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Mind The Gap WP3

3.1 and 3.2 **A comparative study of IBST for scientific literacy in Denmark, The United Kingdom and Hungary** with the collection of examples of good practice (see 3.2)

To fulfill this deliverable, the WP3 partners from Denmark, England/Wales and Hungary compared and contrasted their respective national versions of Scientific Literacy and how they facilitate Inquiry Based Science Teaching. After identifying comparable national statements, they grounded these conceptualizations with each nation's idiomatic cultural and historic influences on Scientific Literacy. To make the statements more comparable, they then created weighted concept maps of the statements. Finally, they looked for opportunities within the statements for Inquiry Based Science Teaching and collected examples of inquiry teaching in all three countries which reflect scientific literacy statements.

Comparable National Statements

Following are the statements of scientific literacy which our workpackage partners (Denmark, England/Wales, Hungary) decided were sufficiently representative of our different perspectives on what a scientifically literate citizen should be able to do and know.

Denmark

Danish Scientific Literacy Statements

The student should realise the significance of knowledge of scientific thinking
The student should realise the significance of understanding scientific thinking
The student can relate to scientific knowledge's strengths
The student can relate to scientific knowledge's limitations
The student has achieved knowledge of some central scientific issues
The student has achieved knowledge of some key scientific issues' societal perspectives
The student has achieved knowledge of some key scientific issues' ethical perspectives
The student has achieved knowledge of some key scientific issues' historical perspectives
The student can express a knowledge based opinion about issues with a scientific aspect
The student can express a knowledge based opinion about problems with a scientific aspect
The student is curious towards the scientific field
The student is engaged in the scientific field
The student can carry out practical investigations in the laboratory to establish simple hypotheses
The student can carry out practical investigations in the laboratory to assess simple hypotheses

The student can carry out practical investigations in nature to establish simple hypotheses
The student can carry out practical investigations in nature to assess simple hypotheses
The student can carry out observations in the laboratory to establish simple hypotheses
The student can carry out observations in the laboratory to evaluate simple hypotheses
The student can carry out observations in nature to establish simple hypotheses
The student can carry out observations in nature to assess simple hypotheses
The student can use models which qualitatively describe simple relationships in nature
The student can use models that quantitatively describe simple relationships in nature
The student can see the possibilities of models which qualitatively describe simple relationships in nature
The student can see the possibilities of models which quantitatively describe simple relationships in nature
The student can see the limitations of models which qualitatively describe simple relationships in nature
The student can see the limitations of models which quantitatively describe simple relationships in nature
The student can communicate a scientific topic with correct use of professional concepts
The student can put in to perspective the scientific subjects' contribution to technological development through examples
The student can put in to perspective the scientific subjects' contribution to social development through examples
The student can work actively with scientific issues
The student can participate in dialogues with correct use of professional concepts
The student should work with various forms of written work with a clear progression in the requirements towards a final written product
The student can use ICT tools in written work
The student can use ICT tools when processing measurement data
The student knows of examples of computer modeling

England/Wales

England/Wales Scientific Literacy Statements

The student can collect scientific data
The student can analyse scientific data
The student understands how creative interpretation of data provides evidence to test ideas
The student understands how creative interpretation of data provides evidence to develop theories
The student can use scientific theories to develop explanations of many phenomena
The student can use scientific models to develop explanations of many phenomena

The student can use scientific ideas to develop explanations of many phenomena
The student is aware that there are some questions that science cannot currently answer
The student is aware that there are some questions that science cannot address
The student can plan to test a scientific idea
The student can plan to answer a scientific question
The student can plan to solve a scientific problem
The student can collect data from primary & secondary sources
The student can collect data using ICT sources
The student can collect data using ICT tools
The student can work accurately when collecting first-hand data
The student can work safely when collecting first-hand data
The student can work individually when collecting first-hand data
The student can work with others when collecting first-hand data
The student can evaluate methods of collecting data
The student can consider the validity of methods of collecting data as evidence
The student can consider the reliability of methods of collecting data as evidence
The student can recall scientific information
The student can recall scientific ideas
The student can analyse scientific information
The student can analyse scientific ideas
The student can interpret scientific information
The student can interpret scientific ideas
The student can apply scientific information
The student can apply scientific ideas
The student can challenge scientific information
The student can challenge scientific ideas
The student can use qualitative approaches
The student can use quantitative approaches
The student can use scientific language to present information
The student can use scientific conventions to present information
The student can use scientific symbols to present information
The student can use technical language to present information
The student can use technical conventions to present information
The student can use technical symbols to present information
The student can use mathematical language to present information
The student can use mathematical conventions to present information
The student can use mathematical symbols to present information
The student can use ICT tools to present information
The student can use scientific language to develop an argument
The student can use scientific conventions to develop an argument
The student can use scientific symbols to develop an argument
The student can use technical language to develop an argument
The student can use technical conventions to develop an argument
The student can use technical symbols to develop an argument
The student can use mathematical language to develop an argument
The student can use mathematical conventions to develop an argument

The student can use mathematical symbols to develop an argument
The student can use ICT tools to develop an argument
The student can use scientific language to draw a conclusion
The student can use scientific conventions to draw a conclusion
The student can use scientific symbols to draw a conclusion
The student can use technical language to draw a conclusion
The student can use technical conventions to draw a conclusion
The student can use technical symbols to draw a conclusion
The student can use mathematical language to draw a conclusion
The student can use mathematical conventions to draw a conclusion
The student can use mathematical symbols to draw a conclusion
The student can use ICT tools to draw a conclusion
The student understands the use of contemporary scientific developments
The student understands the use of contemporary technological developments
The student understand the benefits of contemporary scientific developments
The student understand the benefits of contemporary technological developments
The student understand the drawbacks of contemporary scientific developments
The student understand the drawbacks of contemporary technological developments
The student understand the risks of contemporary scientific developments
The student understand the risks of contemporary technological developments
The student can consider how and why scientific decisions are made, including those that raise ethical issues
The student can consider the social effects of scientific decisions
The student can consider the social effects of technological decisions
The student can consider the economic effects of scientific decisions
The student can consider the economic effects of technological decisions
The student can consider the environmental effects of scientific decisions
The student can consider the environmental effects of technological decisions
The student is aware of the uncertainties in scientific knowledge
The student is aware that scientific ideas change over time
The student understands the role of the scientific community in validating the changes of scientific ideas over time

Hungary
Hungarian Scientific Literacy Statements

Students write down their findings
Students solve basic problems
Students express inquiry
Students find evidence-based answers to questions
Students generate conceptual schemes
Students process ideas of nature
Students read about ideas of nature
Students willingly engage in intellectual inquiry
Students have desire for engage in intellectual inquiry
Students explain phenomena related to every day experience

Students predict phenomena related to every day experience
Students record their findings in figures
Students record their findings in charts
Students describe their findings in speech
Students describe phenomena related to every day experience
Students form hypotheses
Students are able to evaluate the quality of information
Students evaluate information critically
Students carry out experiments
Students link disciplines
Students change their personal features positively
Students interpret basic phenomena
Students interpret basic principles
Students observe natural phenomena
Students observe rules of healthy life
Students focus on systems in their approaches
Students focus on interactions in their approaches
Students focus on relationships in their approaches
Students recognise the unity of the living world
Students recognise the evolution of the living world
Students recognise inaccurate concepts
Students recognise misconceptions
Students recognise naive theories
Students plan observations
Students plan experiments
Students apply general knowledge in decisions related to citizenship
Students apply general knowledge in decisions related to daily life
Students apply scientific results
Students apply their results critically
Students develop comparison
Students develop knowledge about subject matters
Students develop skills about subject matters
Students acquire knowledge about the role of sciences in social processes
Students acquire knowledge about the role of sciences in personal life
Students understand the relationship between nature and mankind
Students understand natural processes
Students understand deduction
Students understand physical processes
Students understand material structure
Students are aware of the principles of proper handling of hazardous substances
Students are aware of the principles of proper handling of hazardous preparations
Students are aware of existing knowledge systems
Students show responsibility towards science-related issues
Students show responsibility toward the environment in general
Students show curiosity towards issues involving science
Students show responsibility to personal health
Students reflect on achievement of Hungarian scientists

Students reflect on achievement of European implications of Hungarian scientists
Students reflect on the role of sciences in social processes
Students reflect on the role of sciences in personal life
Students reflect critically on inaccurate concepts
Students reflect critically on misconceptions
Students reflect critically on naive theories
Students reflect on the problems of technological society
Students obtain information on the history of science
Students obtain information about the life of prominent figures in science
Students obtain information about the work of prominent figures in science
Students identify techniques of inquiry indispensable in life
Students identify techniques of learning indispensable in life
Students identify techniques of interpretation indispensable in life
Students consciously measure quantities familiar from their daily lives
Students consciously use quantities familiar from their daily lives
Students appreciate major human achievements
Students appreciate the diversity of nature
Students appreciate nature
Students build up up-to-date scientific knowledge of their own
Students build up up-to-date scientific world view
Students build up science-related way of thinking
Students build up science-related approaches
Students learn about the properties of substances
Students learn about changes in the natural environment
Students learn about interactions in the natural environment
Students learn about phenomena of nature
Students learn about laws of nature
Students learn about the properties of the most frequently used natural substances
Students learn about the properties of the most frequently used artificial substances
Students learn about the transformation of the most frequently used natural substances
Students learn about the transformation of the most frequently used artificial substances
Students learn about the application methods of the most frequently used natural substances
Students learn about the application methods of the most frequently used artificial substances
Students learn about the specific features of life
Students realize the interconnectedness between humans and natural processes
Students realize personal responsibility
Students realize social responsibility
Students realize the role of sciences in social processes
Students realize the role of sciences in personal life
Students realize the stability of living organisms
Students realize the changeability of living organisms
Students realize the relationship between living and inanimate nature
Students look for solutions to basic natural problems

Students look for solutions to basic technical problems
Students take part in measurements
Students take social conditions into account
Students become active citizens
Students become creative citizens

Weighted Concept Maps

To make the scientific literacy statements more readily useable for analysis and comparisons, we made concept maps of each statement using a mathematical algorithm which features key words and their relationship, according to frequency of use, to one-another. The size of the circles for each key word, their location on the map, whether at the center or on the fringes, and the boldness of connections all represent the relative use of each word in the scientific literacy statement. Following in Figures 1,2 and 3 are the Danish, English/Welsh and Hungarian concept maps.

Denmark

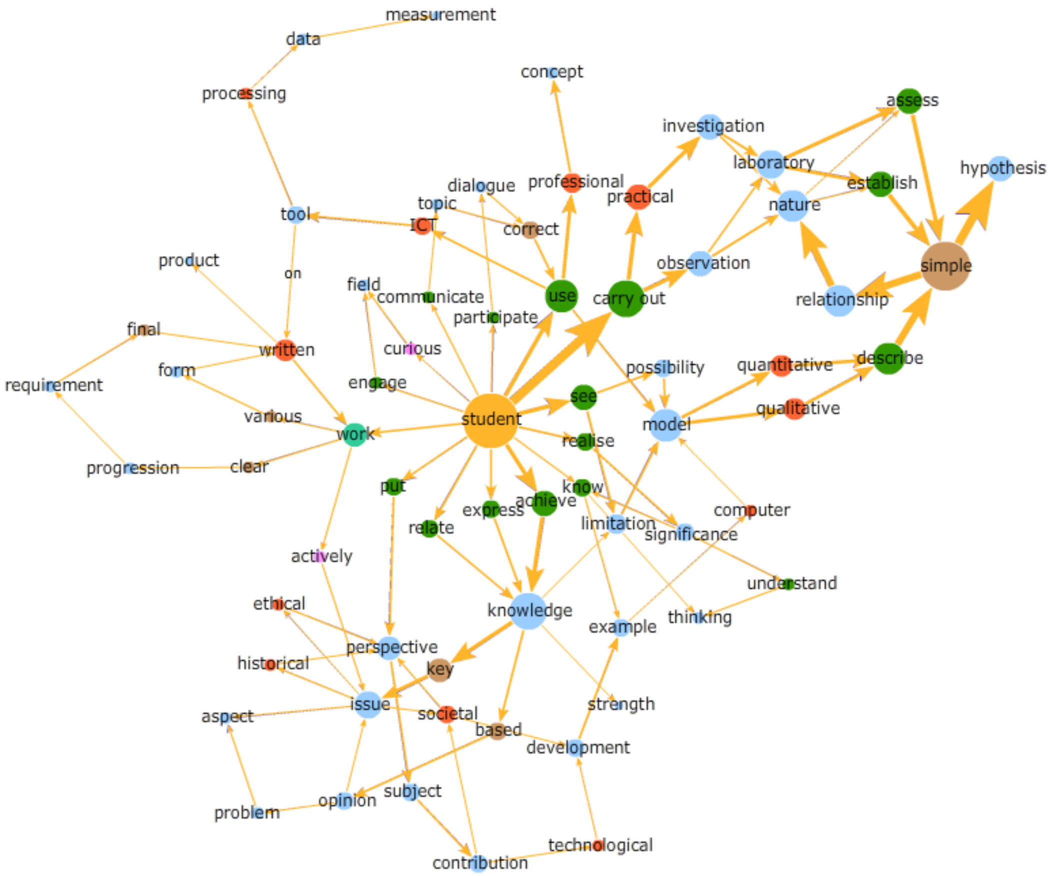

Figure 1. Danish 'weighted' map of Scientific Literacy derived from the Danish statements. Size of both circles and connecting lines is relevant to the frequency of their use in the definition, as are the positions at the center or fringes of the map.

England/Wales

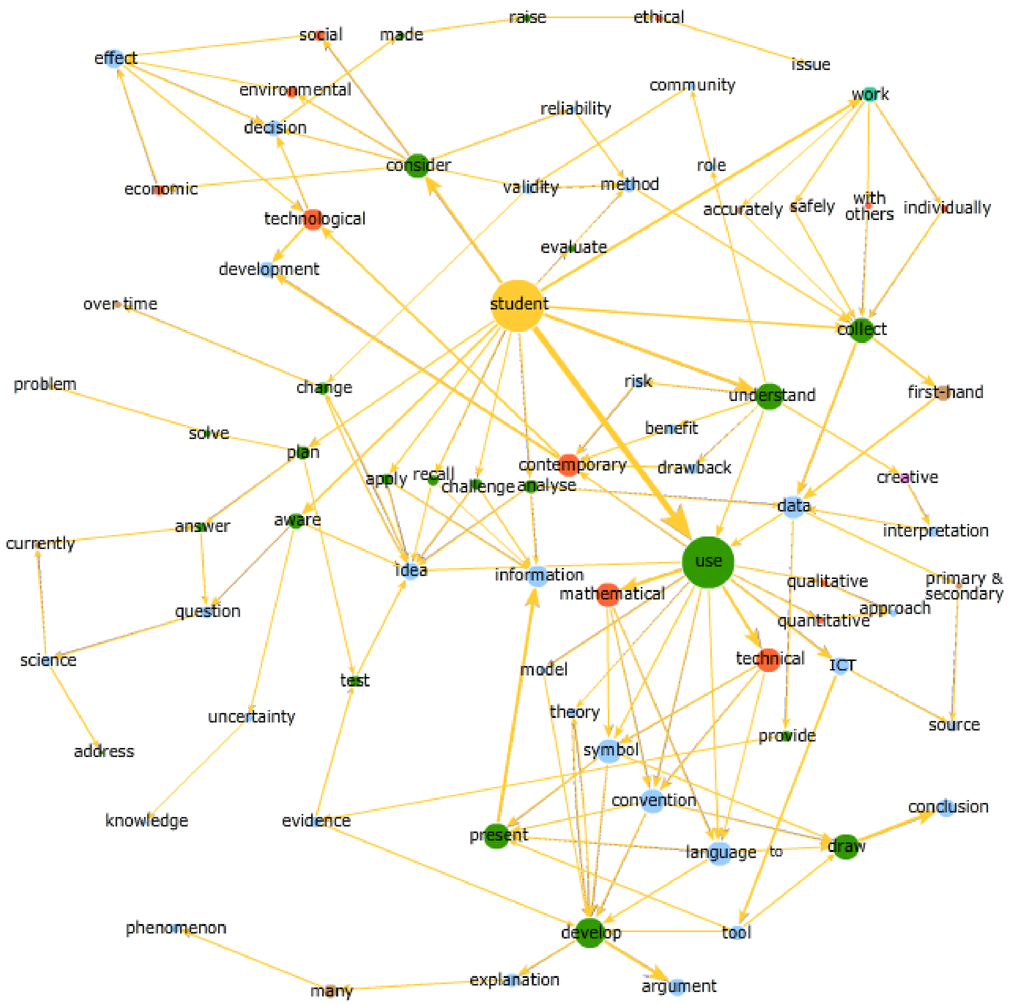

Figure 2. England/Wales ‘weighted’ map of Scientific Literacy derived from the English/Welsh statements. Size of both circles and connecting lines is relevant to the frequency of their use in the definition, as are the positions at the center or fringes of the map.

Hungary

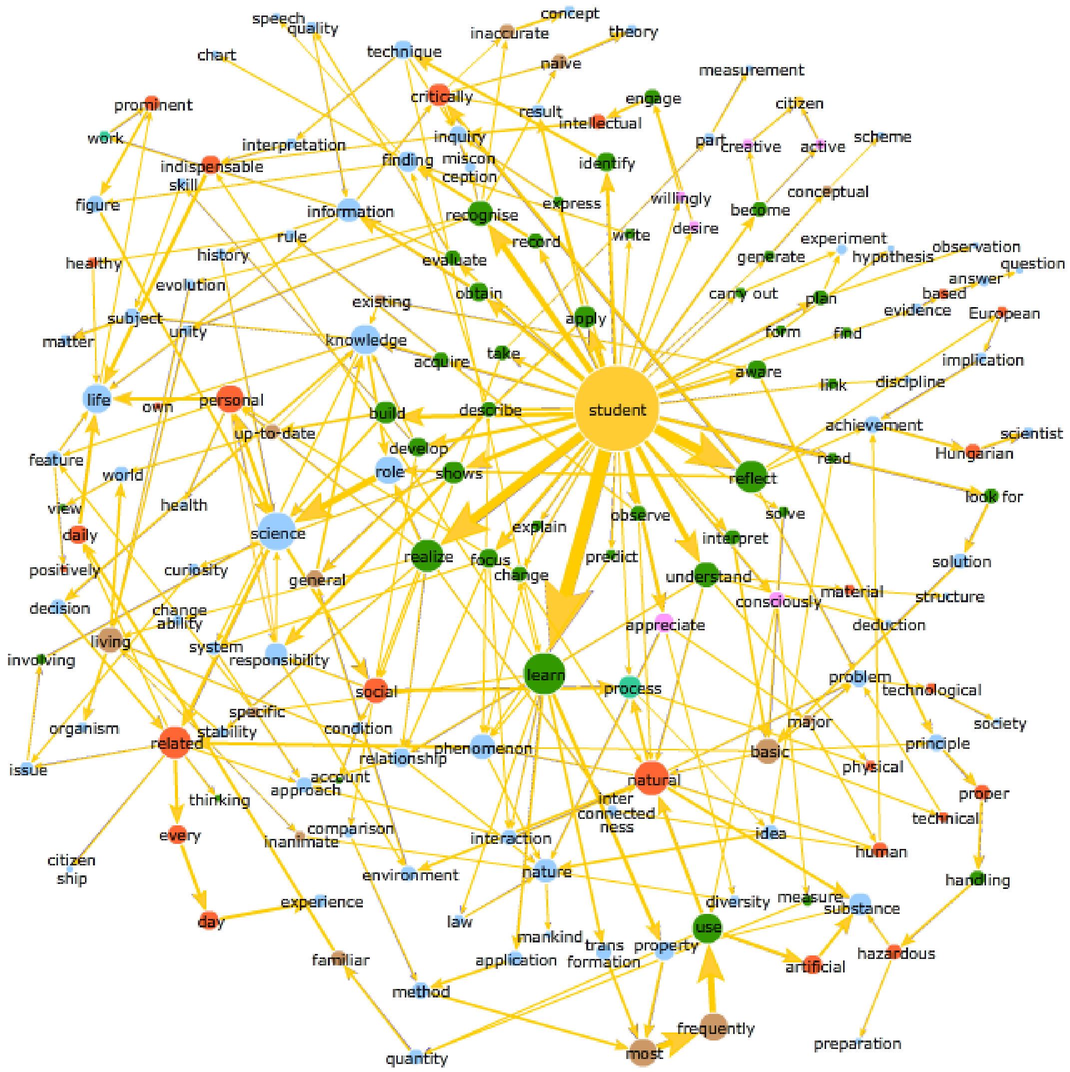

Figure 3. Hungarian 'weighted' map of Scientific Literacy derived from the Hungarian statements. Size of both circles and connecting lines is relevant to the frequency of their use in the definition, as are the positions at the center or fringes of the map.

These same maps in interactive formats that can be enlarged for clarity are available at: http://www1.ind.ku.dk/mtg/wp3/scientificliteracy/maps/2

Cultural and Historical Influences

We analysed the scientific literacy statements from all three of our countries from the perspective of national histories and cultures to not only reveal what had formed them but ultimately to see how they variously facilitate inquiry based science teaching. Following are the reports on these contextual factors.

Denmark Scientific Literacy Context

<u>Danish history and context reflected in national goals for Scientific Literacy</u>

The cultural and historical context of Denmark's goals for scientific literacy are evident in the map of the scientific literacy statement available at: http://www1.ind.ku.dk/mtg/wp3/scientificliteracy/maps/2. One of the most noticeable and important structures in the map is the large wide arrow which connects 'student' to 'carry out'. Running a computer 'mouse' over that 'string' shows connections to active, hands-on experimental science including laboratory investigation with an emphasis on observing and discovering the nature of science. This activation of students in practical work is a century old cornerstone of Danish science education tradition and has a strong presence throughout Danish elementary and secondary schooling. For over a century, laboratories have been built in schools to facilitate this active engagement with science.

Behind this practical work is a belief that students should experience scientific content through hands-on activities and demonstrations before learning about phenomenon through transmissive reading and teaching. As the prominence of the node 'nature' in the experiential part of the map indicates, an important part of this student experience with science is out-of-door explorations. The tradition of using out-of-class expeditions to gain first-hand experience with science content is historically deep and pervades all levels of Danish education.

However, compared to these observational experiences, Danish science literacy is not as strong at deep reflections about science. While the emphasis has been on 'doing science' to get correct results that verify experience, a scientific method of scientific problem solving has not been important in Denmark until recently. For example, the nodes for 'hypothesizing' and 'model' building are recent additions to literacy goals.

Another important dimension of Danish scientific literacy is evident in the connections to 'issue'. To reinforce Denmark's strong social-democratic traditions, the societal perspectives of science are actively taught in schools. Evidential nodes for these emphases include 'societal development', 'ethical perspective' and 'opinion about problems with a scientific aspect'. Science is seen as an important contributor to student democratic values. Danish parents often say that building these social-democratic attitudes through science is more important to them than scientific content.

To facilitate this link between the science classroom and Danish societal values, the map of scientific literacy can be seen to be quite open, particularly when compared to maps of some other countries. This intentional 'space' between nodes is to allow teachers and students to make many decisions about the actual content of science work in response to student and community issues and objectives. The scientific literacy statements are a framework within which teachers and students can develop rather than a prescriptive set of common curricular goals.

An important cornerstone of the Danish educational system is the development of oral communication among students. This can be seen in the network of connections in the map to 'dialogue' and 'communication of scientific topics'. In Denmark, it is often more important to empower students to talk about and discuss scientific issues than it is for them to acquire idiosyncratic scientific language and vocabulary. The 'knowledge' node is clearly not the end point in the Danish scientific literacy map, but on the path to applying knowledge to socio-cultural issues.

Other content courses in Denmark schooling contribute to Danish scientific literacy and vice-versa. There is a universal overall school emphasis on small group project work that is used in science classrooms in the hands-on activities which are a part of every science class and in communication about scientific issues. Furthermore, there is extensive project oriented work, which is also a part of all Danish schools. It is always cross-disciplinary, commonly including a science topic with those of other disciplines. Approximately ten percent of upper secondary time is spent on such cross-disciplinary work through which science literacy is supported through its relevance to other content areas. For example, links to science can be found in Danish literature studies in which student essays can be assigned to scientific issues and then read by language and science teachers, further promoting scientific literacy. Each upper secondary school actually has 'streams' or inter-disciplinary topics which include three subject areas. Every student contributes to projects related to these streams and since the streams often include a science course, there is considerable opportunity to achieve scientific literacy goals through cooperation with other disciplines.
The Danish scientific literacy statement clearly allows for inquiry based science teaching (IBST) through the student activation 'strings' and analysis opportunities in the social-application nodes. Students can suggest problems based on their many observations and use their project-oriented small group work to tackle solutions to them. Inquiry is further made possible by the social and ethical facets of scientific literacy and the cross-disciplinary problem based learning common in virtually all Danish schools. However, since many teachers do not have a deep conceptual understanding of IBST, full activation of student constructive learning through their activities and analyses are only partially realized.

English/Welsh Scientific Literacy Context
The SL map reflects the focus of the science education has been shifted from the concept based to inquiry-based approaches to science teaching and learning

http://www1.ind.ku.dk/mtg/wp3/scientificliteracy/maps/3

The emphasis in science education in England and Wales has been placed on understanding of the nature of scientific inquiry and scientific knowledge in its social context. Students are expected to be able to conduct, communicate and evaluate evidence gathered through scientific inquiries. The change is reflected in the national curriculum in England and Wales as the structure of the curriculum composed of "knowledge, skills and understandings", "how science works" and "Breadth of Study".

The SL map used the visual tool to highlight the above features. We can see the thick connection between the node "students" and "use" represent the practical purpose emphasised in the curriculum. If you use the mouse to activate this link, you will see the strings that presented: The students have been expected to be able to use tools to learn science, to use collected data and evidence to draw and evaluate scientific conclusions, to use various ways to represent scientific language… there are other verbs have been highlighted in the map, such as "understand". "present", "draw (conclusions)" and "collect (data)". These reflect the different areas of scientific literacy have been addressed in the curriculum. In the SL map, we can also see the several concept nodes have been highlighted, such as the "symbol", "convention", "language", "tool" and "information" which represent the aspects of the communication and representation in the scientific literacy. The adjectives of "technical", "social", "environmental" and "contemporary" highlights the link between scientific knowledge and its influence and connection to its social context.

The SL map of England and Wales compared to other countries' maps is more general as a guideline rather than specific detailed requirements. This might be due to the structure of the English school system in the sense that the national curriculum is subsequently interpreted by examination boards which then produce syllabi in more detail.

The SL map in turn really influences what happens in science education in our schools. The map using the visual tool represents the features in national curriculum. The SL map also presents the teaching practice with educators' comments to bridge the gap between policy and practice. It offers the examples for teachers or teacher trainers to implement the national curriculum using inquiry-based science teaching methods. The comments from the educators connect the scientific literacy items in the national curriculum and the features of the inquiry-based teaching methods which offer the teachers concrete examples to start with.

Other courses in our schools help us meet our SL goals (intentionally or not) and our SL goals help other courses meet their own goals (intentionally or not). In this SL map, you may notice "technological", "mathematical" and "representation" have been highlighted. It represents the cross-subject connections of scientific literacy. Scientific literacy is based on the mathematical language, the technological tools and also the representation and communication skills. The emphasis of using small group discussion, group presentation, and use of ICT have also been presented in the map. These have been commonly recommended by educators in teaching and learning, not only in Science subjects.

Hungarian Scientific Literacy Context

<u>Hungarian history and context reflected in national goals for Scientific Literacy</u>

Hungary's history from the Middle Ages until the present is reflected in today's Hungarian scientific literacy (SL) statements (see map of the statements (strings) at (http://www1.ind.ku.dk/mtg/wp3/scientificliteracy/maps/4). Since the middle ages, Hungary has had a strong scholastic tradition of education, later reinforced by the Prussian influence. These effects can still be seen in the map of 'strings' which specify, for example, that students *learn*, *realize*, *acquire knowledge* and *recognize*. Layered on these scholastic traditions are those of the predominant Catholic church whose pedagogy of 'drill' reinforced the earlier traditions. All of these traditional scholastic goals are characterized by teaching that is transmissive, strict, authoritarian, male dominated and which puts considerable pressure on the student. The goals for such instruction predominant in the Hungarian SL map.

In the schools, these elements of scientific literacy are characterized by a sophisticated and highly administered educational system where thoroughness and specific standards for every learner are given in great detail. Historically, it was felt that only through this attention to detail and wide standardization could students' education be assured. Hence, today's map of Hungarian SL shows a large number of 'strings' to provide the details which can lead to this assurance. In all cases, the transmission of significant amounts of information was important since the more you knew the better educated you were. Another aspect of traditional Hungarian SL goals which is still reflected today was the myth that science could 'solve' everything through knowledge, but not process. This meant learning a large amount of science content but not the processes of experimentation was the sign of a scientifically educated citizen.

After World War II, during the communist era, the male-dominated, authoritarian, non-process traditions of the Hungarian curricular goals were further nurtured and maintained since they fit a regime that wanted minute control over education content in every classroom. A large number of transmissive scientific literacy objectives facilitated this control and with the emphasis on content over process, independent problem solving was discouraged since students were limited to just 'knowing'.

Because communism did not want citizens to really 'think' about and consider anything the teaching and learning of 'attitudes' was discouraged since the habit of personal attitudinal development could be a danger to the hegemony of the State. Teachers were actually afraid to teach science that required thinking about things to form a personal 'attitude' or opinion. As a consequence, the Hungarian scientific literacy map of today still does not include anything about attitudes or their development. Concomitantly, communism opposed religions and religious beliefs, including the conceptions and naïve (unscientific) theories which are a part of religion, again because of a perceived threat to the State. Scientific literacy teaching emphasized *recognizing misconceptions* and *inaccurate concepts* to dissuade students from religious perspectives. By reinforcing scientific literacy goals which confronted beliefs and naïve conceptions, the content of science became the explainer of the world and hence diminished alternative religious explanations. These 'strings' are still a part of Hungary's goals for literacy, but of course, they are now also part of accepted international perspectives about the role of science, so keeping them is now consistent with the nature of scientific inquiry. Also, since 1989, processes of science which require thinking as well as knowing, have been added to the Hungarian statements as can be seen in 'strings' such as *carry-out and plan experiments and observations* and *find evidence based answers to questions*.

Opportunities for Inquiry Based Science Teaching

Analyses of the Danish, English/Welsh and Hungarian Scientific Literacy maps show many compelling opportunities for Inquiry Based Science Teaching (IBST). When national statements specify that students are only scientifically literate when they can enact the processes of science rather than only learning its contents, then

learning via IBST is not only possible but more competently accomplishes the learning goals.
For example in the detail from the Danish Scientific Literacy map in Figure 4, the importance of mastering the processes of science such as those highlighted in blue, not only allow teachers to include genuine IBST in their teaching but virtually require it since these objectives are not easily achieved through more transmissive forms of teaching. This means that in both pre-service and in-service teacher professional development, the Danish Scientific Literacy map can be used to motivate teachers to apply IBST in their classrooms.

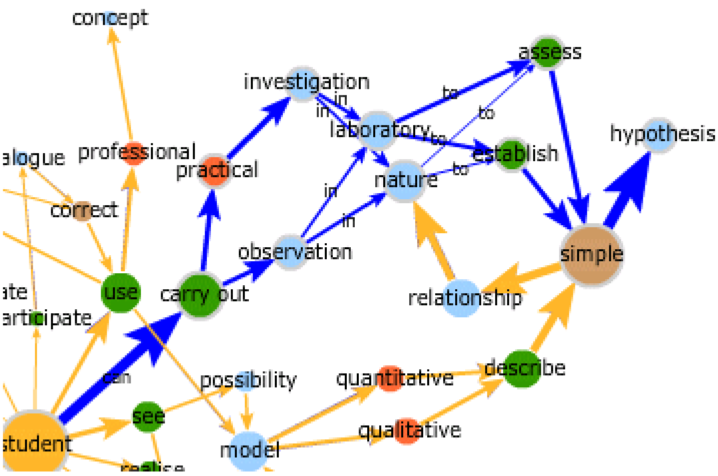

Figure 4. Detail from the Danish 'weighted' map of Scientific Literacy derived from the Danish statements. Size of both circles and connecting lines is relevant to the frequency of their use in the definition, as are the positions at the center or fringes of the map.

Other opportunities for IBST are provided by the English/Welsh scientific literacy statement. As can be seen in the detail from the map in Figure 5, the important 'action' verbs in green circles provide the basis for science lessons which teach processes of science rather than just content. Notably, rather than being given explanations and arguments, students must 'develop' them based on 'models' and 'theories'. The largest 'action' call is for 'use' and that is able to be met only through IBST where students do actually use scientific processes to discover and make sense of the scientific world. Realizing the need for pupils to acquire proficiency at these science 'actions' is a precursor to using IBST to achieve them.

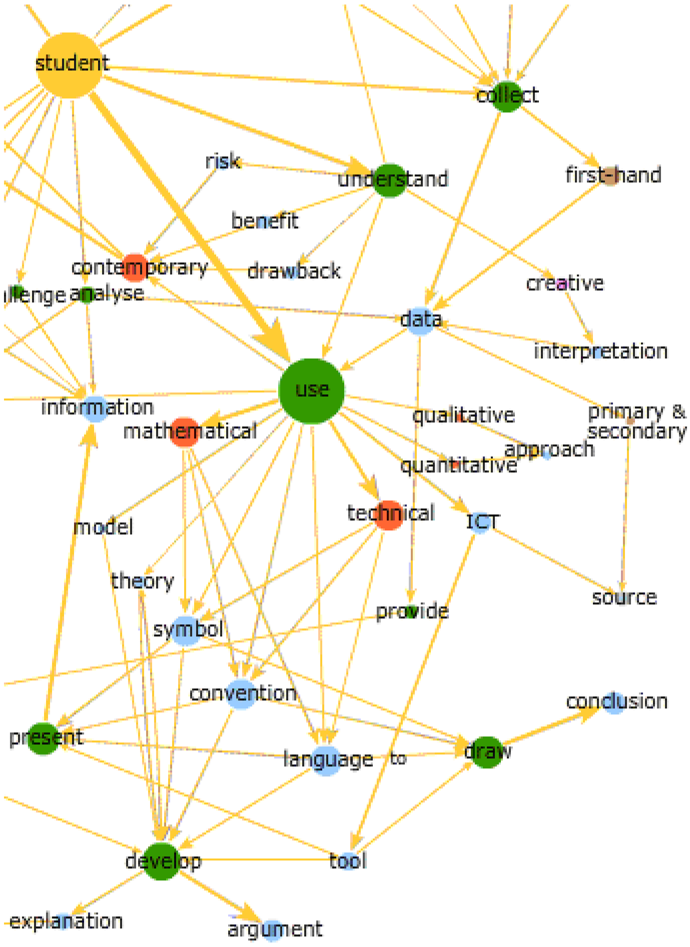

Figure 5. Detail from the English/Welsh 'weighted' map of Scientific Literacy derived from the English/Welsh statements. Size of both circles and connecting lines is relevant to the frequency of their use in the definition, as are the positions at the center or fringes of the map.

The Hungarian map of scientific literacy (see Figure 3), due to the historical and cultural influences on it (see earlier description of those) includes many objectives which do not specifically demand IBST. Due to the quantity of these goals, other methods of teaching are likely to be most efficient. However, an entire quadrant of the Hungarian map (see Figure 6) includes similar science process goals as found in both Denmark and England/Wales. Green circle 'action' words such as 'observe', 'predict', 'plan', 'record' and 'find' resulting in products such as 'experiments', 'hypotheses', 'measurements' and most relevant, 'inquiries', all give clear orientation to Hungarian teacher educators in Teacher Professional Development programs to facilitate IBST for meeting them.

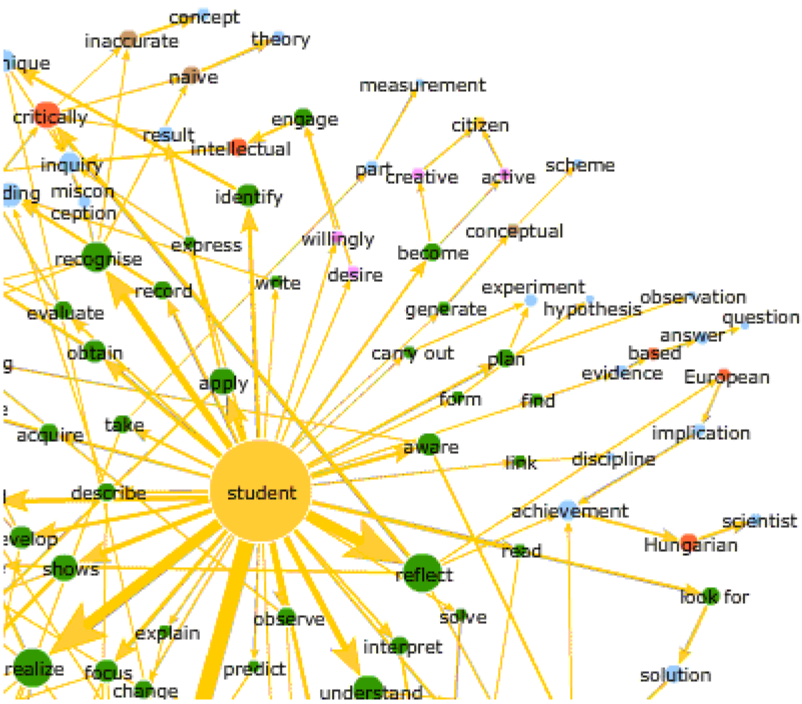

Figure 6. Detail from the Hungarian 'weighted' map of Scientific Literacy derived from the Hungarian statements. Size of both circles and connecting lines is relevant to the frequency of their use in the definition, as are the positions at the center or fringes of the map.

The finding from this comparison of Danish, English/Welsh and Hungarian statements that all three provide significant calls for the acquisition of science process skills for citizens to be scientifically literate, encourages us in the belief that national policy statements are already in place for the promotion of IBST in at least these three sample cultures and possibly in most other EU countries. To the extent that this is the case, Teacher Professional Development workshops and modules for IBST, using the calls from scientific literacy statements, can be developed for use throughout the EU. This analyses provides an important support and basis for the work the succeeding EU project, S-Team, to develop such cross-national workshops.