-levels is still far greater than the number taking 'AS'-levels.

	All values (x1000)	**Age 16**	**Age 17**	**Age 18**
	Population	677	702	732
FULL TIME	School	313	215	30
	Further Education	168	156	89
	Higher Education	1	10	126
PART TIME	Further Education	111	95	97
	Higher Education	0	1	7

Table 1 : Numbers of students in various educational sector

2.2 - Examination at the end of upper secondary school

In England and Wales there are two main examinations for University entrance. It should be noted that the tradition of 'academic' and 'vocational' routes is not well established in the UK compared to other European countries, and that the vast majority of students who ultimately study 'vocational' courses at university (engineering, health sciences etc.), follow an 'academic' curriculum involving 'A' and 'AS' levels at upper secondary school.

2.2.1 - Academic routes

'A'-levels (and, to a lesser extent 'AS'-levels) are the most common route for university entry. Assessment is by written examination, and teacher assessment of practical work for physics, chemistry and biology. This assessment is done by the normal teacher during specific sessions which are spread through the course. More of the assessment comes at the end of the course than at the beginning.

2.2.2 - Vocational or technical routes with technical aspects related to biology, and/or chemistry and / or physics

Students can study GNVQ courses in upper secondary schools. GNVQ science has teacher-assessment of labwork, spread over the duration of courses. This is not a common entry route to university courses at the time of writing.

A small number of students study NVQ courses on a part time basis in FE colleges, while in employment. NVQ courses can sometimes lead to study at university, though this is not common. NVQ stands for National Vocational Qualification. It is usually linked to a specific area of work e.g. catering, motor mechanics. GNVQ stands for General National Vocational Qualification. Students do some study relating to a broad area of work e.g. leisure and tourism, plus some specific study on literacy, numeracy, information technology etc. GNVQs are usually studied by students aged 16-19; NVQs are studied by older students, often already in work and studying part time.

3 - Organisation of Science teaching

3.1 - Science teaching : separate subject disciplines or integrated

Biology, chemistry, and physics are taught as separate subjects at 'A'-level. GNVQ science is taught as one subject.

Generally, teachers will be specialist physicists, chemists and biologists. If geology is taught (rare) it will be by specialists (who are likely to also teach chemistry or biology).

3.2 - Official curriculum , Duration, Official textbooks

(1) At upper secondary school there is no national curriculum. The national curriculum stops at age 16. Some criteria of assessment or some compulsory topics for each subject are given by a national body. There are, also, specific examination courses for particular subjects. For example, students studying 'A'-level chemistry can be entered for a number of different examinations in the subject (e.g. Nuffield, Modular...). Each of these examination courses has to be validated as meeting certain criteria. These criteria are set by a body which is responsible to the government Department for Education and Employment.

(2) There is no official recommendation about time for labwork. However a 'typical' student might study 'A'-levels in physics, chemistry and mathematics. Each subject would have 1/3 of teaching time allocated to it (about 4h40). Out of this, 1/4 of teaching time would be labwork, though this varies a lot between schools. Moreover, a certain percentage of the total examination mark is awarded for labwork.

(3) There is no official textbook. Some 'A'-level courses have a course book (e.g. Nuffield courses). Others do not; it is then up to the teacher to select which book(s) to use. There are a number of 'A'-level text books on the market.

3.3 - Labwork in small groups of students (organisation, duration, equipment, safety regulations)

(1) Labwork is frequently done as part of normal teaching by small groups of students (pairs, threes or four); we can say that labwork is compulsory (and furthermore it is assessed).
The number of students per class at upper secondary school level varies enormously.. between 3 or 4 and 25 or more! All students will do labwork and other aspects of the 'A'-level course together.

(2) The frequency is about once a week for each subject discipline.The duration is about 60 to 70 minutes (1 to 2, 5 hours). The projects are carried out during normal teaching time, but over several weeks. So, students will have a number of 70 minute lessons, spaced out over several weeks, in which they do their projects.

(3) Concerning equipment for labwork and safety regulations, schools are equipped with science teaching laboratories, though these vary in quality. These laboratories are used for both lecturing and labwork. In many cases, there are different laboratories for physics, chemistry and biology. Schools have technician support, though again this varies in both quantity and quality. Data collection sometimes involves sensors interfaced to computers (e.g.

pH meter, pressure sensor etc.). There are safety norms which relate mainly to chemistry and biology, and physics in the domain of electricity, radioactivity and thermodynamics (use of gas).

(4) There are general regulations about safety in workplaces which apply to schools. In practice, this means that teachers must carry out 'risk assessments' of all activities which may involve some risk to teachers, technicians or students. In practice, there is very little monitoring of the risk assessments performed by teachers, however.

3.4 - Introduction of experiments during the "theory" lessons (lecturing)

It is up to individual teachers whether they use demonstrations during lessons. There is considerable variation in practice between different teachers. Demonstrations are closely integrated with lectures. Similarly, student labwork is closely integrated with lectures.

4 - Teacher training

There are two kinds of teachers. Primary teachers teach all subjects in primary schools. There are two training routes for primary teachers. Secondary school teachers are subject specialists.

4.1 - Initial training

Primary school teachers are trained in two different ways. Some come from Bachelor of Education (B.Ed.) degrees which are usually 4 years in duration. Students normally enter these courses after 'A'-level study. The other training route is for students who do an undergraduate degree (e.g. Bachelor of Arts, Bachelor of Science, ...) and then complete a 1 year Postgraduate Certificate of Education (PGCE) course in primary education. Primary teachers tend to specialise in working with younger or older students (age 5-7 or 7-11). Also, many will have a subject specialism within the primary curriculum (e.g. science, English, mathematics, art). B.Ed. courses include subject matter content (maths, English, science...) as well as education content. They are normally taught by ex-teachers with further study in education.

There is only one major route for the training of secondary teachers. Secondary school teachers (lower and upper secondary school) hold a degree. Degree courses are 3 or 4 years long. Teachers then complete a 1 year PGCE course. [Teachers in F.E. colleges do not need a PGCE or FE Teaching Certificate, but the majority who teach 'A'-level do have these qualifications.] During the PGCE course, students spend about 2/3 of their time in a secondary school, and 1/3 of their time at the University or Teacher Training College. Consequently, there is little formal contact time between lecturers and students. The content of PGCE courses includes general educational material (e.g. structure of British educational system, theories of learning..) as well as method courses in teaching a particular subject.

Many teacher education students have very specialised degrees in subjects that are related to their teaching subject, but not necessarily the same as the teaching subject. For example,

teachers training as chemistry teachers may hold degrees in chemistry, biochemistry, chemical engineering, colour chemistry, pharmacology or other related subjects. Consequently, the subject matter knowledge of students relevant to their teaching subject varies enormously.

4.2 - In service training

In-service training is not compulsory for teachers in England and Wales, though in practice a variety of courses are offered and attended.

5 - Labwork activities for each subject discipline

Each 'A'-level examination syllabus for physics, chemistry and biology has particular requirements relating to labwork. However, for a syllabus to be ratified, it has to meet certain criteria which are set nationally. The paragraphs below are taken from the national criteria for each subject discipline relating to labwork. The information is taken from the *ACAC/CCEA/SCAA GCE Advanced and Advanced Subsidiary Examination Subject Cores, January 1997.*

The case of chemistry

Aims
A/AS courses in Chemistry should encourage students to:
(b) develop an understanding of the link between theory and experiment;

Principles for syllabus development
A/AS syllabuses in Chemistry should:
(h) specify how experimental and investigative skills can be developed;
(l) indicate, where appropriate, opportunities for students to improve their own learning and performance, work with others and solve problems in the context of their study of the subject.

Knowledge, understanding and skills
3.12 EXPERIMENT AND INVESTIGATION
AS and A level syllabuses should require students to carry out experimental activities. These activities should allow students to use their knowledge of Chemistry in planning, carrying out and evaluating their work.

Experimental and investigative activities for AS and A level should be set in contexts appropriate to, and reflect the demand of, the content of the respective syllabuses.

3.12.1 Planning
Students should:
(a) identify and define a problem using available information and knowledge of Chemistry;

(b) retrieve and evaluate information from multiple sources, including computer databases where appropriate;
(c) select appropriate techniques, reagents and apparatus, with due regard to precision of measurement, purity of reagents and products, safety, scale of working and the control of variables.

3.12.2 Implementing
Students should:
(a) demonstrate the manipulative skills needed for specific chemical techniques used in the laboratory showing a due regard for safety;
(b) make and record accurate observations and measurements to the degree of precision allowed by the apparatus used, including, where appropriate, logging and processing of data using information technology;
(c) carry out experimental work in appropriate contexts, involving:
(i) techniques of preparation and purification;
(ii) qualitative and quantitative exercises.

3.12.3 Analysing evidence and drawing conclusions
Students should:
(a) present their work appropriately in written, graphical or other forms using chemical nomenclature and terminology;
(b) interpret information gathered from experimental activities including:
(i) manipulation of data;
(ii) recognition of patterns and trends in a set of data or information;
(iii) identification of sources of error and recognition of the limitations of experimental measurements;
(c) draw valid conclusions by applying their knowledge and understanding of Chemistry, reporting quantitative data to an appropriate number of significant figures.

3.12.4 Evaluating evidence and procedures
Students should:
(a) assess the reliability of their data and the conclusions drawn from it;
(b) evaluate the techniques used in the experimental activity recognising the limitations of these.

The case of physics

Aims
A/AS courses in Physics should encourage students to:
(b) develop an understanding of the link between theory and experiment;

Principles for syllabus construction
A/AS syllabuses in Physics should:
(j) specify how experimental and investigative skills can be developed;
(m) identify, where appropriate, opportunities for students to improve their own learning and performance, work with others and solve problems in the context of their study of the subject.

Knowledge, understanding and skills

3.10 EXPERIMENT AND INVESTIGATION

AS and A level syllabuses should require students to carry out experimental activities. These activities should allow students to use their knowledge of Physics in planning, carrying out and evaluating their work and should involve the use of IT in data-processing and capture.

Experimental and investigative activities for AS and A level should be set in contexts appropriate to, and reflect the demand of, the content of the respective syllabuses.

3.10.1 Planning

Students should:

(a) identify and define a question or problem using available information and knowledge of Physics;
(b) choose effective and safe procedures;
(c) consider appropriate methods;
(d) select suitable apparatus.

3.10.2 Implementing

Students should:

(a) set up apparatus correctly and use it effectively with due regard to safety;
(b) make and record sufficient relevant observations and measurements to the appropriate degree of precision;
(c) modify procedures and respond to serious sources of systematic and random error in order to generate results which are as accurate and reliable as allowed by the apparatus.

3.10.3 Analysing evidence and drawing conclusions

Students should:

(a) present their work appropriately in written, graphical or other forms;;
(b) analyse observations and show awareness of the limitations of experimental measurements when commenting on trends and patterns in the data;
(c) draw valid conclusions by applying their knowledge and understanding of Physics.

3.10.4 Evaluating evidence and procedures

Students should:

(a) assess the reliability of their data and the conclusions drawn from it;
(b) evaluate the techniques used in the experimental activity recognising the limitations of these.

The case of biology

Aims

A/AS courses in Biology should encourage students to:

(b) develop an understanding of the link between theory and experiment;

Principles for syllabus development

A/AS syllabuses in Biology should:

(i) specify how experimental and investigative skills can be developed;

(l) identify, where appropriate, opportunities for students to improve their own learning and performance, work with others and solve problems in the context of their study of the subject.

Knowledge, understanding and skills

3.3 EXPERIMENT AND INVESTIGATION

AS and A level syllabuses should require students to carry out experimental activities. These activities should allow students to use their knowledge of Biology in planning, carrying out and evaluating their work.

Experimental and investigative activities for AS and A level should be set in contexts appropriate to, and reflect the demand of, the content of the respective syllabuses.

3.3.1 Planning

Students should:

(a) identify and define a problem using available information and knowledge of Biology;

(b) choose effective and safe procedures, selecting appropriate apparatus and materials and deciding the measurements and observations likely to generate useful and reliable results;

(c) consider ethical implications in the choice and treatment of organisms and the environmental and safety aspects of the proposed procedures.

3.3.2 Implementing

Students should:

(a) use apparatus and materials in an appropriate and safe way;

(b) carry out experimental work in a methodical and organised way with due regard for safety and for the well-being of living organisms and the environment;

(c) make and record detailed observations in a suitable way, and make measurements to an appropriate degree of precision.

3.3.3 Analysing evidence and drawing conclusions

Students should:

(a) communicate biological information and ideas in appropriate ways, including tabulation, line graphs, histograms, continuous prose, annotated drawings and diagrams;

(b) recognise and comment on trends and patterns in data;

(c) apply a simple statistical test and, where appropriate, assign confidence levels to experimental results;

(d) draw valid conclusions by applying biological knowledge and understanding.

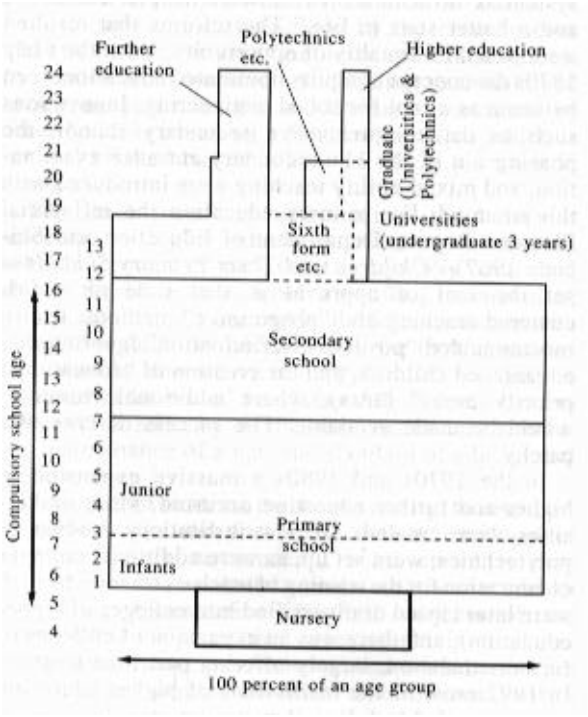
3.3.4 Evaluating evidence and procedures

Students should:

(a) assess the reliability and precision of experimental data and the conclusions drawn from it;

(b) evaluate the techniques used in the experimental activity recognising the limitations of these.

SCHEMA PRESENTING THE STRUCTURE OF THE BRITISH EDUCATIONAL SYSTEMS



Schema from the "International Encyclopedia of National systems of Education". Second Edition
T.Neville Postlethwaite (Ed). Pergamon. (1995)

Science Teaching in France

Science teaching previous to upper secondary school

In France, compulsory education begins at 6 years old and ends up at 16 years. The primary school lasts for 5 years and the lower secondary school ("Collège" in French) lasts for 4 years.

Science in the curriculum and labwork practice

There is a national curriculum which includes science, both at primary and at lower secondary school. It concerns biology / geology and physical sciences (physics / chemistry).

There is an interruption of chemistry/physics teaching at the end of primary school; there is no physical science curriculum during the first two years of intermediate school. Instead, there are basic technical knowledge courses (“technologie”) including conceptual elements of physics.

Both biology and geology are taught in a single compulsory subject during the four years of intermediate secondary school.

Concerning labwork, it is performed at primary school depending mainly on the teachers' decision. In fact, science teaching is not really well developed. Currently, a national initiative called "La main à la pate" is launched out with the aim of having an important development of science teaching at this level.
At lower secondary school, labwork carried out in small groups is regularly done in all science subjects, and teachers use demonstrations during lessons.

Evaluation at the end of intermediate school

A final evaluation ("Brevet des collèges") is applied. The evaluation procedure depends on the subject matter ; it means that physics and chemistry on one hand, and biology, geology on the other hand are assessed all along the year, and the teachers' global evaluations correspond to "physical sciences" and "natural sciences". Thus, there are two marks, one for physics/chemistry, the other for biology/geology which are given by the teachers in each school.

Upper secondary school

Organisation of the different routes

The upper secondary school, that is between 15 or 16 and 18 or 19 years old, lasts for three years in academic routes. In vocational routes it can last for three or four years. In France there are two main types of school where the teaching content and the teaching duration of the disciplines are different:
- Lycée d'enseignement général et/ou technologique
- Lycée professionnel.

The first year of "lycée d'enseignement général" and "lycée technique" is common to all students (corresponding to the 10th grade in other countries). During this year students have one hour and half per week of labwork in physics / chemistry and the same in biology / geology. In addition they have two hours of lectures in physics / chemistry and half an hour in biology / geology. After this common year (determination year), students choose an orientation.

In the 'Lycée d'enseignement général et/ou technologique', the second and the third year have several routes : L for literature, S for science, ES for economic and social, STI for sciences and industrial technologies, STL for sciences and laboratory technics, SMS for medico-social sciences. It is in the S route that the students have the maximum of science (see introduction). Moreover during the second year (11th grade), they can choose more science, instead of a

foreign language, and have four hours and half of 'experimental activities ' in physics / chemistry mainly, and in biology/geology too in 'enseignement général'. In the same way, during the last year of secondary school (12^{th} grade), instead of mathematics, they can choose more science in the 'enseignement de spécialités' which consists in two hours either of physics / chemistry or of biology / geology. The 'spécialité' is generally chosen by a reduced number of motivated students. It is assessed at baccalauréat, by a specific written test. Some details will be given below.

In the Lycée professionnel' (LP) students can stay up to 4 years. In these schools, teachers are more "math and science teacher" than only physics teachers. There are two possibilities:
- after 2 years, pupils take the "brevet d'étude professionnel" . Then they can study for 2 years more to take the "baccalauréat professionnel";
- after the "Brevet des Collèges" (end of lower secondary school), they can study for three years, like in the general teaching route and take the "baccalauréat professionnel".
The "baccalauréat professionnel" is supposed to be a final degree. Pupils may pursue their studies but it is not the actual purpose of this route.

Examination at the end of secondary school

In France, there is an evaluation at the end of secondary school which give the right to enter university.

Academic routes

At the final exam (baccalaureat), in scientific stream (S), physics, chemistry and biology, geology are evaluated during written exams and sometimes, depending on the students' choices there are also oral exams.
In non-scientific streams :
- ES, depending on the student choice, there are oral exams in biology, chemistry or physics.
- L, students have one written exam in only one discipline which is chosen at random each year between biology, physics and chemistry, or math. Depending on the student choice, there may be an oral exam as well.

There is a specific exam on labwork only in technological baccalaureat.
However, a pilot evaluation of labwork activity for the scientific stream has been launched (1996) in some academic zones ('academies'), particularly in the Lyon area . According to the results, this will be or not enlarged to all the country.

Vocational or technical routes with technical aspects related to biology, and/or chemistry and / or physics

According to the main discipline linked to the studies, there is a written examination in physics, chemistry and/or biology at the final exam (baccalaureat). Labwork exams can be part of the baccalauréat if it is in relation with professional training.

Organisation of science teaching

Science teaching : separate subjects domain or integrated

Within the scientific routes, biology, chemistry and physics are taught as separate subjects. In other routes (economic, social, etc.) if these subjects are taught, they can be done as an integrated science, because the teacher is more free to organise a motivating teaching as he wants it.
At upper secondary school, a "sciences physiques" teacher teaches both physics and chemistry, and a 'science de la vie et de la terre" teacher teaches both biology and geology.

Official curriculum, Duration, Official textbook

There is an official curriculum with fixed duration. The time for teaching physics, chemistry, biology depends on the route and is officially given for each one (see table 4). As said above, all students at the first year of the upper secondary school receive a scientific teaching with physics, chemistry, biology, geology.

The teachers can choose among several textbooks published by private publishers. Moreover, there are books dealing only with presentation of labwork (apparatus and sheets), published by private companies as well. Usually the authors are groups of teachers, in some cases inspectors or university professors participate in the writing. There is also a possibility to have labwork sheets in French on line via the web (http//www.ac-lyon.fr/ or http//www.ac-toulouse.fr/).

Labwork in small students groups

In regular teaching, labwork is frequently organised for small groups of students (two or three). The official instructions which make labwork compulsory, are respected. Inspectors check the balance between courses and labwork as advocated by official curriculum. The frequency is about once a week for each subject matter.
The duration on one session is about 1,5 to 2 hours (see above).
Labwork is generally organised with a reduced number of students (15 - 25), but sometimes for the whole class (20 - 35).
Except for the pilot evaluation previously noted, there is no formal evaluation except for routes leading to technical professional work.

Concerning the equipment for labwork, there are private companies selling apparatus specially designed for teaching (Pierron, Jeulin, ...). Generally a specific room for physics / chemistry labwork on one hand and biology labwork on the other hand, exist. Teachers are helped by technicians, at least one by school. The financial support for equipment is regularly provided by the “régions” (local government). In addition, when the national curriculum changes, the ministry provides special credits to the schools.

There are safety norms constraining mainly chemistry and biology, and physics too in the domain of electricity, radioactivity and thermodynamics (use of gas). The regulation is provided by the “direction des lycées”, a unit of the ministry that deals with school

organisation, independently from the General Inspection. There is one General Inspection per discipline ; its role, concerning safety, is limited to check the respect of the safety rules imposed by the “direction des lycées”.

Demonstration of experiments during the lectures

In France, the teachers may perform themselves experiments in front of their pupils during the lectures. The frequency of these experiments is under the teacher's own decision. Demonstrations may be used during science teaching at upper secondary level.

Teachers' training

Initial training

There are two kinds of teachers : primary teacher and secondary school teacher in the sense that the first ones can teach any kind of lessons in primary school and the second one, teaches his/her discipline at secondary schools (lower and upper).
The teachers may have somewhat different initial curriculum; they may have majored in physics or in chemistry during their own university studies. The same is true for biology and geology.

At upper secondary school teachers hold a university degree in the subject they teach (a minimum of 3 years university); then they have to go to a special Institute (IUFM : Institut Universitaire de Formation des Maîtres) for one or two years. During the first year they exclusively work in the subject domain, ending with a national competitive examination (mainly focused on the subject domain) ; during the second year they have the responsibility to give lessons part time (4 hours a week) and they have to follow specific courses mainly on science education, pedagogy and experimental improving of their initial training. Some of the future teachers, with a degree of higher level ('agrégation') can enter directly the second year of these institutes.

Teachers at intermediate school have the same initial training as for upper secondary school .

Primary school teachers hold a degree at university (three years) in any subject. Few years ago, most of the teachers used to get a degree in a **non** scientific domain but nowadays a slight evolution is observed. They have to spend two years in the IUFM institute, as for secondary school. They are trained specifically in sciences. At the end of the first year of IUFM they have to take a national competitive examination.

In service training

For all kinds of teachers, there is continuous in-service training, covering a lot of areas, including scientific subjects, didactics and labwork in science.

Experimental activities by subject matters

As said before, there is an official curriculum, given presently (in 1997) by the following references :
Curriculum of the 10th grade ('classe de seconde'), bulletin officiel numéro hors série. 24 September 1992 tome I page 74
Curriculum of the 11th grade of the scientific route ('classe de première scientifique'), bulletin officiel numéro hors série 24 September 1992 tome II page 25
Curriculum of the 12th grade of the scientific route ('classe de terminale scientifique'), bulletin officiel numéro N°3 16 février 1995 page 3.

Traditionally, physics and chemistry are taught by the same teachers. Though clearly distinguished in the official curriculum, they are often presented in a rather parallel way. Below will be presented separately the main intentions appearing in the corresponding texts for biology, chemistry, geology, physics. Examples of experimental activities will be given for physics and chemistry together. A paragraph will be added to describe the options that students can choose during the last two years of upper secondary school. They have been recently created in order to promote a better initiation to scientific work through experimental method.

N.B. The use of information and communication technologies is not compulsory, though students-teachers ought to study computerised experiments. It is widely encouraged because these technologies are assumed to help students by motivation, facilitation of work, acquisition of autonomy and preparation to their future life in a society where computers are everywhere.
Presently, computers are used in science classes mostly for data acquisition, simulation and exploitation of data banks. The 'General Inspection' is concerned by the progress of the use of computers during labwork and promotes reflection about it .

Case of Physics

Principles directing the experimental dimension of teaching, can be found in the preliminaries to the texts giving the curriculum of each of the classes, namely *' Main principles of Physics and Chemistry education at lower and upper high school'*. It contains a clear claim that experimental activities must be carried out . Among the general objectives are experimental approach, as well as technical applications.

Through an experimental approach, the teacher must favour the acquirement of precise reasoning, scientific method, aptitude to criticising, and intellectual integrity. By doing this with attractive subjects and experiments, the teacher must provoke curiosity.
Teaching must have the preoccupation of technical applications, which, by and large, from engineering science to life science, have bases in physical sciences.

One of the objectives of Physics is to underline that the world is intelligible and can be described by a small number of laws. Experimental activity will be the most frequent one to discover and illustrate these laws.

Teaching must exhibit that this coherent representation is rooted in experiment: the experimental activities do have an essential place.

The curricula are presented with three columns:
- content
- competencies to be acquired by students
- corresponding activities

By introducing activities corresponding to content and competencies, the authors claim the necessity of experimental activity, specially under the form of labwork.

A list of activities is given to be put into operation all along the educational programme. This list is presented as an example to illustrate the spirit of the curriculum. It will allow to choose and to exploit ideas suggested in relation with the intuitions of a given class, with the local context and of course the possibilities of each school
.....
This list refers to experiments which, by and large, can be the topic of labwork during which students can actually have personal hands-on activities, which has been recognised as valuable for long. Labwork of this kind can have different forms: learning skills during moderately directed periods, sequences during which the students can propose a procedure or organise measurements to respond a given question .....
.....
The proposed activities are largely open to the use of modern technologies (video, computer)

Case of Chemistry

Similarly, in the preliminary of the curriculum, the necessity of an experimental approach, as well as of technical applications, is claimed.

One of the first objective of teaching Chemistry, science of the transformation of matter, is to make acquire specific scientific and technical methods, in addition to the scientific and technical disciplines themselves.

The authors claim that chemistry is an experimental science and that teaching this discipline demands experimental activities, most of the time under the form of traditional labwork.

Hands-on activity
It is well known that young people are attracted by the experiments of Chemistry . This can be explained by the spectacular character of some experiments (thermic welding, exploding mixtures, Bengal lights, etc.) Some other experiments can seem magic (blue bottle, invisible ink, magnetic paste, luminescent bar, etc.). Beyond this mediatic character, the experiments of Chemistry are often simple to carry out because they demand few specialised materials. They are short and cheap.

They use procedures which are sometimes useful in everyday life :
- decanting
- heating,
- attributing adapted formulae (cooking, painting),
- dissolving (care of the body, of the clothes , taking drugs),
- extraction (coffee, tea),
- analysis (minerality and pH of different types of water)
- measurement (temperature, volume, mass).
They are opportunities to initiate students to the respect of safety rules.

Exactly like the curriculum of Physics, the curriculum of Chemistry is presented in three columns:
- content
- competencies to be acquired by students
- corresponding activities

The activities are only propositions and are only suggested to illustrate the spirit of the curriculum.

Some examples of experimental activities in physics and chemistry

10^{th} grade ('Classe de seconde')

· Physics

Visualisation and measurement of voltages and intensities with an oscilloscope or an interface and a micro-computer.
Use of a set-up with an operational amplifier
Experimental study of the laws of reflection and refraction.

· Chemistry

Identification of ions in soils, plants, fertilisers and a ionic phytosanitory product.
Quantitative study of a chemical reaction.
Distillation of a mixture of two organic compounds

11^{th} grade ('Classe de première scientifique')

· Physics

Study of an air cushion mobile on a table with a variable angle or with a similar software.
Realisation of experiments analysed in term of energetic chains.
Experiments illustrating the role of an alternator, of a transformer

· Chemistry

Recognition test of metallic ions
Classification of redox couples.
Electrolysis
Measurement of calorific power, of melting latent heat
Titration of sulphur dioxyd by potassium permanganate.

Oxydation and dehydrogenation of alcohol

12th grade ('Classe de terminale scientifique')

· Physics

Verification of the third law of Newton from chronophotographic documents.
Analysis of movements with sensors. Computer processing of results, modelling.
Study with an oscilloscope of the outcome of a dipole (RL, RLC).
Resonance intensity curve for a dipole RLC.
Study with a computer of the equation of Van der Pol : a model (oscillator RLC) for the introduction of non-linear effects
Experiments of diffraction and interference with a laser
Spectrums.

· Chemistry

Ph measurement of acids and bases.
Titration of a strong acid by a base and vice-versa.
Realisation of reactions of esterification and hydrolysis.
Extraction of an essential oil from plants.
Making soap
Synthesis of a drug
Identification by chromatography.

Concerning the place of computers in teaching,

Case of life and earth sciences

In the scientific route, the time is 50 % teaching biology and 50% teaching geology.
In biology and geology, the national curriculum notices that there is a double task, cognitive and methodologic. In the first case, the goal is to insure education toward life, health and environment. In the second case, the goal is to achieve scientific attitude through experimental method. In both cases, pupils' activities must lay on reality and the importance of labwork is emphasised in official instructions quoted above.
Teachers are asked to promote investigative skills according to scientific problems generated by concrete realities, problems being solved through observation, experiments and hands-on activities.
From a methodological point of view, the instructions are to articulate labwork and lectures in order to construct an active knowledge adapted to the level of the class.
National curriculum of biology and geology is presented according three columns :
- contents,
- cognitive tasks
- possible activities.

Actually, the last is a list of labwork that can be done reasonably in most of high schools according to the level of technical equipment and teachers'training. In addition, some publications promote diffusion of innovations and training sessions are organised by academic authorities. Thus, teachers are able to have their pupils doing labwork to follow the curriculum and have opportunity to learn and practice it.

Some examples of experimental activities in biology and geology

- Culture of bacterial populations having various enzymatic equipment on a given substrate (Example : characterisation of beta galactosidase)

- Experimental study of the enzyme catalysis : digestion hydrolysis or other reactions of metabolism

- ExAO : measurement of the rate of reaction for digestion

- Establishing neurone medullar circuits activated during a reflex

- Anatomy and cytology of reflexes

- analysis of records concerning the activity of neuromuscular junctions.

Case of the optional teaching during the two last years of Upper secondary school

As said before this facultative teaching is destined to promote experimental approaches. It gives more freedom to teachers in 1ère S than in TS which ends with baccalauréat.

Experimental sciences in 1stS (11th grade)

6 hours each week are available for experimental work in any domain. The themes can be chosen by the teacher among a list. They are also presented through contents, cognitive tasks and possible activities. It leaves the teacher free to organise research projects without constraints about the number of sessions, the places to visit or any form of cooperation with scientific or industrial partners allowing further development in environmental topics for instance. This new frame more flexible than the « classical » one is also more favourable to using various technologies including computers. This is the result of the lack of concern about immediate « school profit » because evaluation in this case does not depend on classical forms i.e. exams, exercises etc... but on the skills required to work out methods and techniques.
. It is worth noticing that this form of teaching was recommended by high scientific authorities in the country like MM. de Gennes and Lehn, Nobel prizes in physics and chemistry respectively, the «conseil national des programmes» and «inspection générale» of physics / chemistry and biology / geology. Many teachers are highly favourable to carrying on this sort of approach to science laying on observation, manipulation and experiment carries on

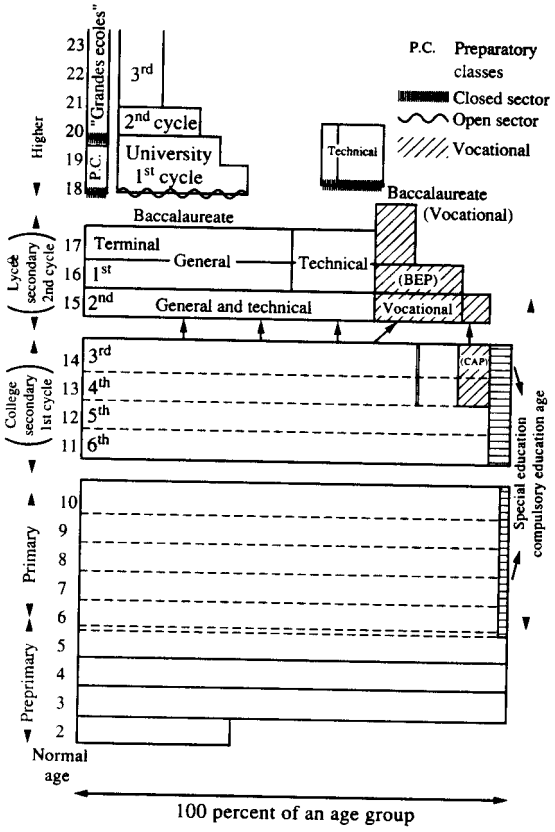
Case of speciality teaching in Terminale S (12th grade)

In this class, a speciality teaching must be chosen between the three scientific topics. It takes 2h a week in small groups and adds two points to the coefficient of the corresponding topics at the exam with a specific question.

Coefficients of scientific topics at the exam are respectively 7/34, 6/34, 6/34 for mathematics, physics / chemistry, and biology / geology. Thus, the part of science in the global mark is 21/34 i.e. 61 % (compared to 2/34 i.e. 6 % in the L route).
Speciality in physics / chemistry and biology / geology is also supposed to be experimental and practical but the 'baccalauréat ' is today uniquely theoretical and at least in biology and geology, the part of class time spent in labwork is low in speciality teaching compared to activities like observations and analysis of experimental results.

APPENDIX

STRUCTURE OF THE FRENCH EDUCATIVE SYSTEM



Schema from the "International Encyclopedia of National systems of Education". Second Edition T.
Neville Postlethwaite (Ed). Pergamon.

SCIENCE TEACHING IN GERMANY

1. Science teaching previous to upper secondary school

In Germany the compulsory education is between 5, and 16 years. There are two types of school, primary and lower secondary schools. Primary school serves children between the ages of 6 and 10, lasting for 4 years. Lower secondary school lasts for 6 years, for students between the ages of 10 and 16 years.

1.1. Science in the curriculum and labwork practice

There is an official curriculum at a regional level for each state and **all levels (primary, lower and upper secondary schools)**. In Germany it is specific for the subject matters, chemistry, biology, and physics (except for primary school and grade 5 and 6). Geology is not taught as a separate subject. (There is a subject "geographie" which is not a science.)

1.2 Primary school

In primary school the subject of scientific contents is called science for young children (“Sachunterricht”). It contains a mixture of biology, chemistry, physics, technics, geography of the immediate environs, domestic science and, in some cases, history and sociology. Sachunterricht is taught between 2 and 4 hours per week from grade 1 to grade 4. Practical work and phenomenology is the main focus of instruction.

1.2. Lower secondary level

In lower secondary level (grade 7 to 10) there is an average of 4 lessons per week in four years for each of the separate subjects of physics, biology and chemistry in all states ("Länder"). There is no regulation of teaching methods by the departments of education at all. There are nearly no “integrated science” courses, both in lower and higher secondary level but some innovation and curriculum development is going on in this direction. The teacher is free to choose the teaching method. The relation between teacher oriented lessons and student oriented labwork is about 4:1. But we have no lectures at all in a sense of “the teacher is reading out of a book and the students listen". Typically teacher oriented lessons are organised as a dialogue between the asking teacher and one answering student. The organisation of labwork at school is a matter of the teachers. There are between 20 to 35 students in a physics, biology or chemistry classroom. If the teacher is able to organise it under the constraints of school reality, labwork can be performed with half of the normal number of students in the classroom.

1.3. Evaluation at the end of lower secondary school

examination	written exam with integrated science	written exam specific for each science	class tests and oral checks
Yes: Mittlere Reife	no	no	all along the year

Table 1 : Evaluation at the end of intermediate (compulsory education)

2. Upper secondary school

2.1. Organisation of the different routes

The upper secondary school is from age 17 to 19 (some states till 18). There are two different types of school
- Gymnasiale Oberstufe at present for about 30% of students which offer the streams to go to university
- Vocational schools (Berufsschule (BS), Fachoberschule (FOS))

Duration : 3 years for Gymansiale Oberstufe and
2 or 3 years for FOS and different types of BS (depending on the aspired profession).

There are two types of teachers with different teacher initial training. One is only allowed to teach in lower secondary (3-4 years training) and one is allowed to teach in lower and upper secondary (4-5 years Training) .

For the following, and for all our project, we shall distinguish two types of routes : academic and vocational routes. Then, we shall distinguish sub routes.

In vocational routes, there are two main types of routes :
- the routes leading to professional work at the end of secondary with technical aspects (related to biology, and/or chemistry and / or physics)
- the routes leading to professional work at the end of secondary without these technical aspects.

academic		vocational	
specific streams for science, economy, etc. school, duration	no specific streams school, duration	with technical aspects school, duration	with no technical aspects school, duration
Gym, 3 yrs and FOS,2 yrs.	/	FOS and different other schools, 2 yrs	FOS and different other schools, 2 yrs

Table 2 : Organisation of upper secondary schools

2.1.1. Examination at the end of secondary school

In Germany there is an examination at the end of secondary school which gives the possibility to enter to university.

2.1.2. Academic routes

Final exam (Abitur) written and oral. No entrance exams (with some exceptions). No specific exam on labwork. Exam in one of the sciences is possible but not compulsory.

FOS: Technical assistant for Physics, Biology and Chemistry
compulsory exam in politics and some of the sciences (differs). 50% of the exam has to be labwork.

2.1.3. Vocational or technical streams with technical aspects related to biology, and/or chemistry and / or physics

Final exam (Fachabitur) written and oral. No entrance exams (with some exceptions). No specific exam on labwork. Exam in one of the sciences is possible but not compulsory.

3. Organisation of science teaching

3.1. Science teaching : separate subjects domain or integrated

In the case of the academic routes in science domains, biology, chemistry, physics are taught as separate subjects. In other routes (economic, social, etc.) if these subjects are taught, they can be done as an integrated science.

Three sciences are taught as seperate subjects. Teachers normally teach two subjects with different combinations (e.g. Math/Phys or Biol/English**)** in all routes**.**

3.2. Official curriculum , duration, official textbooks

Some criteria of assessment or some compulsory topics are given by a national body. Each of the 16 federal States of the Federal Republic of Germany has got its own curricula in physics, chemistry and biology. The common core is given by the "Unified Exam Regulations" (EPA, Einheitliche Prüfungsanforderungen) which are agreed upon by the Conference of the Ministers of Education of the 16 states. The EPAs name the topics, which have to be dealt with in the upper secondary level of gymnasium.

The time for teaching physics, chemistry, biology depends on the route but is officially given for each stream.

There is a list of textbooks accepted by each state (they differ only little in each state). The conference of physics, biology and chemistry teachers at each school can decide which book

of the list will be used in the school. Therefore, the topics taught in upper secondary level are nearly the same in all states.

3.3. Labwork in small groups of students (organisation, duration, equipment, safety regulations)

(1) In Germany, labwork is possible, but is not done to a large extent depending on the individual teacher's' decision . In the regular classroom, the number of students is between 20 and 35.
During labwork they are sometimes less (15 - 25). There are no special courses of labwork. Labwork is part of the normal lessons except in routes leading to professional work. Teachers do not need special guidance because the above explained labwork is part of the teachers' education at university. Normally labwork is performed strongly guided by the teachers. The students work in small groups (3-5) and often all groups do the same. At upper secondary level in specialised courses of the Gymnasium (max. 25 students) labwork is more student oriented and elaborated (between 10% and 25%% of the teaching time). At upper secondary level of the FOS labwork is performed profession-dependent and well organised in special courses (profession-dependent between 2 and 5 hours a week).

(2) In Germany, when there is labwork, the duration is about usually 1 to 2, sometimes up to 5 hours.

(3) There are private companies selling apparatus only for teaching. Physics, biology and chemistry are usually taught in special classrooms which are used for the normal lectures as well as for student labwork. Consequently, there are normally no separate labs. The classrooms are well equipped for demonstration experiments. In case of student labwork the experiments are done in groups of about 4 students. In many domains of physics there is a lack of apparatus for group work.

(4) There are safety norms which constraints mainly chemistry and biology, and physics in the domain of electricity, radioactivity and thermodynamics.

In physics security norms mainly concern student labwork with electricity (no high voltages) radioactive substances and gas. These norms do not effect labwork to a great extend.
In chemistry student labwork is not allowed to involve carcinogenic substances or substances which are suspected to be carcinogenic. Most experiments should take place under a flue that ensures that the gas / smoke is drawn off. This is a severe restriction for student labwork since in most classrooms there is just one flue.
In biology there are also severe restrictions. Many are based on those for chemistry. In human biology experiments with human blood are not allowed.

3.4. Introduction of experiments during the lectures

The teachers demonstrates experiments in front of their pupils during their lectures. The frequency of these experiments is under the teacher's decision.

In physics teachers use demonstration experiments during their lectures regularly. If there is student labwork, it is usually integrated into the normal lessons and as such closely related to the contents of the lectures. In chemistry student labwork is much more part of the lectures. Experiments are demanded as crucial points in chemistry. In biology the amount of student labwork depends very much on the topic. In biology of the cell and in ecology there is a lot of labwork. In biology there are only few demonstration experiments.

4. Teachers' training

There are three types of teachers for Haupt- and Realschule (lower secondary), Grundschule (primary school) and Gymnasium (upper secondary)

4.1. Initial training

For upper secondary school:
After the university exam after 4 to 6 yrs studies all students have to go through special teacher colleges (2 years) which end with a 2nd state exam. During this time future teachers have to give lessons (up to 12 per week) under guidance of a teacher or an instructor of the college or responsible during the last 1 and a half years.

For intermediate school and primary school:
After the university exam after 3 to 6 yrs at university all students have to go through special teacher colleges (2 years) which end with a 2nd state exam. During this time they have to give lessons (up to 12 per week) under guidance of a teacher or an instructor of the college or responsible during the last 1 and a half years..

4.2. In service training

Special institutions (Landesinstitute) and to a smaller extent universities are organising inservice teacher training. It is voluntary, therefore many teachers never take part.

5. Experimental activities by subject matters

References :
Die Schule in Nordrhein-Westfalen. Eine Schriftenreihe des Kultusministeriums. Richtlinien Physik, Chemie, Biologie, Gymnasiale Oberstufe.In Nordrhein-Westfalen (different from the other states) the curriculum of Chemistry, Physics, Biology is presented in 6 chapters:
General introduction, aim of teaching, contents, organisation, control of the results and optional lessons.

5.1. Case of chemistry

In the preliminary of the curriculum of Nordrhein-Westfalen (the curricula of the other states are similar in this case) the necessity of an experimental approach is claimed.

Chemistry is seen as an experimental science and therefore students' should learn about experimental activities in form of traditional labwork (similar to university), demonstration experiments and theoretical explanations which refer to experiments and technical use. Hands-on activities are propagated to train activities which refer to chemistry like decanting, heating, measuring temperature and using simple devices like litmus paper etc.

5.2. Case of physics

Experiments and Theory are supposed to be the main elements to learn physics. Education in physics is structured by means of cognitive, affective, psycho-motor and social aims. In this context the experiment is seen not as separated but as an element in relation to theory to understand phenomena in the area of physics.

By introducing activities corresponding to content and competence, the authors claim the necessity of experimental activity, specially under the form of labwork. The content is structured as it is at university. Mechanics, thermodynamics, electricity, quantum mechanics, atoms, relativity.

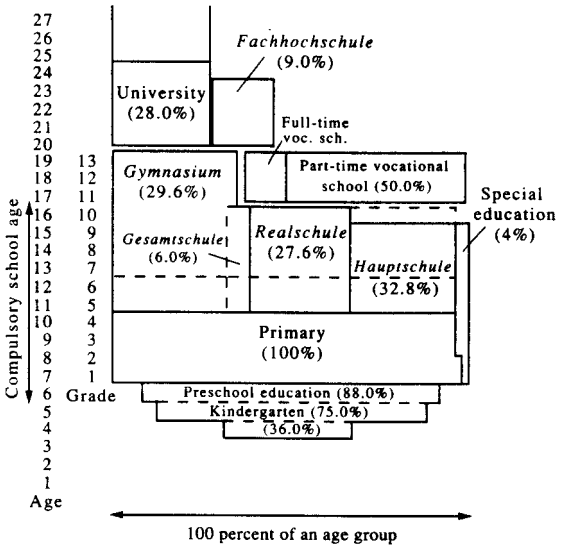
5.3. Case of biology

(Missing so far.)

5.4. Case of Earth Sciences

Earth science is not seen as a part of science, it is taught only as "geography".

SCHEME PRESENTING THE STRUCTURE OF THE GERMAN EDUCATIONAL SYSTEMS



Scheme from the "International Encyclopedia of National systems of Education". Second Edition T.
Neville Postlethwaite (Ed). Pergamon.

SCIENCE TEACHING IN GREECE

General remarks
In Greece, secondary education is under reform. In the case of science education new curricula have been developped and will be implemented next academic year 1997 - '98. These new curricula are oriented more on labwork. The teaching materials include labwork guides and textbooks for students and guidelines for teachers. During the academic year 1996-97, Labwork Centres for Science (EKFE) were established through out the country, one in every prefecture (except capital, Athens). The role of these centres is to help teachers in applying the new curricula by means of equipment and media.

Science teaching previous to upper secondary school

Greece compulsory education begins at 6 years old and ends up at 16 years old. There are two types of school, primary and lower secondary schools. Primary school serves children between the ages of 6 and 12, lasting for six years. Lower secondary school lasts for 3 years, for students between the ages of 12 and 15 years.

Science in the curriculum and labwork practice

Physics, Chemistry, Geography and Biology (Botany, Zoology and Anthropology) are taught as separate, compulsory subjects in several forms of Secondary Education. The guidelines of

the National Pedagogical Institute propose to the teachers to accompany the teaching of theoretical subjects with experiments aiming at the verification of the corresponding theory. In Gymnasium, no particular laboratory sessions are scheduled. Science teachers develop demonstrations.

Evaluation at the end of lower secondary school

The evaluation at the "lower secondary school" is based on a combination of continuous assessment (by means of oral - everyday assessment, written tests) throughout the year and examinations at the end of the year. This pattern applies in the first, second and third form of the Gymnasium. Students have to obtain at least pass marks (in average 10/20) in order to be able to attend successively the second and the third form, or to take "apolytirion" (certificate) of the Gymnasium at the end of the third form. 90% of the students obtains the "apolytirion" (certificate) of the Gymnasium.

Upper secondary school

Organisation of the different routes

At upper secondary school, that is between 15 and 18 years old, the situation is as following:
General Lycei (GL) for the majority of students (57%), Technical & Professional Lycei (TPL) for 30% (usually followed by the lower strata as rated in their intermediate certificate) and Multi-Disciplinary Lycei (MDL) for 13%. The Multi-Disciplinary Lycei are located only in big cities, one in each, except Athens. The only criterion for entrance is the locality of students.

Duration : Three years for all schools. All Lycei include first, second and third form.

In GL the 1st and 2nd form are common and the 3rd form has 4 routes, leading to different disciplines of the Tertiary Education. In the 3rd form there are common lessons for 10 hours (e.g. philosophy, foreign language, history etc) and specific lessons for 20 hours according to the following routes (physics chemistry and math at the 1st route leading to science departments, polytechnics etc, physics. chemistry and biology at the 2nd route leading to medicine disciplines, ancient Greek, history at the 3rd route leading to law, literature disciplines and economics, sociology at the 4th route leading to economics, school of education)
In TPL and MDL there is a common 1st form. At the 2nd and 3rd form, apart from common lessons, there are also lessons leading to specializations (e.g. there are 17 specializations in MDL). At the 3rd there are also the above mentioned routes leading to Tertiary Education (i.e. university level).

In all these schools the requirements for the biology, chemistry or physics teachers' initial training are the same (graduate of relative science department, with four (4) years of education). In principle, such secondary school teachers can teach various science lessons

during the same year, in any type of school (e.g. 2 to 4 from biology, physics, chemistry, geology, anthropology, astronomy etc.)

The differences in upper secondary schools appear in duration of teaching, importance of labwork, examination according to the routes which are proposed by the educative systems.

For the following, and for all our project, we shall distinguish two types of routes : academic and vocational routes. Then, we shall distinguish sub routes.

In vocational routes, there are two main types of routes :
- the routes leading to professional work at the end of secondary with technical aspects (related to biology, and/or chemistry and / or physics)
- the routes leading to professional work at the end of secondary without these technical aspects.

Examination at the end of secondary school

There is a main examination for the entrance at university.

Academic routes

The evaluation at the Lycei is based on a combination of continuous assessment (by means of oral - everyday assessment, written tests) throughout the year and final examinations at the end of the year. This pattern applies in the first, second and third form of the Lycei. Students have to obtain at least pass marks (on average 10/20) in order to be able to attend successively, the second and the third form. After passing successfully examinations at the end of the third form, external highly competitive exams at national level, in specific lessons are taken by the students applying for the universities.

Vocational or technical routes with technical aspects related to biology, and/or chemistry and / or physics

For routes leading to professional work at the end of secondary with and without technical aspects (related to biology, and/or chemistry and/or physics), there are examinations to obtain the “apolytirion”.There is an assessment in labwork in both technical and professional lycei (TPL) and multidisciplinary (MDL)

Organisation of Science teaching

Science teaching : separate subjects domain or integrated

In upper secondary education, science domains: biology (incl. Anthropology), chemistry, physics, astronomy and geology are taught as separate subjects. ~~In other routes (economic, social, etc.) if these subjects are taught, they can be done as an integrated science.~~

Upper secondary school teachers can teach in any form various science lessons at the same year (e.g. 2 to 3 from biology including anthropology, physics and geology, physics, chemistry). Those teaching in the routes should preferably be experienced.

Official curriculum , Duration, Official textbooks, Official support

There is an official curriculum with duration (time table)
The time for teaching physics, chemistry, biology depends on the route but is officially given for each route.
In relation to the official curriculum, there is an official book, teacher's guidelines (from the National Pedagogical Institute and the school consultants) and an official labwork manual only in physics at present.
Official support is provided by experienced teachers, usually holding a master or PhD degree, who are in charge of the EKFEs.

Labwork in small groups of students (organisation, duration, equipment, safety regulations)

(1) Labwork (done in small group: 2 to 4 students) is very rare, only in experimental teaching. Labwork (done in small group: 2 to 4) is carried out in a number of schools where special curricula are adopted at present. Otherwise labwork depends on teachers initiative. In general, labwork rarely takes place, because of shortage of equipment, lack of laboratories and overloaded curricula.
When there is labwork, the duration is about 1 to 2, 5 hours.
In regular classroom, the number of students is between 20 and 30 (the upper permitted level, 35, seems to be rare). This number doesn't change during labwork.
There is no formal evaluation, except routes leading to professional work.

(2) duration: when there is labwork, the duration of the lesson is usually the same.

(3) There are private companies selling apparatus specifically made for labwork. The apparatus are made more or less according to an official handbook. Usually, the Ministry of Education buys the apparatus and provides them to public schools. As a result, a considerable part of the equipment remains out of work. Private schools buy the apparatus from their own budget. Such a situation makes the replacement of the apparatus inflexible.

(4) There are no official security norms related to science lessons, though teachers take care by themselves. However, safety norm, adopted by Unesco, are sent to particular lycei where teachers are involved in innovative teaching.

Introduction of experiments during the lectures

The teachers may occasionally carry out demonstrations during their teaching. The frequency of these experiments depends on individual teachers, type of lycei, curricula and laboratory equipment.

Teachers' training

There are two kinds of teachers: the teachers in primary education (Dimotiko), who teaches any kind of lesson apart from foreign languages and gymnastics, and the teachers in secondary education (Gymnasium and Lyceum) who are subject specialists and teach only specific lessons such as language and literature, mathematics, foreign languages, science (physics, chemistry, biology, geology e.t.c). At secondary level, all science teachers form the science group in schools are in principle entitled to teach any science subject. In practice, several physicists teach Chemistry or even Biology. However, this happens only in small - sized schools. In schools with large staff numbers, subject specialists have priority in choosing their preferred subject.

Initial training

For upper secondary school:
Teachers hold a university degree in the subject they teach (4 years university). Science teachers are subject matter specialists in one discipline but may teach other disciplines as well e.g. a physicist may teach chemistry or biology. No other specific qualifications are demanded by law
Orientation courses are provided to those entering the teaching profession by in service schools. (P E K)

For intermediate school: It's the same initial training as for upper secondary school.

At primary school:
Teachers hold either a two year degree from an Academy or after 1985, a university degree in pedagogy (4 years university). Pre service teachers take several compulsory science courses, including laboratory ones, during their education.

In service training

For both kinds of teachers there is continuing in-service training, not obligatory, covering a lot of areas, including scientific subjects, didactics and labwork in science.

EXAMPLE FROM GREECE

Experimental activities by subject matters.

References:
a) Textbooks (T) of all grades and
b) Official guides for the curriculum implementation and science teaching (edited by National Institute, at 1996 and 1997)(OG96 and OG97 respectively).

CASE OF PHYSICS

One of the main objectives of official Physics curriculum, both in lower and upper secondary education, is to exercise the students in observing and in experimenting (OG96, p.30 and 34).

Students' participation, of any kind, in the experiments is rather rare. Teachers usually carry out demonstrations.

Especially in upper secondary education the teacher must favour the acquirement of precise reasoning, scientific method and aptitude to criticism through an experimental approach. By doing this with attractive subjects and experiments, the teacher must provoke curiosity. (OG96, p34)

Various laws are introduced through simple experimental activities. The teacher explain the role of each instrument/equipment, either scientific or everyday's life, introduce the students to the procedure of measurements, the importance of parameters and the way a law is formed. The teacher while demonstrating the experiment asks students to observe, to forecast, to conclude. (OG96, p 30-31)

Some examples:

Lower Secondary

Hook's law: extension/stretching force. (2nd grade T, p.54-55)

Linear and cubic expansion of solids. (2nd grade T, p.128)

Study of pressure in liquids: parameters that influence pressure. (2nd grade T, p.95-96)

Measuring resistance (verification Ohm's law). (3rd grade T, p.108-109)

Upper Secondary

Forces acting on a falling body and on a sideways thrown body. (1st grade T, p.73-75)

Verification of conservation of mechanical energy (1rs grade T, p.189-192).

Experimental study of the laws of refraction. (2nd grade T, p.101-102)

Parameters influencing the magnetic field of electric current. (2nd grade T, p.64-65)

in the 3rd grade, there is only a mathematical approach to physics due to examinations for entrance the university.

CASE OF CHEMISTRY

The objectives we have analysed in the case of Physics, are also may be found in "Teaching Chemistry" (OG96, p.36, 38). One more major objective is to explore quantitative the chemical phenomena. This can be done by demonstrating spectacular, even "magic", experiments. Having earned the students' curiosity and attracted their attention, the teacher introduce the content. (OG96, p.36-37)

Some examples:

Lower Secondary

Preparation of homogenous mixtures (e.g. NaCl and water) (2nd grade T, lesson 11)

Separation of mixtures (e.g. shavings of Fe and S) (2nd grade T, lesson 13)

Verification of some properties of metals (laminable, conductor of electricity or of heat) (2nd grade T, lesson 15)

Defining the pH of acids and bases. (3rd grade T, lesson 1/2 and 1/6)

Making soap. (3rd grade T, lesson 5/1)

in the Upper Secondary (all grades), there is a non experimental approach (rather mathematical) to chemistry.

CASE OF BIOLOGY

Of the main objectives put forward by the official Biology curriculum, both in lower and upper secondary education, is to gather, to classify, to interpret and to evaluate various kinds of information that are observed during simple experiments. (OG97, p. 34) The main instrument that is used in a a great number of experiments is the microscope. (Almost every school has one).

Some examples:

Lower Secondary

Cell and tissue observation. (1st grade T, unit 1)

Observation and compare of movement of an amoeba, of an invertebrate and of a human. (1st grade T, unit 2)

Simple chemical activities e.g. tracing starch in a cotyledon, extraction of chlorophyll on acetone etc. (1st grade T, unit 3)

Experiment on fermentation. (2nd grade T, unit 3, lesson 2)

Estimation of pollutants in the water and in the atmosphere (2nd grade T, unit 6, lesson 2)

in the Upper Secondary (2nd and 3rd grade), there is a non experimental approach to biology.

CASE OF GEOGRAPHY
(only in lower secondary)

The new curricula in effect from the academic year 1997-98, emphasise the students' familiarity with charts and maps. Students must observe maps and with the help of keys and indexes to extract various kinds of information. (OG97, p. 37)

Some examples:

Comparing the population distribution through a climate map.

Comparing distances between two fixed points, in maps with different projection.

Extracting information of landforms through contour patterns.

CASE OF GEOLOGY

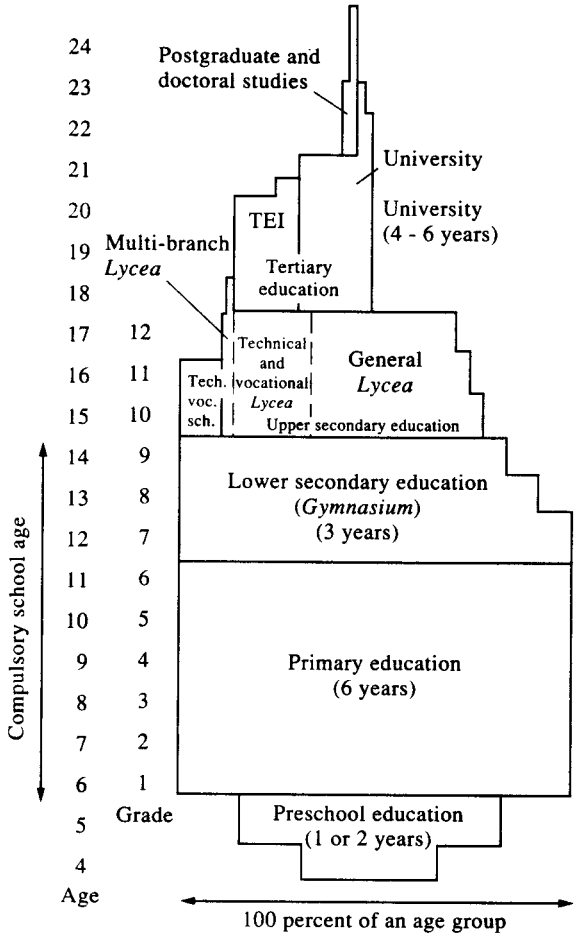
(only in upper secondary, 1st grade)

The current curricula aims at discribing the geological phenomena, classification of rocks, observation of fossils especially in the Greek area (OG97, p. 41). This can be helped experimentally with the use of set of rocks, fossils, charts etc.

Some examples:

Extracting information of landforms through contour patterns. (T, lesson 12)

SCHEMA PRESENTING THE STRUCTURE OF THE GREEK EDUCATIONAL SYSTEMS



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SCIENCE TEACHING IN ITALY

1. Science teaching previous to upper secondary school

In Italy, compulsory education begins at 6 years old and ends up at 14 years old. The primary school lasts for 5 years and the lower secondary school lasts for 3 years

1.1Science in the curriculum and labwork practice

The national curriculum refers to "science" as a subject. Primary school curriculum has been defined by law in 1985 and teaching "science" has become compulsory. Teachers decide at the beginning of each year how to organise the school activities in relation to the whole curriculum. They are free to choose topics, activities, methodology in accordance with the official curriculum which stresses the importance of the observation of phenomena and of experimental activities. Theoretical explanations are strongly discouraged and teachers are expected to encourage the formulation of explanations by children themselves. It must be stressed that the official curriculum takes into account the results of the research on "students conceptions". An examination concludes the primary level.
The lower secondary level curriculum has been defined by law in 1968. At the lower secondary level the number of hours to be devoted to science is fixed by law (6 hours a week, including math). Again the study of phenomenological aspects is stressed with respect to theoretical explanations. Most teachers follow textbooks closely.
Attention to labwork activities is increasing and, when possible, students work themselves in a laboratory. Sometimes a connection is held with upper secondary school teachers who provide apparatus, chemicals and share their knowledge.

1.2Assessment at the end of lower secondary school

The evaluation during the year is based on continuous assessment (oral or written) with a formal communication of the results at the middle of the year. The assessment through the years in both secondary and upper secondary school is decided by a class council formed by the teachers of the class, evaluating students achievement in all subjects during the year. Marks are from 0 to 10, 6 being the minimum requested to pass. When several marks are below 6, students are not admitted to the next year. Students with a limited number of low marks are bound to attend special compulsory courses meant to help them covering the gap. The last procedure is now going to change.
At the end of secondary school an examination must be passed with the same teachers of the school plus an external member. The examination consists in three written tasks (Italian, foreign language and mathematics/science), and an oral exam regarding all subjects.

2. Upper secondary school

2.1. Organisation of the different routes

At upper secondary school , that is between 15 or 16 and 18 or 19 years old, the situations are more complex; in secondary school education, all of which allow to enter to university. There are several types of school. Roughly speaking there are three branches in secondary school education:

- 'classical' education, which lasts five years and is chosen by about 33% students. It comprises *classical lyceum*, which gives a highly academic education based on Latin and Greek; *scientific lyceum* which is more based on mathematics and science; *istituti magistrali*, schools which prepare teachers for primary schools; art schools; language schools
- technical education (*istituti tecnici*), which lasts five years and is chosen by 47% students. The curriculum depends very much on the kind of specialisation chosen: chemical, industrial, mechanical, as accountant, as land surveyor, and so on
- professional education (*istituti professionali*) which lasts three years and is chosen by about 20% students. The curriculum varies according to the kind of training. After the first three years, there are courses for two more years which enable students to have the same opportunities as technical students.

2.2Examination at the end of secondary school

At the end of secondary school, for all the routes (lyceum, technical, professional, etc.), there is an examination which gives the possibility to enter to university.

a) Academic routes

The evaluation at the upper secondary school (5 years) is based on continuous assessment (oral or written) throughout the five years. At the end of the fifth year students are examined by a commission of teachers external to the school. The examination consists in an Italian written task plus a second one according to the specific route. The oral exam is only on 2 subjects, one chosen by the commission, the second one by the student. This procedure is expected to change as a new organization in which students will be examined on all subjects of last year is going to be discussed by actual government.
A very high percentage of students (about 90%) pass these examinations in both levels of school.

a) Vocational or technical routes with technical aspects related to biology, and/or chemistry and / or physics

The same as before.
Note : next year final upper secondary school examination will change.

3. Organisation of Science teaching

3.1Science teaching : separate subjects domain or integrated

In the case of the academic routes in science, biology, chemistry, physics are taught as separate subjects. In other routes (economic, social, etc.) if these subjects are taught, they can be done as an integrated science.

Sometimes the same teacher teaches different matters (e.g. Math/Phys or Biol/Chem). In vocational routes (both professional and technical school) scientific matters are taught separately.

3.2 Official curriculum , Duration, Official textbooks

Waiting for upper secondary school reform there are official curricula specified for each route by the Ministry of Education. Syllabuses were not issued at the same time. Some of them are quite recent and result from rather diffuse experimental projects which have become compulsory. Others are still at an experimental level and will probably become compulsory in the future. The tendency is to convert to mandatory what has been successfully (for the Ministry) tried out. In other words, there is not a general project for secondary school but each area develops rather independently from others. Teachers tend to follow syllabus quite strictly.

The time for teaching physics, chemistry, biology depends on the route but is officially given for each route.

There is not an official book. Textbooks writers produce textbooks related to the official curriculum. Textbooks are proposed by publishers to teachers at spring time and teachers have to decide what book to adopt for the following year. The authors are secondary school or university teachers. Also textbooks from other countries are available in Italian translation.

3.3 Labwork in small groups of students (organisation, duration, equipment, safety regulations)

(1) Labwork (done in small group : 2 to 4 students) is very rare, except in experimental courses , usually depending upon teachers' initiative. In general terms, reasons are shortage of equipment, lack of laboratories and overloaded curricula. In classical or scientific lyceums experimental work in class or in the lab is very rarely performed.
The average number of pupils in the classroom is 25. The same number in labwork. They can be divided in groups or perform their task individually in professional or technical schools. They attend demonstrative sessions in the other type of schools.

There is no formal evaluation.

(2) If any, the duration is about 1 to 2, 5 hours.

(3) There is no laboratory at all or is not properly equipped. Moreover it must be taken into account that there are some peculiar problems for the different disciplines. In technical and professional schools labwork is compulsory and school laboratories are usually properly equipped. Scientific lyceums are better equipped than classical lyceums.

(4) There are safety rules which constrain mainly chemistry , biology, and physics (in the domain of electricity, radioactivity and thermodynamics (use of gas)). Safety rules are usually well known by chemists, much less by others. Teachers seem not always aware of the importance of safety measures and tend to follow the norms to a limited extent.

3.4Introduction of experiments during the lectures

Generally speaking teachers do not like to perform experiments during lectures. Unless experiments are an integral part of the course they are conceived merely to illustrate some points and there is a sharp division between experiments and theory.

4. Teachers' training

There are two kinds of teachers: one for the primary and one for the lower secondary schools. Teachers in primary school (grade 1-5), according to the reform of 1985, deal with humanistic as well as scientific subjects all together. Different teams are often formed (composed by 3 teachers usually) to organise different areas, the scientific one being called "logical-mathematical- scientific area ".
Teachers in secondary school (grade 6-8) and upper secondary school (grade 9-13) teach separate subjects. They have a specific university degree, although the subject they teach doesn't always match closely their university degree. Sometimes different subjects are taught by the same teacher, say for instance Italian literature- History- Geography, or Chemistry- Biology- Geology- Anthropology- Astronomy (in both levels).
Lower secondary school teachers, with a degree either in Mathematics, or Physics, or Biology, or Chemistry, or any other degree in the Natural Sciences (4 or 5 years of university) teach a course named "Mathematical, Chemical, Physical and Natural Science". Also lower secondary school teachers enter the school through a national competition.
In technical or vocational school usually three people work together in the laboratory: the teacher, who has a university degree, a technician who has an upper school degree and a worker who is in charge of the maintainance of the lab and has a secondary school degree.

4.1Initial training

For upper secondary school :
Teachers enter the school by means of their disciplinary degree (4 or 5 years of university) , through a competitive examination (Concorso) which includes some laboratory questions. After which one year's training in a school, checked by an experienced teacher (tutor), is compulsory.. Teachers are then expected to attend in-service training courses for at least 100 hrs every six years as progression in salary depends on observance of this rule.
A law of 1990 has established that the teachers should be trained in a two year post laurea School of Specialisation. The curriculum of the School has been defined and some experimental courses have taken place giving suggestions for the organisational and content structure. This school is not yet activated mainly for bureaucratic and economic reasons, but there is a strong evidence that it will start at the end of 1998.

For lower secondary school:
It’s the same initial training as for upper secondary school.

At primary school:
Nowadays, a University degree is not requested to become a primary school teacher. Up to now they are prepared only by a route of the secondary school (4 years) and they enter the school through a national competition. In the immediate future University degree courses especially designed for primary school teachers (provided for in a law of 1990) will be available and it will become compulsory to have this degree.

4.2In service training

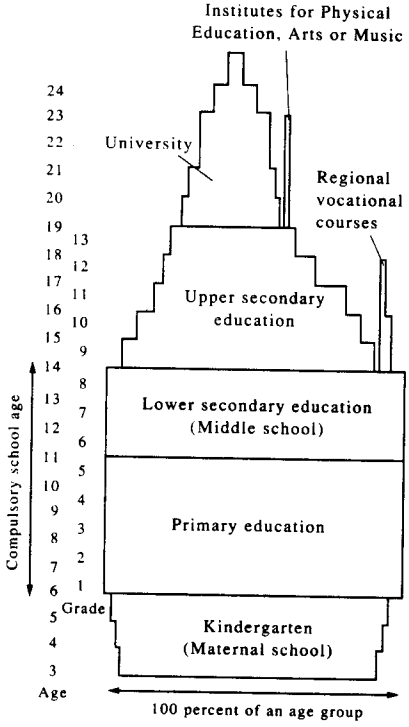
For both kinds of teachers in-service training courses organized by University or teachers' associations are available, covering a lot of areas including scientific subjects, didactics and labwork in science. Continuous in-service training has in fact become compulsory as the participation to courses and similar activities for at least 100 hours every 6 years enables the teacher to achieve (slightly) higher salary levels.

5. Experimental activities by subject matters

(The list of the subject matters depends on the taught subject matters).

1. **Case of chemistry**
2. **Case of physics**
3. **Case of biology**
4. **Case of Earth Sciences**

SCHEMA PRESENTING THE STRUCTURE OF THE ITALIAN EDUCATIONAL SYSTEMS



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SCIENCE TEACHING IN SPAIN

Science teaching prior to Upper Secondary School

In Spain, compulsory education begins at 6 years and finishes at 16 years. Primary school lasts for 6 years and lower secondary school (ESO: Enseñanza Secundaria Obligatoria) lasts for 4 years.

Science in the curriculum and labwork practice

Science is taught at primary school, where it is emphasised during the last two years. The subject matters are taught as 'integrated' science by the same teacher.

During the first two years of lower secondary school, science continues to be taught as integrated science and remains compulsory. Afterwards, during the third year of ESO, science is still compulsory, but is now separated in to physics-chemistry and biology- geology. These two subjects are taught by two different teachers, but when it comes to evaluation it is considered as one subject only giving rise to one mark only. Science is no longer compulsory during the last year of ESO. Pupils can choose it as an option. As in the previous year, biology-geology and physics-chemistry are taught by two different specialised teachers and are assessed by one mark only. Currently efforts are being made to set up technology as a

separate subject matter, in spite of some difficulties. The topics are mostly related to ideas occurring in physics: (electronics, lever and pulley, sometimes to chemistry (plastics, paper etc.).

As for labwork at these levels, its occurrence depends mainly on the teachers' decision. The official instructions require conceptual knowledge and practice to be taught together, and experimental methods to be taught separately. Demonstrations are often performed in front of the whole class.

Evaluation at the end of intermediate school (lower secondary school)

There is no exam at the end of intermediate school. This means that entrance to Upper Secondary School is very open. Another possibility at the end of ESO is vocational training, which starts at an age of around 16 years.

Upper Secondary School

Organisation of the different paths

A reform is currently being put into operation. According to the geographical locations, and the type of schools, the new organisation of Upper Secondary School (named "Instituto") should be completed around 2001. In the new framework, the Upper Secondary School will last 2 years (final two years prior to University). In the current organisation, it lasts for 4 years split into two cycles named BUP ("Bachillerato unificado y polivalente": first three years) and COU ("Curso de orientacion universitaria": final year). As previously explained, pupils enter Upper Secondary School, having possibly already given up learning science. At this level they are presented with four possible paths, from which they choose one right from the first year :

- science and technology
- humanities and social sciences
- biomedicine
- art

In the first section, the number of hours devoted to science during the last year is around 16 hours per week (cf. the table for different countries in the introduction). Specialisation is completed only during the last year when students choose a subset of the four subject matters.

Examination at the end of Secondary School

At the end of Secondary School, if the students have passed the examinations in the different subjects, they can sit the "Selectividad" which is the entrance exam to University. It is entirely written. Only the students in the science and technology section are presented with an examination in science.

Overall it can be said that the type of studies that a student can undertake in University depends on the path he/she followed during Secondary School, and on the mark obtained in the Selectividad. More and more often, the global mark is not the only criterion. In order to promote flexibility, Universities tend to adapt the general Selectividad examination to the different types of studies offered by giving more weight to the marks corresponding to these studies.

Organisation of science teaching

During the first year of Upper Secondary School, sciences are separated in to two domains: physics-chemistry and biology-geology. Both are compulsory for the scientific and technological path. During the last year, it is different, in the sense that the four disciplines are taught separately, and students have the possibility of dropping some of them. This produces a first specialisation.

Official curriculum

In Spain, an official curriculum is defined by the Ministry of Education. It states a core of compulsory topics to be studied and is considered as a minimum. It does not give any rule on how the time should be allocated. This core represents approximately 80 % of the curriculum, the remaining 20 % is left to the initiative of the different regional governments. For instance at the ESO level, the official curriculum is available in the publication B.O.E. (Boletin Oficial del Estado). For example, the 26/6/91 issue of B.O.E exposes, as an annex to the general laws, what is compulsory in the natural sciences. The annex has the following structure:

1 - Introduction - Emphasis is placed on various aspects of teaching.
'The knowledge of the natural sciences implies conceptual and theoretical elements as well as methods of investigation, and the ability to understand the real world and to intervene in it'.
The social dimension of science is emphasised, as well as the necessity to take into account that learning is a constructive process.
2 - General objectives
3 - Contents
The contents are divided into 11 sections (electricity and magnetism, diversity and unity of the living being, chemical changes, etc.). For each section, the headings are :

- concepts
- procedures
- attitudes

4 - Assessment criteria

More details are given below for Upper Secondary School , according to the subject.

Textbooks

The teachers can choose among several textbooks published by private publishers. Usually the authors are groups of teachers, and in some cases University professors participate in the writing.
Few of these books are devoted solely to labwork, due to the aim of ensuring teaching which considers both concepts and practice. Consequently every textbook contains a description of the appropriate experiments.

Experimental activities

In regular teaching, teachers have the possibility to make demonstrations in front of the whole class. They also organise labwork for small groups of students (generally 3 or 4). If possible, labwork is organised for a smaller number of students. Labwork in small groups represents around 10% of the total time devoted to science whatever the level, which means that each student carries out an experimental procedure 5 times a year at the most. The decision to introduce labwork or not depends entirely on the teacher. Labwork is most of the time "classical" guided labwork, mainly in physics. In biology, around 20% of labwork time is

dedicated to open-ended activities. Whatever the case, the intention is to develop a strong link between lessons and experiments.
The teachers draw the experiments mainly from their initial training and their personal experience. But in-service training also exists and the textbooks for students and for teachers strive to present experiments which can be put into practice. Teachers are not using Internet to achieve this. Students are provided with a guide during labwork, which always presents the question to be treated and the theoretical background. When computers are used, which is not frequent, it is mainly for data processing and for simulation. Their use is especially appreciated by biology teachers.
The biology teachers assess the students during labwork and also attach importance to written reports. But physics teachers prefer to ensure assessment through a written report only. This is important for the students' overall assessment. The most frequent criteria involve a detailed discussion of the results and correct data acquisition. It is less frequent to take into account the quality of group work.
In every school there are generally laboratories devoted only to labwork. The safety standards are considered more and more seriously, especially in the official instructions. There are no technicians to provide help. The specific equipment for labwork is designed and sold by private companies. Teachers generally think that the material is not very satisfactory, never mind if it intended for physics or biology experiments. In chemistry it is easier to manage without important funding.
Overall, if teachers refrain from doing labwork it is mainly because of the pressure of time and because of poor equipment. They may occasionally state that experiments take too much time and that they are not sufficiently trained, but these are not the main reasons.

Teachers' training

There are 2 kinds of teacher: Primary School teacher and Secondary School teacher, who have pursued very different studies..
- Primary School teachers hold a University degree after completing 3 years in University (named Diplomado en Magistero).
- Secondary School teachers must have a degree (called "Licenciatura") after completing 5 years at University. At this level, they are specialised in science, generally in two subject areas. Having obtained a "Licenciatura", trainee-teachers must spend several months (around 6) undergoing theoretical training (courses on pedagogy and specific didactics) and practical training (in school). This period is called CAP. The current reform of Education in Spain is also influencing the teacher's initial training, so CAP will be replaced by a slightly different training period called CCP.
CAP is compulsory in order to be enrolled for the exam which allows a student to become a teacher (the exam is called "oposicion"). This exam is partly written, partly oral. The candidate has to give a lesson on a given topic.

In-service training is becoming more and more developed and is proposed more often to teachers.

Case of physics and chemistry

Reference should be made to the chapters concerning physics and chemistry in the BOE dated 21/10/92. After an introduction, general objectives, contents and assessment criteria are given, with the following headings:

GENERAL OBJECTIVES:
- To understand the main concepts of physics (respectively chemistry) ...
- To solve problems originating from everyday life ...
- To use autonomously the strategies specific to investigation ....
- To understand the nature of physics (respectively chemistry) and its limitations ....
- To evaluate the information coming from different sources to form a personal opinion ....
- To understand that physics and chemistry develop in a complex dynamic process ...

CONTENTS:
1 - Approximations in scientific work
2 - Physics (respectively chemistry), technology and society
Afterwards the contents are separated into sections.

ASSESSMENT' CRITERIA

This official text makes clear the principle of giving an actual experimental dimension to physics and chemistry teaching. This is mainly expressed in the 3rd general objective (see above), where special importance is attached to the strategies of scientific investigation and to the procedure involved in carrying out small investigations.
'Objective 3: To apply autonomously the strategies specific to scientific investigation (to pose problems, form and test hypotheses, plan experimental devices, etc.) and to undertake the specific approaches in order to carry out small investigations and, generally, to explore situations and phenomena unknown to students.'
Some more details are given in the first paragraph of the contents:
1 Approximations and scientific work
The processes which constitute the basis for scientific work: to pose problems, form and test hypotheses, design and master experiments, interpret results, be able to achieve a scientific communication, evaluate the uncertainty in measurements, use different sources of information.
Importance of the theories and models with which the investigations are compared.
Attitudes in scientific work, questioning evidence, necessity of proof, rigor and precision, openness to new ideas.

LIFE AND EARTH SCIENCES

The national curriculum for Biology and Geology has the following structure:

Introduction: The introduction focuses on the importance of Biology and Geology in the basic scientific formation of students. Such knowledge considers competence and skills in

direct relation to the scientific method. Natural sciences should therefore introduce students to experimental activities and problem solving.

General objectives: These objectives are basically the following: (1) learning science; (2) learning about science; (3) doing science. The first general goal ensures that students acquire knowledge of basic concepts and laws in Biology and Geology. The second goal teaches students about the complex relationship between science, technology and society. Finally, the third goal helps students to achieve a scientific attitude through knowledge and experience in the experimental method.

Contents: This defines eight basic sections: (1) An approximation to the scientific method; (2) Earth: its origin and evolution; (3) Mankind: origin and evolution; (4) Reproduction; (5) Genetics; (6) Chemistry of life; (7) Earth and its environment; (8) Science-Technology-Society.

Assessment: This involves the following:

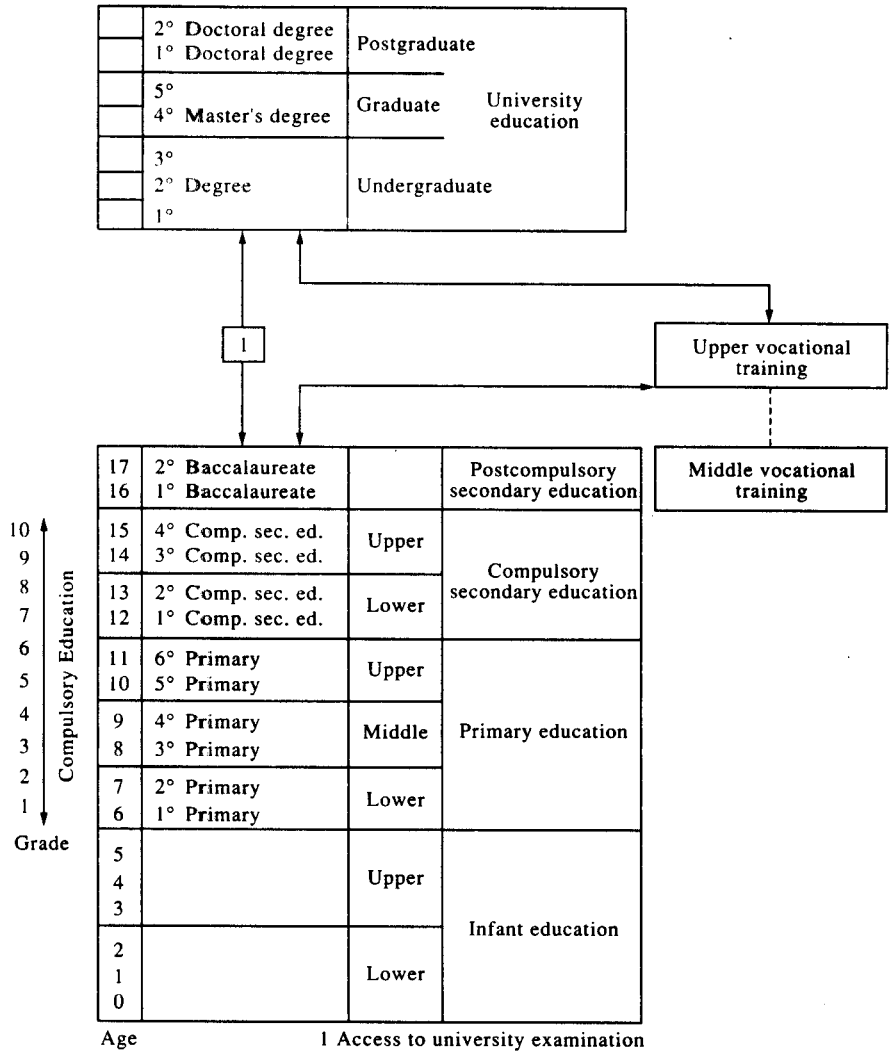
1. Explanation of the characteristics of the Earth based on geological theories.
2. Use of the scientific method to solve problems pertaining to the structure of the Earth.
3. Application of tectonic theory to different geological situations.
4. Application of genetics, mainly the Laws of Mendel, to problems of heredity.
5. Explanation of sexual reproduction and its advantages over other types.
6. Explanation of the processes of animal nutrition.
7. Explanation of the process of neuroendocrine regulation, etc.

At all times, the teacher should encourage the use of the scientific method and the application of new technologies.

Finally, there is a list of suggested labwork that can be accomplished at school. Examples of such activities are the following :

1. Observation, drawing and classification of animals and plants.
2. Manipulation and use of a microscope.
3. Experiments with lipids, vitamins, proteins, etc.
4. Explanation and interpretation of a geological map.
5. Staining and observation of plant and animal tissues/cells.
6. Staining and observation of different kinds of blood.
7. Observation of meiosis and mitosis in onion cells.
8. Drosophila heredity.
9. Chromosome models.
10. Classification of rocks and minerals.

SCHEMA PRESENTING THE STRUCTURE OF THE SPANISH EDUCATIONAL SYSTEMS



Schema from the "International Encyclopedia of National systems of Education". Second Edition
T.Neville Postlethwaite (Ed). Pergamon. (1995)