Project no. 217725

Project acronym: Mind the Gap

Project title: Mind the Gap: Learning, Teaching, Research and Policy in Inquiry-Based Science Education

Dissemination level: O

Thematic Priority: Science in Society

Funding scheme:

Deliverable N° 2.5

Deliverable title ESERA presentation

Due date of deliverable: Month 18
Actual submission date: **01/10/2009**

Start date of project: **01/04/2008** Duration: 24 months

Name of Coordinator: Professor, Doris Jorde, University of Oslo, Norway
Name of lead partner for this deliverable: Doris Jorde

Date: [1-3/9/09]
Place: [Istanbul Turkey]
Activity: [Conference Presentation]

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R E P O R T

Presentation of findings at the European Science Education Research Association (ESERA)Deliverable 2.5

Deliverable 2.5

Presentation of findings at the European Science Education Research Association (ESERA) 2009

Science Curriculum and Evaluation Minding the Gap between Policy and Practice of Inquiry Based Science Teaching in Seven European Countries: Norway, Germany, Denmark, Spain, France, Hungary and the United Kingdom

Chair: Reinders Duit

INQUIRY BASED SCIENCE TEACHING - AN OVERVIEW OF WHAT WE KNOW AND WHAT WE DO

Doris Jorde (University of Oslo, Norway)

POLICIES AND FRAMEWORK FOR INQUIRY BASED SCIENCE TEACHING (IBST) ACROSS EUROPE

Kirsti Klette (University of Oslo, Norway)

PROMOTING ARGUMENTATION IN SCIENCE EDUCATION: MIND THE GAP PROJECT
PERSPECTIVES FROM ENGLAND AND SPAIN

Sibel Erduran (University of Bristol, England)

DIVERSITY OF SCIENTIFIC LITERACY IN EUROPE

Jens Dolin (University of Copenhagen, Denmark)

ENHANCING INQUIRY-BASED SCIENCE TEACHING WITH ONLINE RESOURCES

Ghislaine Gueudet (CREAD & IUFM Bretagne UBO, France)

Mind the Gap is an EU supported consortium whose aim is to critically look at Inquiry-based science teaching (IBST) in seven countries in Europe and to offer ideas for improving the way science is taught in secondary schools. Several "work packages" link a comparative analysis of IBST in participating countries (including policy documents and classroom video analysis), an analysis of how IBST is linked to scientific literacy in policy documents, an analysis of innovative methods in teaching science (including ICT and argumentation) and finally a framework for teacher professional development for disseminating ideas and changing classroom practice based on the SINUS project from Germany (Prenzel, M., & Ostermeier, C. 2006). In this symposium we focus on the comparative aspects of how different countries represent IBST in their official documents for science. We begin with a presentation on IBST policy analysis related to national frameworks for science teaching. We then present an analysis instrument for assessing links between IBST and scientific literacy policy statements. A third presentation considers how IBST is used in web-based science materials (examples from Viten and Pegase) and finally the link between argumentation and IBST in the curriculum in England and Spain is presented.

Minding the Gap between policy and practice of inquiry based science teaching in seven European countries: Norway, Germany, Denmark, Spain, France, Hungary and the United Kingdom

Paper 1: Inquiry-based science teaching- an overview of what we know and what we do

Recent concerns for recruitment to science and technology careers in Europe have forced educators and policy makers to take a critical look at the way science is taught in schools. In the last 10 year period several reports have been published, confirming the same results – that revisions are needed in the way we teach school science and in how we educate science teachers (EU, 2004; EU, 2007; OECD, 2008; Osborne and Dillon, 2008). In response to European concerns for science education, the **Mind the Gap** project was established to critically look at the role of Inquiry based science teaching (IBST) in policy documents, to consider how innovative practice in science teaching is related to ideas of IBST and finally to further develop an established model (SINUS) of teacher professional development for the dissemination of our ideas for improving the teaching of science based on IBST.

Inquiry is at the heart of the scientific method. It is what scientists do when they attempt to understand the natural world by asking questions about systems or objects, by collecting data, making predictions, testing out ideas and making conclusions. Though what scientist do is not the same as school science, a scientific way of thinking is an important component of understanding scientific processes and becoming a scientifically literate citizen. Placing inquiry at the heart of school science is what models of inquiry-based science teaching set out to do – by creating opportunities for students to engage in the creative exercise of asking questions and being curious about the world around them.

It may be argued that there is no one 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 (Linn et al., 2004; Anderson, 2006).

Generally, inquiry-based science teaching may be characterized by activities that pay attention to engaging students in:

- authentic and problem based learning activities where there may not be a correct answer
- a certain amount of experimental procedures, experiments and "hands on" activities, including searching for information
- self regulated learning sequences where student autonomy is emphasized
- discursive argumentation and communication with peers ("talking science")

These four dimensions of inquiry-based science teaching define the field of IBST and are used as a framework for policy and curriculum analysis in the Mind the Gap project.

The Mind the Gap consortium is dedicated to minding many of the gaps found between theory and practice, between policy and practice and between teaching and learning as they are related to the use of inquiry based science teaching. IBST is recognized as a one of the major forces for realizing educational goals and curriculum efforts across European contexts as evidenced by national and local science framework documents. Yet despite this emphasis at the political and intended levels, IBST does not seem to be the dominating mode of science teaching at the secondary level in Europe.

Current video studies in several European countries (Norway, Germany, Switzerland, France) indicate that teachers at the secondary level make

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little use of the tremendous repertoire of ideas for teaching that may be indicated by an IBST influenced curriculum (Klette, 2009; Klette et al, 2007; Tiberghien & Buty, 2007; Seidel & Prenzel, 2006). Over the decades a vast research literature has reported on how curricula initiatives and reforms have little or minimum impact on practices at the classroom level. There is reason to ask for more systematic and evidence based answers to the many questions that can be raised about the place and role of inquiry-based science teaching as well as the tools available to support it. What does IBST mean? What are the central tools, artifacts and models for realizing IBST? Does IBST mean the same thing in varied contexts and cultures? Are teachers able to implement IBST teaching within current educational structures? What are the connections between IBST and scientific literacy? Does IBST allow for the incorporation of modern teaching tools, including ICT? Does IBST promote relevance in science lessons? To put it shortly: What are the merits of IBST as a teaching method in science education?

Paper 2: Policies and Framework for Inquiry Based Science Teaching (IBST) Across Europe

The first contribution explores the relationships between policy documents and inquiry based science teaching. An overview of policies and curriculum frameworks of IBST across participating countries (cultures, educational systems, subject areas, recruitment issues) and how IBST is framed within these school systems will be presented. Understanding the cultural contexts of IBST in policy documents is a necessary step in the process of spreading and implementing models of science teaching in countries other than where they originate.

In the first level of analysis we look at the question of HOW science education is organized in five of the participating countries, according to national curricula as the textual policy level. Since all countries have national curricula we used these texts as a baseline for comparison. Lower secondary level is the unit of analyses, covering the age of 12- 16 in most countries. All curriculum texts were analyzed according to three dimensions:

- Structural features regarding how science education is organized
- Structural features of the science curriculum text
- Substantial features of the science curriculum texts

Results:
The analyzed countries operate with different models of how to organize 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) and then specializing into the sub disciplines. Required teacher competence points to quite distinct models, with Norway at one side of the continuum, requiring no subject specification, while subject specification is a prerequisite for teaching science at lower secondary level in all 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 analyzed 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 consensus across the countries in how to define the main subject areas of science education. All curricula text pay attention (though with different labels) to the four following areas: Organism and health; Chemical and material behavior; Energy, electricity and radiations; and Environment, earth and universe. The role of technology in science is especially emphasized in Spain and Norway but not in the other three countries.

Substantial features of the texts point to both differences and similarities. The analyzed texts represent different models in whether learning areas are nationally prescribed or left to the local level to define and interpret. While learning areas are nationally defined in Germany (i.e. Länder); France, Norway, Spain and UK have a combination of nationally defined learning areas supported with room for local interpretation.

Whether learning goals in science education focus on content areas versus competences is another dimension of variation between the analyzed countries. Germany specifies learning goals in terms of content areas while Norway and UK link learning goals to competences. France and Spain have a mixture of 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 emphasized in the UK curriculum text but not in the other countries. Problem based learning and exploratory learning appears in the curriculum texts in all analyzed countries but means rather different things in the different countries. While the Spanish text underscore "strategies for problem solving" as central to define problem based learning, the French text pays attention to "choice of problematic situations". In the UK texts, authentic learning and to "learn how science works" are emphasized. Linguistic and more elaborated in depth analyses in how the different curricula texts understand IBST will continue to be explored and refined as the Mind the Gap consortium continues.

Paper 3: Diversity of scientific literacy in Europe

The growing importance of scientific issues in our daily lives – on a both a global, a national, and a local level - demands an insight in science and a willingness to engage in the socio-scientific debate on an informed basis. The ability to do this is often captured by the concept of *scientific literacy*. At the same time traditional teaching is necessarily changing from a rather transmissive teaching style to a more interpretive, in order to make students able to use and communicate their knowledge in out of school settings, and to prepare them for lifelong learning and future citizenship. Inquiry based science teaching (IBST) is a central element in this process. By focusing on the students' own questions and their ability to answer them, IBST is an efficient way to obtain scientific literacy.

It is therefore important to collect and develop good practices of IBST for scientific literacy and citizenship within the EU countries. The science literacy/IBST project does this in three countries: Denmark, England, and Hungary. The research questions addressed in this part of the symposium are:

- How is scientific literacy conceptualized in the curriculum in Denmark, England, and Hungary, and how are these conceptions influenced by local cultures?
- How have good science teachers in these countries implemented scientific literacy in their science classes?

As a theoretical background we have analyzed international literature on scientific literacy, and based on Roberts (2007) we have divided the many different approaches into two visions:

Vision I:	'looking inward to science itself' The products and processes of science itself Literacy, through knowing, is within science but relates to matters other than science
Vision II:	'looking inward from situations to science' Characterized by situations with a scientific component which students are likely to encounter as citizens

To have a type of benchmark for scientific literacy we have utilized the PISA Framework 2006 definition (OECD 2006). This definition and the matching text have been influential in the way countries integrate scientific literacy into the national curriculum.

The methodological challenge was to find a way of comparing how different curriculum texts conceptualize scientific literacy. Rather than just adding to the textual analyses of scientific literacy available from each country and cross-nationally, we have chosen to create maps in order to make analyses and comparisons more precise and informative. These maps have been produced in the PAJEC software based on complex network theory. As a special feature these maps reveals strings of defining elements (concepts, actions, contexts, levels, etc.) showing the relative importance of the connections between the elements. The maps thus make up a visual representation of often complex texts with an integrated quantitative approach.

Maps have been produced for central curriculum texts from Denmark, England, and Hungary (and other countries) and by a special overlay technique these maps have been compared to each other and to the PISA definition. These representations make it possible to separate characteristic features of the different countries' understanding of scientific literacy, and especially to analyze how the two visions are weighted different. The presentation will demonstrate and analyze a selection of these maps, and discuss the validity and the reliability of the method.

Paper 4: Enhancing Inquiry-based science teaching with online resources

Web-based resources for science teaching and lesson preparation are increasing in their use throughout Europe. These resources bring new ways of presenting science into the classroom creating challenges for teachers, students and the curriculum. In this third paper we look at how inquiry based science teaching may be enhanced through the use of web based resources, asking about which features found within web-based resources are in fact appropriate for IBST.

In the first phase of the work, a focus was made on analysis by inspection of web-based resources. We drew on research about technology and inquiry in science teaching (Kim et al. 2007, Linn et al. 2003, Linn, 2004), and about the design of web-based resources (Fischer & Ostwald 2005, Gueudet & Trouche 2008), from which a grid of criteria aiming to analyze the IBST-potential of such resources has been developed.

The following IBST categories for the creation of an evaluation grid were used:

- General criteria: ergonomy, possible student customization, media, legal aspects;
- Scientific criteria: authentic problems, robustness of the problems across different teaching contexts, epistemic value of the situations; IBST-scaffolding for students, for teachers (proposition of scenarios – of helps for the students);
- Collective dimensions: possible involvement of the users in the design process, possible development of communities of practice.

During the symposium, we will elaborate on the criteria for development of the grid and apply this for the analysis of extracts of two resources: VITEN[1], and Pegase[2]. Researchers in science education were involved in the design of both resources; they are nevertheless quite different in their aims and objectives.

VITEN (Jorde & Mork 2007) is designed in Norway (generalizing its English translation is a part of the Mind the Gap project); it is widely used in science classes by teachers and students. VITEN offers interactive content, dynamic representations, tries to develop argumentation by proposing material to implement debates in class etc.

Pegase is designed in France, for teachers and teacher trainers. It proposes presentations for teachers of the outcomes of several research projects in science education, about modeling, students' misconceptions etc. It also includes lesson plans with various materials, grounded in the research results.

The application of our criteria to these resources provides evidence that each of these resources has qualities for IBST, but also possible improvements, in several directions could be made. Some of the interesting situations proposed can loose their IBST- potential if they are misused; enriching the teacher scaffolding is thus an important issue. Nevertheless, the usefulness of additional material for the teachers depends on its appropriation; giving too much details and advice can

[1] http://genetechnology.viten.no/
[2] http://www.pegase.inrp.fr

hinder the use of a resource. Developing possibilities of collective work for the teachers seems a promising means to improve scaffolding and foster appropriation at the same time. Beyond these examples, we will provide first elements of guidelines for the design of quality IBST online resources.

Paper 5: Promoting argumentation in science education: Mind the Gap Project Perspectives from England and Spain

In recent years, the teaching and learning argumentation i.e., the coordination of evidence and theory to support or refute an explanatory conclusion, model or prediction has emerged as a significant educational goal. The case made is that argumentation is a critically important discourse process in science (Toulmin, 1958), and that it should be taught and learned in the science classroom (Duschl & Osborne, 2002; Erduran, Simon & Osborne, 2004; Jimenez-Aleixandre, Bugallo-Rodríguez, & Duschl, 2000; Kelly & Takao, 2002; Zohar & Nemet, 2002). In this paper, results from the Mind the Gap Argumentation projects based in England (Osborne, Erduran & Simon, 2004b) and Spain will be presented. The overall objective of the paper is to contextualize the role of argumentation in science teaching, learning and teacher education. The projects have integrated available teacher resources developed in England and Spain for supporting argumentation in classrooms and professional development, and embedding these in inquiry based science teaching. Sequences of lessons have been trialed across languages and contexts.

An argumentation package for teachers is being developed and will include resources for teachers (e.g. lesson plans and pupil materials) as well as snapshots of video to show examples of how argumentation ideas may be implanted in science teaching. The work in England and Spain is aiming to: (a) Produce resources for supporting argumentation-based inquiry activities, in collaboration with secondary school teachers; (b) Develop guidelines and resources for professional development related to scaffolding argumentation-based inquiry activities; (c) Generate rubrics, informed by criteria and guidelines for assessment of resources and professional development programs aimed at supporting argumentation-based inquiry activities. The key outcomes of the projects are resources for students, teachers, teacher's trainers and policy makers for example; teaching sequences; guidelines for professional development program leaders; and assessment rubrics for quality performances for purposes of self-assessment and for policy makers.

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