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Report on Policies and Framework for Inquiry Based Science Teaching (IBST) Across Seven European Countries

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This report has been produced as a part of work package 2 (deliverable 2.1) within the Mind the Gap project, following the activities and national workshops conducted between January 2009 and January 2010 in partner countries. It draws on contextual descriptions of national curricula and policies from each of the seven participating countries (Denmark, France, Germany, Hungary, Norway, Spain and United Kingdom). In the report that follows we draw together some of the central findings regarding national policies and solutions when it comes to how to organize inquiry based science education at lower secondary level across the European countries.

The Work package 2 authors are Kirsti Klette and Doris Jorde, University of Oslo. The report is however leaning on the descriptive analyses that has been provided form each of the participating countries (for more information about the national policy analyses, see list of national reports in the reference list). We would like to thank all the participants in the national workshops for their time and expert contributions, and all the national partners who helped to organize and host the workshops and meetings.

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Oslo, April 2010

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Section One: Summary and Introduction

Summary

- This report shows that the seven analysed European countries provide culturally distinct and rather different institutional infrastructures and contexts when it comes to how science education is organised in the respective countries. National science curricula text for lower secondary education (age 12- 16) provides the baseline for comparisons.

- The analysed countries operate with different models in how they organise science education at lower secondary level. While science education is treated as an integrated discipline at lower secondary level in Norway, science education in Germany is based on the sub disciplines of Physics, Biology and Chemistry from grade 1. France, Spain and United Kingdom use a mixed model, keeping science education integrated up to a certain level (grade 6 or 7) for then specialise into the sub disciplines. Also required teacher competence points to quite distinct models with Norway on the one side of the continuum, setting no subject specification requirements for teaching science education at lower secondary level while subject specification is a prerequisite for teaching science at this level in the six other countries.

- Structural features of the curriculum texts, such as legal status, accessibility and main subject areas in defining science education point to a great deal of similarities across the analysed nationalities. All curricula texts have regulative status and all texts are available on the internet. For most countries a hard copy version is also available. There is a large degree of consensus across the countries in how to define the main subject areas of science education at this level. All curricula texts pay attention (though with different labels) to the four following areas: Organism and health, Chemical and material behaviour, Energy, electricity and radiations and Environment, Earth and universe. The role of technology is especially emphasised in Spain and Norway but not in the other three countries.

- Substantial features of the texts point to both differences and similarities. The analysed texts represent different models in whether learning areas are nationally prescribed or left to the local level to define and interpret. Learning areas are nationally defined (i.e. Länder) in Germany, whereas France, Hungary, Norway, Spain and UK use a combination of nationally defined learning areas supported with spaces for local interpretation.

- Whether learning goals in science education focus on content areas versus competences is another dimension of variation between the analysed countries. Germany specifies learning goals in terms of content areas while Norway and the UK link learning goals to competences. France, Hungary and Spain have both models.

- All countries link inquiry based science teaching (IBST) to skills of argumentation and communication. All countries further link IBST to practical experiments and “hands on” activities. Students’ autonomy is explicitly emphasised in the Danish and UK curriculum text but not in the other countries. Problem based learning and exploratory learning appears in the curriculum texts in all analysed countries but mean rather different things in the different countries. Linguistic and more elaborated in depth analyses in how the different curricula texts understand IBST would enrich this analysis further.

- As a policy framework the UK model is interesting in terms coherence and focus. The role of argumentation and communication, and authentic learning is strongly underscored in the UK curriculum. This is recognised and supported throughout broad generic knowledge areas, required teacher expertise *and* the formulation of science education as generic competences, and with ample room for local interpretations. The role of assessment as central when it comes to science education and “talking science” contributes to that the policy framework stands out as a coherent line of reasoning.

Introduction: Aim and purpose of this report

The key issue in the Mind the Gap project is inquiry-based teaching of secondary school science. The project was designed to gather, exchange, develop and disseminate frameworks and ideas of good practices in inquiry based science teaching across seven European countries. The participating countries were composed to represent a variety of cultures and traditions in the way IBST is realized at the national level (Denmark, France, Germany, Hungary, Norway, Spain & UK). Nordic countries (Norway/ Denmark) represent long traditions of student autonomy and cross disciplinary work in science education while in France, Germany and Spain, models of conceptual and textual comprehension and interpretation have been important models in realising IBST. The United Kingdom has a long tradition of activity based science teaching with a well developed curriculum that supports such teaching. Hungary represents a more traditional culture for science teaching with a keen interest in modernisation.

The aim of this work package (WP2) was to identify and evaluate policies and frameworks of Inquiry Based Science Teaching (IBST) across the seven participating countries. As indicated above the seven countries were selected to provide a variety in how science education is organised and taught and still similar enough to expand our understanding of possible solutions and practices. As a first attempt we will give an overview of policies and curriculum frameworks of IBST across the involved countries and how the different frameworks of IBST might contribute to the promotion of scientific literacy. The following report draws on data and analyses from work within the participating partners in the Mind the Gap project, and with a special focus on policy frameworks for IBST within a European context. The report is organised in five sections. This first section provides a summary and an introduction to the overall aim of the report. The next section (section 2) will give an overview and description of the comprehensive educational system in each of the participating countries. These descriptions will briefly outline the basic structure of schooling in each country and rather shortly touch upon how inquiry based teaching is understood in the respective countries. The third section will report on data and data sources and provide an analytical outline for the comparative analyses that has been performed. In this section we will discuss *why* study frameworks of IBST across Europe and why using lower secondary level as a unit of analyses. Framework and analytical dimensions for comparisons will also be sketched out in section. In section four, findings and possible patterns across the national contexts will be presented. In section five, we conclude with a final line of argumentation regarding how inquiry based lower secondary science teaching is institutionally framed and organised across the European landscape.

Section two: Country descriptions

Denmark

The Education System

Basic Structure of Schooling
According to the Danish Ministry of Education, compulsory education in Denmark includes both one year of kindergarten or pre-primary education and nine years of basic education, in Denmark named Folkeskolen, which equals primary education (grades 1-6) and lower secondary education (grades 7–9). Most institutions offering basic education also offer a voluntary 10th grade. Children start their basic education at the age of seven. The curriculum is comprised of three subject blocks: The humanities, practical/art subjects and science. The science block consists of mathematics (all pupils), science/technology (1st to 6th grade), geography (7th to 9th grade), biology (7th to 9th grade) and physics/chemistry (7th to 9th grade) (Eurydice 2009).

After the 9th or 10th grade pupils can choose to continue with upper secondary education. General upper secondary education is divided into four programmes, three 3-year programmes for pupils with nine years of basic schooling and one 2-year programme for pupils with ten years of basic schooling (Eurydice 2009). One of the core subjects studied at different stages of general upper secondary education is science.

The following link gives a chart picturing the Danish educational system: http://www.dr-bongardt.de/uni/bongardt/archiv/projekte/schule_in_europa/organigram/Danmark.gif

Inquiry Based Science Teaching

Inquiry in the School Curriculum
Aspects of IBST are present in science education in Denmark, but it is not an explicit part of this education and it is therefore difficult to entangle IBST from other parts of this education. Questions about inquiry in the school curriculum are therefore difficult to answer and the presence of inquiry in school seems to depend to a great extent on the individual teacher, and his/her chosen teaching methods.

France

The Education System

Basic Structure of Schooling
Education is compulsory between the age of 6 and 16. From the age of 6-11 pupils attend primary education and from the age 11-15 they attend lower secondary education (Eurydice 2009). The primary school curriculum concentrates to a large extent on the basic skills of reading, writing and arithmetic.

At the age of 15, students can start upper secondary education for three years. Mathematics and physics or chemistry and life and earth sciences are among the core subjects in the first year of upper secondary education.

The following link gives a chart picturing the French educational system: http://en.wikipedia.org/wiki/File:EducationFr.svg.

Germany

Education System

Germany consists of 16 federal states (*Länder*), which are in charge of their own education systems. Thus, Germany has 16 more or less different school systems. Whereas the structure of the individual systems was quite comparable up until the 1970s, it started to be more complex when the comprehensive school was added to the three already existing types of schools (Hauptschule, Realschule, Gymnasium) in some of the federal states. Reforms within the last 10 years have subsequently led to some diversity. Agreements between the federal states and the Federal Ministry of Education ensure that despite differing regulations, examinations and certificates are recognised between the federal states in order to allow people to move freely within the whole country.

Basic Structure of Schooling

Pre-school education in kindergarten is offered from age 3 to 6 and has to be paid by the parents. There are public as well as private institutions. Sometimes, the third year of kindergarten is organised as a pre-school year shifting activities from playing to learning.

Compulsory school lasts for nine years ranging from age 6 to 15. Primary education runs from grade 1 to 4 (in two federal states to grade 6). Core subjects are language, mathematics and – as an integrated subject – social and natural sciences (Sachunterricht). Lower secondary education comprises grades 4 to 9 or 10. Core subjects are mother tongue, a foreign language and mathematics. The sciences are obligatory, mostly taught as individual subjects (biology, physics and chemistry) but regarded as minor subjects.

After finishing primary school the pupils are distributed to different types of schools having different curricula, leading to different school leaving certificates and different career choices. The transition to the respective school type should depend on the performance of the pupils. In half of the federal states the decision follows the recommendation of the school, in the other half the parents decide.

On average, about 20% of German pupils join Hauptschule ranging from 0 to more than 30% in the different federal states. This proportion has been decreasing for more than 50 years. Science topics are mainly from biology and physics. On finishing Hauptschule after grade 9 (some federal states have an optional 10th grade) with sufficient marks, pupils get a leaving certificate that allows them to apply for vocational training in less prestigious professions.

On average roughly 30% of the pupils go to Realschule. This proportion has been quite stable since the 1980s. Compared to Hauptschule more lesson time is devoted to science subjects. The leaving certificate after grade 10 allows for applying for more prestigious jobs.

The Gymnasium is the only secondary school type present in all 16 federal states. Around 35% of the pupils in Germany go to Gymnasium. During the last 50 years this proportion has more than doubled. Attending a Gymnasium is the most promising way to move on to higher education and academic careers. By now, all federal states offer the certificate of this school track (Abitur) after 12 years of schooling (formerly 13 years). It allows pupils to move to higher education and especially to universities. Science subjects are compulsory throughout the lower secondary level. At upper secondary level it is possible to choose between biology, chemistry and physics.

About 16% of the students enter secondary schools offering more than one of the above-mentioned certificates or having several tracks in one institution. In some of those, Abitur can be achieved after 13 years of schooling.

Theoretically, the possibility exists to move between the different school tracks. Reality however, shows that transfers are mainly directed downwards towards less prestigious school types.

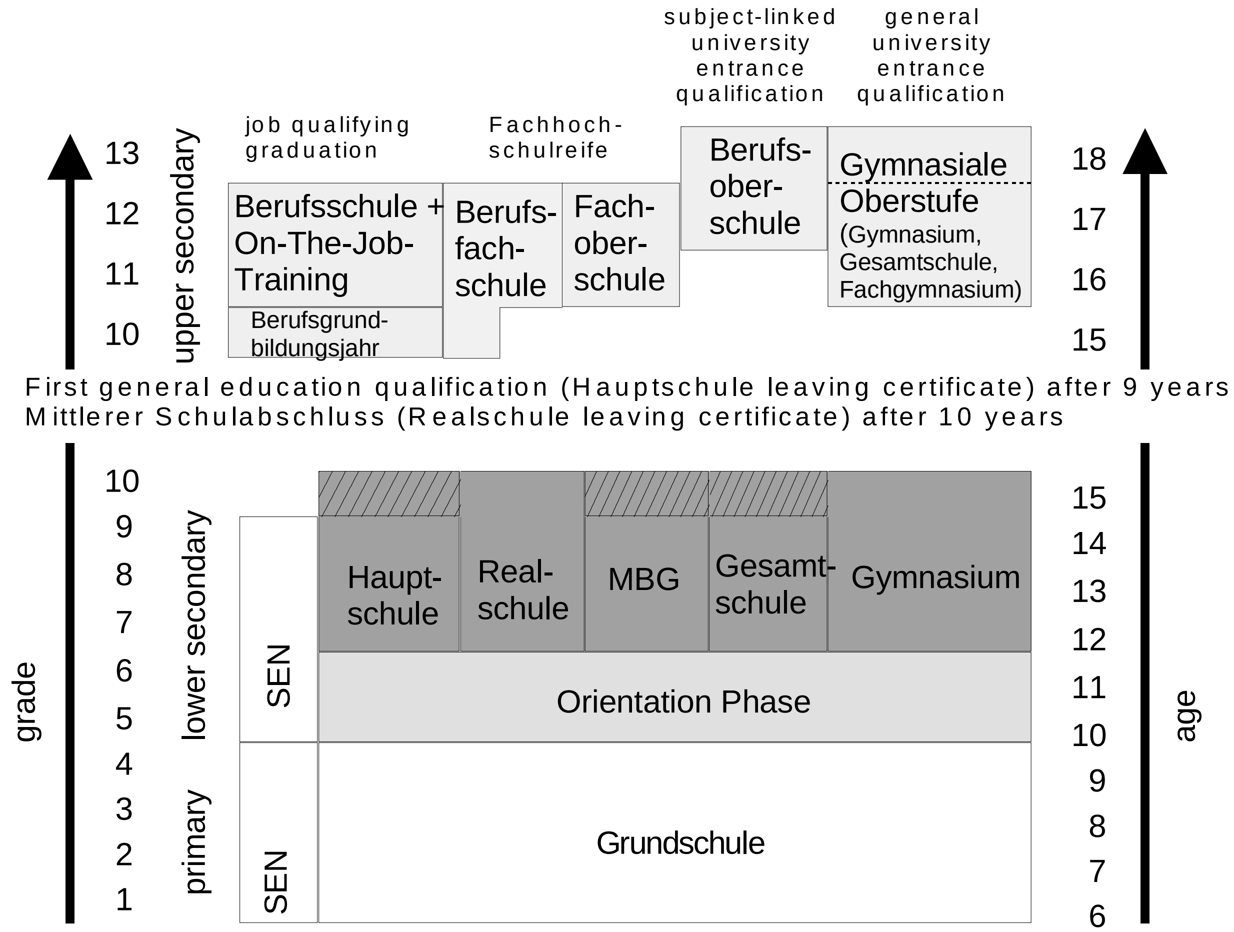

Fig.1 The German Educational System

Inquiry Based Science Teaching

Inquiry in the School Curriculum

Germany has no national curriculum. There are at least 16 (federal states) x 4 (school types) curricula. Some of them are quite traditional, i.e. they prescribe in great detail the content, experiments and the methods of science lessons at each grade level. Sometimes influenced by SINUS, but more by the national educational standards, curricula are currently changing towards a competency orientation. Since epistemological questions (how knowledge in science is developed), communication and assessment of scientific knowledge are three of the four competence areas, many aspects of inquiry-based teaching have entered these new curricula.

However, classroom reality has still to follow the changes in the curricula and there seems to be a lack of support for teachers to adopt and develop the required teaching style. Many teachers cite the need to cover overcrowded curricula as a barrier to introducing inquiry-based methods.

In Germany there are more than 200 pupil laboratories, mostly at universities but also at research institutions and major companies. They offer pupils from all ages – in groups or as a whole class – the possibility to visit an authentic environment and conduct experiments. In some of them, pupils are conducting real research.

Hungary

The Education System

The year 1995 brought major changes in the educational system of Hungary. The new National Curriculum introduced in that year was written according to the concept of competency-based learning, rather than the traditional knowledge-based teaching. Although it did not use the term "scientific literacy", the basic idea was already there. Since then the National Curriculum has been changed several times and the Hungarian expression "természettudományos műveltség", which is (roughly) the equivalent of the scientific literacy has appeared explicitly in it. Its latest version [implemented in 2007, see No. 202/2007. (VII. 31.) modifying the No. 243/2003. (XII. 17.)] contains the concept of lifelong learning and the 8 key competences considered to be crucial for that [based on the following document: "*Recommendation of the European Parliament and of the Council of 18 December 2006 on Key Competences for Lifelong Learning* (2006/962/EC)].

The National Curriculum sets the goals for teaching students (age 6-18) in schools in wide terms and speaks about knowledge to be learnt and competencies to be developed at certain territories of knowledge by the age of 10, 12, 14, 18 years. These general requirements were matched against the themes and topics taught in each subject year by year. These latter documents are called "frame curricula" of the various subjects [first introduced by the government in 2000, No. 28/2000. (IX. 21)] that have to be accredited (acknowledged) in an official process by a professional body. They also describe what the students should know in the given subject (e.g. chemistry) after finishing the school year.

Inquiry Based Science Teaching

Inquiry in the School Curriculum

At present secondary schools in Hungary work with their local science curricula that is accepted by their maintainer (mostly local government authorities) and checked by the Ministry of Education. These local curricula must harmonise with the national core curriculum – however the official versions of frame curricula only mean a recommendation therefore the system is extremely diverse such as the everyday classroom practice.

Networking within and between schools is not common, which means that even the best examples are really isolated.

We can assume that at presence teaching science is either compete-driven or has a high level of avoidance – in latter schools stakeholders are "fighting for survival" (on the students' side: to pass the requirements, on the parents' side: to support students with a number of tutoring, on the management's side: to meet different expectations, finally on the teachers' side: to keep their job.

IBST is not directly represented in the core curriculum as the present epistemology in Hungarian literature still gave no explicit translation for the term. The word inquiry is represented several times in the text describing the cultural domain "Man and Nature". Despite differences it is also substituted by such terms as project based approach, research based teaching or problem base learning. Besides language differences and difficulties in translations another reason can be that Hungary had been isolated from other European countries till the past decades and it takes time to mainstream pedagogy to establish exact epistemology and introduce it to professionals. This phenomenon can also be observed in some frame curricula (for example the new integrated science one) where the terms problem and inquiry based approach seem to be interchangeable.

The core curriculum does not aim to pass on direct recommendations to teachers but it does contain certain elements which suggest on the proposed methodology. This way IBST can be found in many places within the core curriculum.

Norway

The Education System

Basic Structure of Schooling

In Norway pupils attend 10 years of compulsory education, from the age of 6 to the age of 16. This includes both primary education (grades 1-7) and lower secondary education (grades 8-10). Among the mandatory subjects at these levels we find mathematics and natural science.

At the age of 16, after having finished compulsory education, pupils may start their upper secondary education, choosing the academic/general programme or the vocational programme. The former is a three-year programme qualifying students for acceptance to higher education. Pupils attending the vocational programme who would like to qualify for higher education may either attend a fourth year or change programmes after the second year, and follow supplementary studies the third year. Norway has a national curriculum for grades 1-13. Mathematics is compulsory both the first (Vg1) and the second (Vg2) year of the general upper secondary education programme. According to the mandatory guidelines there are two mathematics subjects for Vg1 and Vg2; curriculum T and curriculum P. The former is more theoretically oriented, whereas the latter is more practically oriented. Natural science is compulsory only for the first year (Vg1). For the second and third year the natural science subjects are elective and go from being integrated subjects to being organized according to discipline (biology, chemistry, physics and recently earth science/geology).

For those pupils choosing a vocational upper secondary education, mathematics and natural sciences are obligatory in the first year. However, the curriculum is not the same, as these pupils have three fifths of the mathematical curriculum for Vg1P or Vg1T and only parts of the natural sciences curriculum for Vg1.

Inquiry Based Science Teaching

Inquiry in the School Curriculum

Inquiry in Norwegian natural science teaching has been given a boost with the subject area “the budding researcher”, introduced as a part of the curriculum by the Knowledge Promotion reform of 2006. This subject area deals with natural science methodologies for developing knowledge which involves the formulation of hypotheses, experimentation, systematic observation, openness, discussions, critical assessment, argumentation, grounds for conclusion and presentation.

"The budding researcher" is introduced in the first grade and accompanies the pupils all through primary; lower upper secondary and upper secondary school, even though the name changes after Vg1 to "the young researcher".

One of the challenges with "the budding researcher" is that teachers do not necessarily have the skills to use IBST in the classroom, as IBST demands not only methodological skills but also subject knowledge and confidence in one's own subject knowledge (Pedagogical Content Knowledge). The lack of subject knowledge in the natural sciences is therefore a common challenge and an obstacle for the use of IBST in the classroom.

The budding researcher is clearly a part of the intended curriculum, but it is difficult to estimate how much of this is actually being implemented in Norwegian schools.

Spain

Education System

Basic Structure of Schooling

The compulsory education in Spain consists of primary and lower secondary education. Children attend primary education from the age of 6 to the age of 11, i.e. grades 1-6. The lower secondary education includes grade 7 through 10 (ages 12 – 15). After the 10th grade pupils can continue with upper secondary education or "Bachillerato" for two years. This is a non-compulsory education, but is required for those who wish to continue with higher education. The table below gives a summary of the Spanish educational system.

Table 1: The Spanish educational system

Age	Grade	Year	Stage	Character
		Doctoral programme 5th (and 6th) Master 1st-4th Grade		
17	12	2nd year "Bachillerato"	Upper Secondary (1)	Not Compulsory
16	11	1st year "Bachillerato"		
15	10	4th ESO	Lower Secondary (ESO) (2)	Compulsory
14	9	3rd ESO		
13	8	2nd ESO		
12	7	1st ESO		
6-11	1-6	1st – 6th Primary Education	Primary Education	

Vocational training is an option to academic "bachilleratos". It starts at 16 for two years (intermediate grade vocational training), and may continue on higher grade vocational training.

(1) ESO: "Educación Secundaria Obligatoria" (Compulsory Secondary Education)

With regards to the curriculum, the Ministry of Education designs the guidelines for the national curriculum, and then the development for each programme and subject is agreed between the universities and the Departments of Education in each of the 17 autonomous regions in Spain.

Inquiry Based Science Teaching

Inquiry in the School Curriculum

There are explicit references to IBST issues in the curriculum frameworks of both primary and secondary school. Regarding IBST dimensions such as problem based learning, argumentation, communication and other strategies for IBST (i.e. as defined within this Mind the Gap project), a reference search was made in the Secondary Spanish and Galician Decrees. Besides some references in the competencies and objectives sections, there are references to IBST (for instance, "strategies for problem-solving", "argumentation using scientific method", "critical thinking", "communication of science", and "media as a source of information about nature" and "STS perspective") in the content list for all secondary years. These are meant to be taught mainly in a subject area (content block) related to scientific work and practices.

United Kingdom

Education System

Basic Structure of Schooling

Compulsory education in UK is divided into four key stages (KS) (see table below). The first one includes grade one and two, for pupils aged 5-7. The second key stage includes grade 3 through 6 (age 7-11), and the third key stage includes grades 7-9 (age 11-14). In the first KS pupils are subject to national tests and tasks in English and mathematics. In KS 2 and 3, national tests are arranged for the subjects English, mathematics and science. In 10th grade some pupils take their General Certificate of Secondary Education (GCSE), but most pupils take GCSEs or other national qualifications in the 11th grade. From the age of 16 pupils may attend post-compulsory education.

According to the University of Bristol (Erduran & Yan, 2008) science is taught generally at KS3 and distinctly at KS4 and A-levels. Science is a part of a comprehensive educational model up to the age of 16. Specialization starts in year 12, i.e. the first year of post-compulsory education.

Table: The Education system in England (Source: Erduran & Yan, 2008)

Age	**Stage**	**Year**	**Test/Qualifications**
3-4 **4-5**	Foundations	Reception	n/a
5-6 **6-7**	Key Stage 1	Year 1 Year 2	National tests and tasks in English and mathematics
7-8 **8-9**	Key Stage 2	Year 3 Year 4	National tests in English, mathematics and science

9-10 **10-11**		Year 5 Year 6	
11-12 **12-13** **13-14**	Key Stage 3	Year 7 Year 8 Year 9	National tests in English, mathematics and science
14-15 **15-16**	Key Stage 4	Year 10 Year 11	Some children take GCSEs Most children take GCSEs or other national qualifications
16-17 **17-18** **18-19**	Post-compulsory education/or training	Year 12 (College year 1) Year 13 (College year 2)	Learning programmes leading to general, vocationally-related and occupational qualifications for example A-level, vocational A level, NVQ, modern apprenticeship

The following link gives a chart picturing the educational system in UK: http://www.dr-bongardt.de/uni/bongardt/archiv/projekte/schule_in_europa/staaten/england.htm.

Inquiry Based Science Teaching

Inquiry in the School Curriculum

According to the University of Bristol (Erduran & Yan, 2008) inquiry has been integrated in the national curriculum. For key stage 3, the national curriculum addresses the importance of science education and learning goals using IBST: The study of science fires pupils' curiosity about phenomena in the world around them and offers opportunities to find explanations. It engages learners at many levels, linking direct practical experience with scientific ideas (problem based learning). Experimentation and modelling are used to develop and evaluate explanations, encouraging critical and creative thought (hands-on activities). Pupils learn how knowledge and understanding in science are rooted in evidence. They discover how scientific ideas contribute to technological change – affecting industry, business and medicine and improving quality of life. They trace the development of science worldwide and recognise its cultural significance. They learn to question and discuss issues that may affect their own lives, the directions of societies and the future of the world (argumentation and communication).

More specifically, Key Stage 3 curriculum requires pupils to have:

1) Practical and enquiry skills

Pupils should be able to use a range of scientific methods and techniques to develop and test ideas and explanations [problem based learning]; assess risk and work safely in the laboratory, field and workplace; plan and carry out practical and investigative activities, both individually and in groups (hands-on activities).

2) *Critical understanding of evidence*

Pupils should be able to obtain record and analyse data from a wide range of primary and secondary sources, including ICT sources, and use their findings to provide evidence for scientific explanations; evaluate scientific evidence and working methods [hands-on activities].

3) *Communication*
   Pupils should be able to use appropriate methods, including ICT, to communicate scientific information and contribute to presentations and discussions about scientific issues [argumentation and communication].

Section three: Data sources and analytical design

This section will give an overview of data and data sources and provide an analytical design for comparing policy frameworks across the participation countries.

Since all participating countries have national curricula we used those texts as a baseline for comparisons. In some countries additional texts[1] were analysed for the reasons of supplementary information. In the discussion that follows we will however restrict our analyses to the national curricula texts from the participating countries as a chain of lenses to discuss how science education is organised across cultural and national contexts.

We use lower secondary level as a unit of analyses covering the ages of 12-16 in most countries. In some of the countries secondary level starts at the age of 11-12 (France) while in other countries (Norway), secondary education begins at the age of 13[2]. Nevertheless lower secondary level includes pupils between the ages of 12 and 15 in all participating countries

Grade/ Key st	1	2	3	4	5	6	7	8	9	10	11	12	13
Age	6	7	8	9	10	11	12	13	14	15	16	17	18

Why using lower secondary level as a viewpoint for discussing issues and challenges for science education?

Lower secondary level is interesting for two reasons. From a vast research literature we know that science at this level is taught with approaches that focus on transmission and outcomes and with little emphasis on relevance to real world science or to future career possibilities (Cuban 1993, Driver 1983, Goodlad 1984, Lemke 1990, Mortimer & Scott 2003, Schmidt, Jorde et al. 1996). Secondary science is a critical subject offering for students since in many countries it is a prerequisite for further studies in science. In addition, secondary science will be the last science taught to many students so it becomes a valuable component of scientific literacy. In both cases (scientific literacy for all argument and future scientist argument) we need however to recognise the need for changing the way science is being taught throughout Europe if we are to acknowledge the increasing need to promote scientific literacy for huge groups of young people as well as to make studies and careers in science and technology attractive for young people.

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[1] In Spain for example they used policy texts such as Royal Decree 2006 (1631/2006) as well as national curricula texts. Regional texts such as the regulative text for ESO Galicia (the Decree 133/2007 of July 5th, 2007,) have additionally been analysed.

[2] In Denmark, France and Spain lower secondary level covers grades 7,8,9 (age 12-15) while lower secondary starts at grade 6 in Germany (11-12 years old) and in grade 8 (13 years old) in Norway. Key stage 4 (UK) covers the ages between 14 and 16.

National curricula as a base line of analysis

All participating countries had national curricula as regulative bases and framework for the science education being taught. An analysis of policies and curriculum frameworks of IBST in the participating countries were therefore performed for each country[3]. The national analyses paid attention to the following analytical dimensions:

i) Structural features regarding how science education is organised in each country such as:

- required teacher competence for teaching science at this level (lower secondary level)
- whether science is treated like an integrated or disciplinary organised school subject
- amount of hours (= 60 minutes) per week regulated for science education in the different countries

ii) Structural features of the curriculum texts such as:

- legal status of the curriculum text
- how to get access to the text (Hard copy/Internet)
- main subject areas that define science curricula at this stage

iii) Substantial features of the curriculum texts such as:

- whether the curricula is nationally versus locally defined and interpreted
- whether the curricula goals focus on competences or content issues (i.e. competence versus content curriculum)
- how the curricula texts fits with the different understandings and interpretations of inquiry based science teaching.

[3] For the respective country analyses, see list of national reports in the reference list

Section four: Findings and results

The following patterns and results are based on policy analyses from respectively Denmark, France, Germany, Hungary, Norway, Spain and the United Kingdom.

Vocabulary for age/ grade (key stage) in the different countries

As indicated above the notion of lower secondary education refers to different age groups in the analysed countries. While primary level covers grades 1- 4 in most countries, and upper secondary at least covers grade 11 and grade 12, lower secondary covers the span of grades 5-10 in the analysed countries. Whether the students start schooling at the age of five (UK), the age of six (Spain, France, Hungary, Germany and Norway), or the age of seven (Denmark), makes comparison between the countries even more problematic. Despite differences in time span, lower secondary includes however, in minimum, the ages between 13- 15 in all analysed national contexts. We will therefore use the years between 13- 15 as a base line for comparison. The below table indicate differences in how lower secondary level is defined in the different countries:

Table

	Grade Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13
UK		5	6	7	8	9	10	11	12	13	14	15	16	17	18
Spain			6	7	8	9	10	11	12	13	14	15	16	17	18
France			6	7	8	9	10	11	12	13	14	15	16	17	18
Germany			6	7	8	9	10	11	12	13	14	15	16	17	18
Norway			6	7	8	9	10	11	12	13	14	15	16	17	18
Denmark			7	8	9	10	11	12	13	14	15	16	17	18	19
Hungary			6	7	8	9	10	11	12	13	14	15	16	17	18

Structural features regarding how science education is organised

Science treated as integrated or a disciplinary knowledge area?

The analysed countries operate with different models in how to organise science education at lower secondary level. While science education is treated as an integrated discipline at lower secondary level in Norway, science education in Germany is based on the sub disciplines of Physics, Biology and Chemistry from grade 1. France Spain and United Kingdom use a mixed model, keeping science education integrated up to a certain level (grade 6 or 7) for then specialise into the sub disciplines.

The following figure can illustrate:

Integrated/ Disciplinary organisaiton:

No (10th) Sp (7-8th) Fr (7th /6th),

Dk (7th), UK (KS4) Hu, Ge (7th)

Integrated Disciplinary organisation

Required teacher competence

Also required teacher competence points to quite distinct models with Norway on one side of the continuum, setting no subject specification requirements for teaching science education at lower secondary level while subject specification is a prerequisite for teaching science at this level in the four other countries. Denmark, as a part of the Nordic general teacher tradition, is close to Norway regarding required teachers' disciplinary competence.

No, Da UK, Sp, Fr, Ge, Hu

No subject *Subject specification*

Specification required *required*

Hours spent on science education per week

The estimated hours spent on science education is an important way of paying attention to science and scientific literacy. The estimated amount of required hours varies between 3 – 5 hours per week across the analysed countries, with Norway spending the least amount of hours (3) and most others up to 5.

Structural features of the curriculum texts

Structural features of the curriculum texts, such as legal status, accessibility and main subject areas in how to define science education, point to a great deal of similarities across the analysed nationalities. All curricula texts have a regulative legislative status, and all texts are available on the internet. For most countries a hard copy version is also available.

For the case of Norway – the national curriculum has only been available as an online version since 2008. Denmark is almost in a similar position although still with some printed versions obtainable. Whether the text is accessible through online resources or as factual book seems to have huge implication for teachers' way of interpreting and enacting upon the curricula plans. When accessing the science curriculum in Norway for example, the teachers are introduced to an interactive room, and where the *factual* curriculum texts, and different versions and copies of the *reception* of the curriculum text are played out in a horizontal, non- hierarchal landscape. Science teachers' capacities to evaluate and differentiate between the different curricula receptions and interpretations are beyond the limits of this investigation. Substantial disciplinary knowledge seems however to be a central prerequisite for such professional judgements and evaluations.

Main subject areas

There is a great consensus across all six countries in how to define the main subject areas of science education. All curricula texts pay attention (though with different labels) to the four following areas: Organism and health, Chemical and material behaviour, Energy, electricity and radiations and Environment, Earth and universe. The below list of topic areas from respectively UK and Norway can serve as an illustration:

UK:	*Norway:*
Organism and health	Body and health
Chemical and material behaviour	Phenomena/Substances/elements
Energy, electricity and radiations	Technology and Design
Environment, Earth and universe	The Universe

The role of technology is especially emphasised in Spain and Norway but not in the other four countries. Scientific methods and scientific thinking (generally and disciplinary specific) are strongly underscored in the Spanish and Danish curriculum text, both as a generic competence (Spain) as well as linked to the different subdisciplines (Denmark: '…methods and ways of thinking in geography'). The notion of "The budding researcher" in the Norwegian science curriculum is yet another way of conceptualising the role of inquiry and investigation as central to science education. "The budding researcher" should accompany all science teaching in Norway according to the national curriculum. Assessment as central to science learning is explicitly underscored in the English curriculum.

Substantial features of the curriculum texts

Substantial features of the texts point to both differences and similarities. The analysed texts represent different models in whether learning areas are nationally defined and prescribed, or left to the local level to decide on.

Nationally prescribed vs locally interpreted learning areas?

Most countries use a combination of nationally (or regionally) prescriptions of knowledge areas formulated in broad terms, and which give rooms for - or require - local interpretations. In Denmark general aims are laid down on the national level while the main subject areas are supposed to be defined at the local level. In Germany, representing the other side of the spectrum, learning areas are defined regionally (i.e. Länder). France, Hungary, Norway, Spain, and UK have a combination of nationally defined learning areas supported with spaces for local interpretation. The below figure can illustrate:

Dk No, Fr, UK, Hu Sp Ger,

←――――――――――――――――――――――――――――――→

Local interpretations *Nationally prescribed*

Content driven or competence driven curricula?

Whether learning goals in science education focus on content areas versus competences is another dimension of variation between the analysed countries. Germany specifies learning goals in terms of content areas while Norway and UK link learning goals to competences. France, Spain and Denmark have 'a both and' model.

UK, No Fr, Sp, Hu Ger

←――――――――――――――――――――――――――――――→

Competence driven *Content driven*

Definitions of Inquiry Based Science Education

Inquiry based science education is not a very clear cut and distinct concept and it might be argued that there is no correct definition or unified concept for inquiry based learning methods in science education. Generally the concept refers to learning and instruction designs that engage students in active and authentic problem solving activities that pay attention to diagnosing problems, critiquing experiments, distinguishing alternatives, planning investigations, researching conjectures, searching for information, constructing models, debating with peers, and forming coherent arguments (see for example Linn et al., 2004, Anderson 2006). In our analyses we have distinguished between four dimensions of inquiry based science teaching:

i) authentic and problem based learning activities where there may not be a correct answer (problem based learning)

ii) a certain amount of experimental procedures, experiments and "hands on" activities, including searching for information ("hands on" activities)

iii) self regulated learning activities where students' autonomy is emphasised (student's autonomy)

iv) discursive argumentation and communication with peers (argumentation and "talking science")

The four dimensions were not designed to be mutually excluding, and the curricula texts might pay attention to all of them in different ways.

The analyses show that all country curricula texts link inquiry based science teaching (IBST) to skills of argumentation and communication. All countries further link IBST to practical experiments and "hands' on activities. Students' autonomy is explicitly emphasised in the Danish and UK curriculum text but not in the other countries. Application of science to everyday problems is argued in the Danish curricula text but not so strongly in the other countries' text. Problem based learning and exploratory learning appears in all seven curriculum texts analysed but imply rather different things in the different textual descriptions. While the Spanish text underscore "strategies for problem solving" as central to define problem based learning, the French text pay attention to "choice of problematic situations". In the UK texts authentic learning and to "learn how science works" are emphasised while application of science to everyday problems is central to the Danish understanding of problem based learning. "The budding researcher" is the baseline for the Norwegian curricula understanding of problem based learning. Linguistic and more elaborated in depth analyses in how the different curricula texts understand and define the different notions of IBST would here enrich the analyses further.

Country/IBST	**Problem based learning**	**Argumentation & Communication**	**'Hands on'**	**Students' Autonomy**
Denmark	**x**		**x**	**x**
Germany	**X** Exploratory learning Inquiry based learning	**x**	**X** Acting based learning	
France	**x** 'Choice of problematic	**X**	x	

	situation'			
Norway	**x**	**x**	**x**	
Spain	**X** ' strategies f problem solving'	**x**	**x**	
UK	**x** Authentic learning "How Science works"	**x**	**x**	**X**
Hungary	**x**	**x**	**x**	

Section five: Conclusive discussion

How science education at lower secondary level is structured at the national level has huge implications for students' possibilities for a future career in science and technology as well as to be scientifically literate. The seven European countries provide culturally distinct and rather different institutional infrastructures and contexts when it comes to how science education is organised in the respective countries at this stage. The Norwegian curricula text gives ample room for teaching science as an integrated discipline and provides grounding for science as a tool for problem solving and applications to everyday settings. The lack of expertise and scholarship regarding teachers required competence might however counteract these ambitions. To be specific on required teacher competence when it comes to science teaching relevant for this age group might be a prerequisite and necessity to be able to perform and produce stimulating science education learning environments able to produce students well equipped for a future career in science and technology. The policy frameworks of France, Germany, Spain, Hungary and UK on the other hand place clear standards when it comes to required teacher education for teaching science at this stage. Adequate time resources (such as hours spent on science education per week) are subsequently of critical importance, and also at this point we recognise huge variations between the seven countries. Regarding features of how science education is organised we might conclude that the seven countries analysed provide distinct different institutional features for producing learning environments when it comes to inquiry based science teaching.

When it comes to how the curricula texts are organised and structured there are however many similarities such as the form and status of the texts as well as the central knowledge areas acknowledged within the texts. From a European outlook it seems like there is a strong consensus regarding recognised central knowledge areas for this level and stage of science education (Body and health, Chemical and material behaviour, Energy and electricity, and Environment, Earth and the Universe are identified as the four core areas for science education in the curricula in all seven countries). To understand scientific thinking and how "science works" are appreciated to be central for science education at this stage in all seven analysed countries. Interesting enough these rather broad and generic knowledge areas are to be realized within a disciplinary mode of science learning in most countries (Hungary, Germany, France, Denmark, UK and Spain) while as within an integrated model in Norway. The integrated model for science education, as recognised from the Norwegian curriculum text, seems however more coherent and relevant as policy tools to fulfill these rather broad and generic knowledge ambitions. The critical role of assessment and assessment tools are emphasised in the English curricula texts but not in the others.

Substantial features of the designation of the respective curricula texts produce yet another pattern. All countries, accept Germany, subscribe to a model where they combine nationally prescribed knowledge domains with local interpretations and definitions. The curricula texts differ however when it comes whether the learning goals, as inscribed, are content defined or competence defined. Germany is found on one side of this continuum, paying attention to learning goals as content driven, while UK and Norway are found on the other side of the continuum, with a focus on competences. Denmark, France, Hungary and Spain draw on the both versions (both nationally and locally defined *and* content and competence) in how they have designated their learning goals.

All curricula text pay attention to argumentation and “hands on activities” as central to how they define inquiry based learning. UK strongly emphasise argumentation and communication and the role of students ‘ autonomy when it comes to produce inquiry based learning situations in science. Inquiry learning, authentic learning, exploratory learning are emphasised in all curricula texts, but the concepts and labels used are rather indistinct, whereas a more rigid and detailed analytical approach would be valuable.

Taken together the different policies and curricula frameworks might contribute to and produce different environments for inquiry based science learning. Germany stands out as the most traditional model in how science education is organised and treated structurally (required teacher expertise, hours spent on science education, science treated as a integrated versus a disciplinary organised school subject) and substantially (goals nationally (i.e Länder) prescribed, and formulated as content areas). Norway on the other hand has the least regulated and prescribed curricula, in terms of disciplinary areas, hours estimated for science education, and required teacher expertise.

As a policy framework the UK model is interesting in terms coherence and focus. The role of argumentation and communication, and authentic learning is strongly underscored in the UK curriculum. This is recognised and supported throughout broad generic knowledge areas, required teacher expertise *and* the formulation of science education as generic competences, and with ample room for local interpretations. The role of assessment as central when it comes to science education and “talking science” contributes to that the policy framework stands out as a coherent line of reasoning.

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List of national reports available on the Mind the Gap webpage :

http://www.uv.uio.no/english/research/projects/mindingthegap/index.html

Denmark: Jens Dolin: Policies and Framework of IBST, Denmark

France: Andree Tiberghien: Policies and Framework of IBST, France

Germany: Tina Seidel, Katrin Lipowski and Katharina Schwindt: Policies and Framework of IBST, Germany

Hungary: Monica Reti: Policies and Framework of IBST, Hungary

Norway: Anne Kristine Byhring and Kirsti Klette: Policies and Framework of IBST, Norway

Spain: *Maria Pilar Jimenez-Aleixandre and Juan Ramon Gallastegui Otero:* Policies and Framework of IBST, Spain

United Kingdom: *Sibel Erduran and Xiaomei Yan:* Policies and Framework of IBST, UK

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