CULTURAL PERSPECTIVES IN SCIENCE EDUCATION

Science Education Research and Practice in Europe

Retrospective and Prospective

Doris Jorde and
Justin Dillon (Eds.)

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CULTURAL PERPECTIVES IN SCIENCE EDUCATION
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DORIS JORDE AND JUSTIN DILLON

1. SCIENCE EDUCATION RESEARCH AND PRACTICE IN EUROPE: RETROSPECTIVE AND PROSPECTIVE

INTRODUCTION

In editing this volume of **The World of Science Education** devoted to Europe, we have invited a range of authors to describe their research in the context of developments in the continent and further afield. In this chapter, we begin by considering what we mean by Europe and then look at the historical, social and political contexts that have driven developments in science education research over the years. We finish with a look forward to where science education in Europe might be going in the years to come.

WHAT COUNTS AS EUROPE?

Europe is generally defined as one of the seven continents bordered by the Atlantic Ocean to the west, the Arctic Ocean to the north, the Mediterranean Sea to the south and the Black Sea to the south east. The border to Asia is usually considered as being the Urals and the Caspian Sea. There are 50 countries within Europe with at least as many languages and cultures.

The creation of the European Union has given us an additional way to think of Europe. At the end of 1945 much of the continent lay in disarray and yet by 1950 a group of six countries (Belgium, France, Germany, Italy, Luxembourg and the Netherlands) had united to form a European coal and steel community so that a peaceful future might be secured. Subsequent unifying events included the signing of the Treaty of Rome in 1957 and the establishment of the European Economic Community (EEC).

Denmark, Ireland and the United Kingdom joined the European Union (EU) in 1973, raising the number of member states to nine. Greece joined in 1981 followed by Spain and Portugal in 1986 making a total of 12 member states. Communism collapsed across Europe in the 1990's and in 1993 the EU introduced the idea of four basic 'freedoms': movement of goods, services, people and money. Three more countries joined the EU in 1995: Austria, Finland and Sweden. Borders between countries were opened and students were encouraged to study in other EU countries. Eight new countries were added in 2004: the Czech Republic, Estonia, Latvia, Lithuania, Hungary, Poland, Slovenia and Slovakia. Cyprus and Malta were added soon afterwards. Bulgaria and Romania became members in 2007

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taking the total to 27 member states. There are three candidate countries: Croatia, the former Yugoslav Republic of Macedonia and Turkey.

Today there are nearly half a billion people living within the European Union – the world's third largest population after China and India. The EU is less than half the size of the United States, but its population is over 50% larger. Norway, Iceland and Switzerland are outside the official EU but they have a special agreement allowing many of the same opportunities that exist between member countries.

It is no secret that the EU has ambitions of becoming the world's most dynamic knowledge-based economy, a status which will require substantial investments in research and education. The Bologna Declaration of 1999 (www.ehea.info) established compatibility and comparability between institutions in Europe on the way towards international competitiveness. The declaration has objectives to establish the European area of higher education and to promote the European system of higher education world-wide through the following measures:

1. The adoption of a system of easily readable and comparable degrees
2. The adoption of a system based on two main cycles, the undergraduate (3 year BA) and graduate (2 year MA followed by a 3 year Ph.D.)
3. The establishment of a system of credits (European Credit Transfer and accumulation System)
4. The promotion of mobility for students, teachers, researchers and administrative staff
5. The promotion of European co-operation in quality assurance
6. The promotion of the necessary European dimensions in higher education (curricular development, inter-institutional co-operation, mobility schemes and integrated programmes of study, training and research.

Today over 47 countries (from within and outside of the EU) have signed the Bologna Declaration, committing to the goals of the European Higher Education Area. Comparability and compatibility are important for European countries as higher education and research are transcending country boundaries on the way to common goals of excellence in the knowledge society.

The impact of the EU on education in Europe is seen most within higher education as most educational systems have comparable structures for degree programmes (3 year BA + 2 year MA + 3 year Ph.D.), common grading systems (A-F), and financial schemes to encourage student exchange. Degrees are more easily accepted across country borders, also encouraging movement of academics within Europe. And, finally, financial schemes for research are in place for the advancement of international comparisons in education.

Becoming a more integrated Europe in search of a common identity also brings with it the challenges of cultural diversity. As science educators we want to think that the content of science is and should be broadly the same regardless of where it is taught in the world. However, cultural diversity means that the delivery of the science curriculum happens in many different ways, thus producing very different learning outcomes. Some countries differentiate early, others not at all. Some countries include science in a core curriculum while others only include language and mathematics. Some countries follow what we could call a “student-centered” ideology for teaching whereas others continue to be “teacher-centered”. Some countries have resources to include Information and Communications Technology (ICT) throughout the curriculum whereas others have little to no funding for such resources. Some countries are able to provide teacher professional development courses for teachers, thus encouraging life-long learning; others have almost no opportunities for teachers.

The issues of language diversity are also overwhelming in Europe. In the EU alone there are 23 official languages into which documents are translated. Many European countries have multiple languages into which all documents, including school textbooks, are translated. Switzerland has three official languages: German, French and Italian; Spain has Spanish as its official language yet includes Catalan, Basque, Galician and Aranese as Co-official languages; Belgium has three official languages: Dutch, French and German, and so on. Now add to this the challenges of immigration from other regions of the world and consider the impact of language on a school system.

An interesting language issue within the science education community in Europe arose over the translation of the German tradition of “bildung” and “didaktik”. It has been argued that an appropriate English translation was difficult to achieve (See Duit, Gropengießer, Kattmann, Komorek and Parchmann as well as Wickman, Liberg and Östman in this volume). (The term didaktik in German is not to be confused with the English word didactic since they have very different meanings.) Today it is not uncommon to use the German words within an English text since a broader understanding of their meaning has been accepted by the English-speaking community.

A RETROSPECTIVE LOOK AT SCIENCE EDUCATION IN EUROPE

The history of science education in parts of Europe has many similarities to the development of the field across the Atlantic. As the United States was reacting to the post-Sputnik shock in the 1960’s and developing new types of curriculum for science, similar types of developments were going on in Europe. For example, Jean Piaget’s Centre d’Épistémologie Génétique, established in 1955 in Geneva, had tremendous impacts on educational thinking in Europe. In the following section, we use England as an example of European development in science education.

England: An Example of the Development of Science Education in Europe

Since the 1960s, science education in European schools has been through a process of almost continual change. In England, for example, the most significant changes include the introduction of Nuffield Science; the move towards ‘balanced science’ (that is, the teaching of biology, chemistry and physics for all students); the rise of ‘process science’ (as opposed to focusing on ‘the facts’) and, more recently, the introduction of a National Curriculum and the associated assessment procedures. Each innovation has challenged existing science teacher pedagogy in some way or another and, in turn, has had consequences for teacher development. The complexity of the relationship between pedagogic change and changes in the representation of science in the curriculum is indicated by this comment from Monk and Dillon:

> Shifting pedagogic perspectives have been the major surface feature of the changes in discourse of science education in the metropolitan countries of the old imperial powers. Generally we have moved from transmission views to more constructivist views. Older views of science as an empirical, inductivist enterprise with access to a knowledge base of an independent reality have been gradually eroded and replaced by newer constructivist views. These are not unitary (Solomon 1994), but multiple. However they all share a concern for the student's knowledge base as being idiosyncratic and biographical. (Monk and Dillon, 1995: 317).

This gradual erosion of older views of science have come about through curriculum change, the introduction of new courses and through changes to the nature of pre-service and in-service courses for science teachers. The process of change in science education, since the 1960s, though gradual, has not been one of seamless transition, rather it has involved reconstruction, reversal and high levels of political engagement (Donnelly and Jenkins, 2001).

Dissatisfaction with school science education was evident in the USA and in the UK before the launch of the Sputnik satellite in 1957 (Klainin, 1988: 172). The Nuffield Science projects, mentioned above, owe at least some of their success to what is sometimes termed the post-Sputnik angst (Waring, 1979). However, despite the innovations of the Nuffield era in science education, successive government reports and political commentary have continued to focus on the inadequacy of science education in both primary and secondary schools. The criticisms, which, in part, continue today, were partially responsible for the changes in the science curriculum.

In *Beyond 2000*, a critique of science education at the turn of the 21st century, Millar and Osborne (1998) picked out what they considered to be the major developments in education, and particularly in science education in England since 1960. First, they identified 'the major curriculum innovation, undertaken by the Nuffield Foundation which ... gave greater emphasis to the role and use of experimental work' (p. 2002–3). Nuffield Science involved a more experimental, investigative approach to science education pedagogy than had previously been the case (Jenkins, 2004).

The Nuffield approach involved an emphasis on practical activities, supported by worksheets, teachers' guides, a network of teachers, examiners, academics and publishers. *Nuffield Combined Science*, first published in 1970, was probably the most influential course and was common in schools in the late 1970s. Indeed, Keohane (1986: vi) remarked: 'by 1979 (as the survey by her Majesty's Science

Inspectorate showed) over half the schools in England were using the course wholly or in part'.

The 1986 revision of the *Nuffield Combined Science* materials, published as *Nuffield 11 to 13*, took into account various changes that had taken place since the first version was published in 1970:

> ... in that period, school children, schools, science, technology, and society at large have undergone great change. And that is not to mention the great changes in children's expectations of schools and science lessons, in teachers' expectations of children and resources for learning, and in society's expectations of teachers. (Nuffield Science 11 to 13, 1986: 2)

Second, Millar and Osborne noted another significant development in science education as the introduction of the comprehensive school system in the mid-1960s which led, *inter alia*, to the development of courses 'for the less academic pupil' (1998: 2003). This change had enormous implications for science pedagogy. Third, they noted that courses developed during the 1980s aimed to increase the emphasis placed on the processes of science (that is, the skills necessary to undertake science experiments) (Jenkins, 2004). Fourth, they noted the influence of the Department of Education and Science policy statement, *Science 5–16* (DES, 1985) which argued that all young people should have a 'broad and balanced' science education (that is, a curriculum containing biology, chemistry and physics throughout the school system) and occupying (for most pupils) 20% of curriculum time from age 14 to 16 (Jenkins, 2004). Fifth, Millar and Osborne noted the impact of the introduction, in 1986, of the General Certificate of Secondary Education (GCSE) which resulted in a variety of science courses that included all three main sciences intended for all students. Sixth, they highlighted the introduction of the National Curriculum in 1989, which made science a 'core' subject in the curriculum for students aged 5 to 16 (Millar and Osborne, 1998: 2002–3).

Millar and Osborne (1998: 2003) also argued that since science had become one of the three core subjects of the National Curriculum in England, the nature of science education had changed and that 'there has been a general acceptance that learning science involves more than simply knowing some facts and ideas about the natural world' and that 'a significant component of science curriculum time should be devoted to providing opportunities for personal inquiry [that is, doing experiments]' (for a counter view, see Hodson, 1990, 1992).

Since *Beyond 2000* was published, science education in England has continued to evolve. A growing number of schools offer students the possibility of studying biology, chemistry and physics as separate subjects (Triple Science). A national network of science learning centres has been set up and continues to attract interest from policy makers from other countries. A growing number of science centres and museums offer educational events and activities aimed at school students and provide opportunities to meet real scientists.

Debate about the quantity and quality of practical work continues to be an issue, just as it was in the 1960s and 1970s. Support for teaching science outside the classroom has grown over the years although its provision is very variable across the country with some teachers still reluctant to take their students outside.

In general, science education in English schools has made some progress since the 1960s. There is more gender equity and more focus on teaching about the nature of science. Students can experience a range of scientific ideas inside and outside the classroom. The overall quality of science teaching is probably better now that it was some years ago. However, many of the curriculum, assessment and pedagogical issues that challenged teachers in the post-war era can still be found in today's schools.

RESEARCH IN SCIENCE EDUCATION IN EUROPE

As science education in Europe has developed through policy reform and through curriculum development, so too has the quality and quantity of research. Many countries have their own associations promoting research in science education generally or in the separate sciences. Increasing collaboration between countries led to the setting up of pan European organisations such as ERIDOB – European Researchers in the Didactics of Biology - which meets every two years.

Early collaborations between European science educators led to summer schools for Ph.D. students in Zeist in the Netherlands in 1993 and Thessaloniki, Greece, in 1994. As more European researchers attended conferences in the US organised by the National Association for Research in Science Teaching (NARST) and Australasia (Australasian Science Education Research Association (ASERA) so the desire to create a European equivalent grew. In 1995, a group of science educators including Rosalind Driver, organised a science education conference in Leeds. One key purpose of the conference was to create a European association of science educators. It is to the credit of a large number of European science educators, assisted by colleagues from Australia and the USA, that the association was born. Few people who were present at the final plenary discussion, orchestrated by John Gilbert from Reading University, will ever forget the challenges of language, culture and regional loyalties that helped to create the organisation that ESERA (www.esera.org) is now.

ESERA's first President was Dimitris Psillos from Greece and the Secretary was Philip Adey from the UK. Piet Lijnse (Netherlands), Reinders Duit (Germany); Maria Pilar Jiménez Aleixandre (Spain); Martine Méheut (France) and Helene Sørensen (Denmark) made up the rest of the Executive. Subsequent ESERA Presidents have included Robin Millar and the two editors of this volume. ESERA has grown from strength to strength and has held biennial conferences in Rome, Kiel (Germany), Thessaloniki, Noordwijkerhout (Netherlands), Barcelona, Malmö, Istanbul and Lyon. In the intervening years it has organised Ph.D. summer schools in Barcelona (Spain), Marly-le-Roi (France), Gilleleje (Denmark), Radovljica (Slovenia), Mülheim (Germany), Braga (Portugal), York (UK), Udine (Italy) and Bad Honnef (Germany).

POLICY TEXTS AND THE NATURE OF SCIENCE EDUCATION

In recent years, several documents have been published in Europe that more or less described a crisis situation for the recruitment of Science, Technology, Engineering and Mathematics (STEM) students to higher education and eventually the workforce. The first was the report published in 2004: *Europe Needs More Scientists* (EC, 2004) chaired by the former Portuguese Science and Technology Minister Professor José Mariano Gago. The focus of this report was not only that Europe needed to promote more students to careers in STEM areas, but also that the focus needed to be on educational systems for improving school science. The importance of stressing hands-on science based on experiences was suggested to increase motivation. The focus shifted from science for future scientists to a science education that promoted science for all and scientific literacy.

In 2006, the Nuffield Foundation convened two seminars involving science educators from nine European countries. The seminars investigated the extent to which the issue of poor attitudes towards science was common across Europe, the similarities and differences between countries, and some attempted solutions and remedies. The idea behind these two Nuffield-funded London seminars was to draw together a group of leading science educators, from across the continent, to consider the state of science education in the EU. Invitations were extended to those engaged in science education, albeit principally academic science educators, from a range of European countries that were felt to represent the diversity of countries within the EU. The first seminar was held at the Nuffield Foundation headquarters, on June 1–2, 2006 and the second was held, in the same year, on December 7–8. In addition, an initial draft of the main findings was presented and discussed at ESERA's biennial conference in Malmö, Sweden in August 2007. The focus of the first seminar was very much on exploring the current state of science education across Europe, the issues that are confronting it, and the evidence for those views. The seminars sought to explore what were felt to be the four key issues that are central to the nature of the teaching and learning experience offered by school science. That is: curriculum; pedagogy; assessment and teacher supply, professional development and retention. Introducing the subsequent report, *Science Education in Europe: Critical Reflections* (Osborne and Dillon, 2008), the Director of the Nuffield Foundation, Dr Anthony Tomei wrote:

> Its message is clear. There are shortcomings in curriculum, pedagogy and assessment, but the deeper problem is one of fundamental purpose. School science education, the authors argue, has never provided a satisfactory education for the majority. Now the evidence is that it is failing in its original purpose, to provide a route into science for future scientists. The challenge therefore, is to re-imagine science education: to consider how it can be made fit for the modern world and how it can meet the needs of all students; those who will go on to work in scientific and technical subjects, and those who will not. The report suggests how this re-imagining might be achieved.

The authors of *Science Education in Europe* examined the concern about science education, expressed in reports such as *Europe Needs More Scientists* which, they argued 'concentrates solely on the supply of future scientists and engineers and rarely examines the demand.' Their critique noted that:

> There is, for instance, a failure to recognise that science is a global activity where the evidence would suggest that there is no overall shortage at the doctoral level [2] although there may be local shortages of particular types of scientists and engineers, for example, pharmacologists in the UK. There may also be shortages at the technician and intermediate levels of scientific and technological work but better data is needed before making major policy decisions on science education. In such a context, encouraging or persuading young people to pursue careers in science without the evidence of demand would be morally questionable. (p. 7)

Osborne and Dillon argued that framing the discussion about school science in terms of the supply of the next generation of scientists is problematic because it defines the primary goal of science education as a pipeline, albeit leaky.

> In so doing, it places a responsibility on school science education that no other curriculum subject shares. Our view is that a science education *for all* can only be justified if it offers something of universal value for *all* rather than the *minority* who will become future scientists. For these reasons, the goal of science education must be, first and foremost, to offer an education that develops students' understanding both of the canon of scientific knowledge and of how science functions. In short that school science offers an *education in science* and not a form of pre-professional training. (p. 7)

The report, which has been cited almost 200 times, according to Google Scholar, makes a series of seven recommendations including:

> More attempts at innovative curricula and ways of organising the teaching of science that address the issue of low student motivation are required. These innovations need to be evaluated. In particular, a physical science curriculum that specifically focuses on developing an understanding of science in contexts that are known to interest girls should be developed and trialled within the EU. (p. 8)

and

> EU governments should invest significantly in research and development in assessment in science education. The aim should be to develop items and methods that assess the skills, knowledge and competencies expected of a scientifically literate citizen. (p. 8)

A report published by the OECD titled: *Encouraging Student Interest in Science and Technology Studies* (OECD, 2008) looked at the overall trends in higher education compared with other disciplines. The report suggested that whereas absolute numbers of science and technology students have been rising in accordance with increased access to higher education in OECD countries, the relative share of science and technology students in the overall population has been falling. Of particular importance is that female students also continue to lag behind. Recommendations from this report are similar to others which call for curriculum reforms, improved science teacher education and in-service and particular attention to ideas to increase the number of females studying science and technology subjects.

SCIENCE EDUCATION RESEARCH AND DEVELOPMENT IN THE EU

In response to the situation found in Europe for recruitment into the STEM areas, the European Commission established a research programme in Science in Society (SIS) with a broad perspective on marking the importance of Science in Europe (http://cordis.europa.eu/fp7/sis). The SIS programme in the Seventh Framework Programme (FP7) has a budget of EUR 330 million, reflecting a strong commitment to the significance of science in Europe. The SIS Program has been charged with the responsibility of supporting the following specific research activities: the connection between science, democracy and law; ethics in science and technology; the reciprocal influence of science and culture; the role and image of scientists; gender aspects; science education methods; and science communication. Science educators and researchers have been particularly active in research calls dealing with science education methods, science communication, gender aspects and the role and image of scientists.

In 2006 an expert group under the leadership of Michel Rocard, former prime minister of France and member of the European Parliament, was established to look more closely at on-going initiatives funded by SiS in Europe to identify the necessary conditions for bringing about change in young people's interest in science. The timing of the report, published in 2007, was important for France, since they were to assume the EU Presidency in 2008. The expert group looked particularly at successful projects that worked with the way science is taught in schools, concluding with an appeal to promote inquiry based science teaching and learning as a basis for improving the way science is taught in schools. The report, *Science Education NOW: A Renewed Pedagogy for the Future of Europe* (EC, 2007) came with recommendations for politicians in member states for how to go about making changes in how science is taught. The most important impact of the report was the release of additional research funding in this area.

Two initiatives were described in the *Science Education NOW* report, serving as examples of successful projects having had an impact on science teaching through inquiry in Europe. The first was the Pollen project (www.pollen-europa.net), launched in 2006, in which inquiry based science education (IBSE) at the primary level was implemented within 12 seed cities throughout Europe. The major goal of Pollen was "to provide an empirical illustration of how science teaching can be reformed on a local level within schools whilst involving the whole community, in order to demonstrate the sustainability and efficiency of the Seed City approach to stakeholders and national education authorities, and to seek leverage effects" (www.pollen-europa.net). It should be noted that the Pollen project was supported by the French Academy of Sciences, also responsible for the *La main à la pâte* programme, launched in 1996. The more recent EU supported Fibonacci Project (www.fibonacci-project.eu) continued from this line of prestigious predecessors by increasing the number of participating countries and also including mathematics. The project is based on the idea that local and regional initiatives are appropriate for the reform of science education in Europe.

The second project described by the *Science Education NOW* report was the German SINUS-Transfer project (http://sinus-transfer.eu) based on years of experience working with discussion between teachers on their pedagogical practices in teaching science and mathematics in German schools. The Mind the Gap and the S-TEAM (www.s-teamproject.eu) projects described by Stadler and Jorde (in this volume) are supported through EU funding under the SiS funding scheme for science education methods in inquiry based science education. It is an important point to make that the individual countries in the EU have responsibility for their own curriculum (what is to be taught). However, it is possible to establish norms about matters concerning the pedagogy of teaching and thus create international networks of researchers concerned with teaching.

Coordinating the many projects supported within the 7th Framework Programme is a task taken on by the newly established SCIENTIX (The community for science education in Europe) project and website (www.scientix.eu). Even a quick look at this site shows the tremendous amount of supported activity in Europe in STEM areas. The searchable website is in itself a challenge for Europe, as language and culture need to be considered in all types of search engines.

Europe is definitely talking about STEM issues. The question remains, are we able to coordinate our efforts to make the impact desired for general scientific literacy as well as for Europe's need to compete within the worldwide knowledge society? The many STEM projects launched in the past few years are based on solid science education research, going on in Europe since the 1960's. Much of this research has been done locally – within national boundaries. The trend towards large-scale inquiry based science projects in Europe is influenced by European funding within the 7th framework for SIS. Whereas this is a very positive movement for bringing ideas, researchers and teachers together throughout Europe, it is not the type of funding that allows basic types of research. What is drastically needed now and in the future is funding to work comparatively with educational research in science education so that we can begin to develop a better understanding of what actually works and whether ideas are transferable to other cultures and contexts.

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REINDERS DUIT, HARALD GROPENGIEßER, ULRICH KATTMANN,
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2. THE MODEL OF EDUCATIONAL RECONSTRUCTION – A FRAMEWORK FOR IMPROVING TEACHING AND LEARNING SCIENCE[1]

OVERVIEW

To improve instructional practices – in schools, universities and in out of school settings has been a major concern of science education research and development. The intensive international debate on *scientific literacy* in the 1990s and the series of international monitoring studies like TIMSS and PISA in the 1990s and in the 2000s have fuelled this debate substantially. Various strands of science education research contribute to the stock of knowledge on more efficient means of teaching and learning science. The Model of Educational Reconstruction (MER) presented in this chapter provides a conception of science education research that is relevant for improving instructional practice and teacher professional development programs. The model is based on European Didaktik and Bildung (formation) traditions – with a particular emphasis on the German tradition. A key concern of the model is that science subject matter issues as well as student learning needs and capabilities have to be given equal attention in attempts to improve the quality of teaching and learning. There are three major emphases that are intimately connected:

(1) The clarification and analysis of science subject matter (including key science concepts and principles like evolution, energy, particles, or combustion, and science processes and views of the nature of science, as well as the significance of science in various out of school contexts).
(2) The investigation into student and teacher perspectives regarding the chosen subject (including pre-instructional conceptions, affective variables like interests, self-concepts, attitudes, and skills).
(3) The design and evaluation of learning environments (e.g. instructional materials, learning activities, teaching and learning sequences).

The first emphasis comprises analyses of subject matter from science *and* educational perspectives. Research and development activities are closely linked.

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ON THE INTERDISCIPLINARY NATURE OF SCIENCE EDUCATION

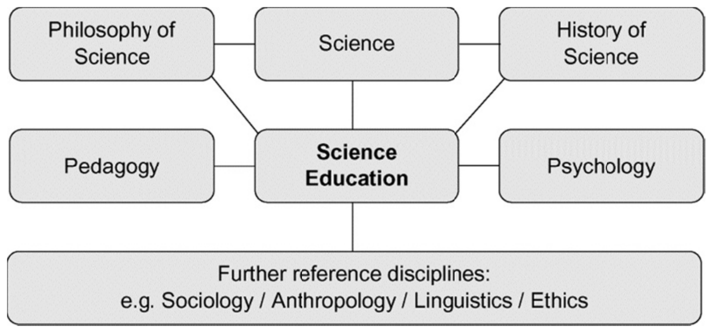

Figure 1. Reference disciplines for Science Education (Duit, 2007).

There are several *reference disciplines* that are needed to meet the challenges of investigating and analysing key issues of teaching and learning science. Philosophy and history of science provide thinking patterns to critically analyze the *nature of science* (McComas, 1998; Lederman, 2008), and the particular contribution of science to understand the "world", i.e. nature and technology (Bybee, 1997; de Boer, 2000). Accordingly, these disciplines allow us to discuss what is special in science (as compared to other disciplines) and therefore what is special in teaching and learning science. Pedagogy and psychology provide competencies to consider whether a certain topic is worth teaching and to carry out empirical studies whether this topic may be understood by the students. There are further reference disciplines that also come into play, such as linguistics which may provide frameworks for analysing classroom discourse or conceptualizing learning science as an introduction into a new language or ethics for framing instruction on moral issues.

The interdisciplinary nature of science education is responsible for particular challenges for carrying out science education research and development. Not only sound competencies in science are necessary but also substantial competencies in various additional disciplines. In principle the same set of competencies – though with different emphases – has also to be expected from teachers. To know science well is not sufficient for them. At least some basic insight into the nature of science provided by the philosophy and history of science and familiarity with recent views of teaching and learning science provided by pedagogy and psychology are needed.

Shulman (1987) introduced the idea of *content specific pedagogical knowledge* (briefly: PCK – Pedagogical Content Knowledge). It has been widely adopted in science education (Gess-Newsome & Lederman, 1999; van Dijk & Kattmann, 2007). The key idea is the following. There is a close link between content knowledge and pedagogical knowledge which in traditional approaches is often disregarded. Shulman (1987) holds that the PCK linking the two kinds of knowledge is the major key to successful teaching. The conception of science education outlined in Figure 1 includes Shulman's idea of PCK (for an elaborate analysis, see van Dijk & Kattmann, 2007).

TRADITIONS OF SCIENCE EDUCATION RESEARCH[2]

Dahnke et al. (2001) argued that there is a split in the science education community. On the one side the major focus is on science. Research work in this group is usually restricted to issues of subject matter knowledge or presentation techniques – neglecting the way in which the ideas discussed may be learned by the students. On the other hand, there are science educators who try to find a balance between the mother discipline and educational issues. This is the position depicted in Figure 1. Jenkins (2001) provided another distinction. His *pedagogical* tradition aims at improving practice. He claims that the followers of this tradition remain close to the academic science disciplines. The major concern of his *empirical* tradition is acquiring "objective data" that are needed to understand and influence educational practice.

Clearly, there is a substantial degree of commonality of Jenkins' (2001) distinction and the previous view of Dahnke et al. (2001). This distinction may be seen in terms of differentiating *applied* and *basic* research. It was argued in science education (Wright, 1993) and in research on teaching and learning in general (Kaestle, 1993) that basic research in education is viewed as irrelevant by practitioners. Still there is an intensive debate on overcoming the gap between theory and practice (Luft, 2009). Hence, a fine-tuned balance between the two positions is needed in research that aims at improving practice (Gibbons et al., 1994; Vosniadou, 1996). The most prominent positions merging the above applied and basic research positions seem to be variants of *Design Based Research* (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003; Sandoval & Bell, 2004; Tibergien, Vince, & Gaidioz, 2009). As will be outlined more fully below the model of educational reconstruction presented here is also based on merging the applied and basic research side.

The two traditions briefly outlined above may be characterised in the following way. On the one side, there is a group of science education researchers who are close to the particular science domain. Their attention is not only near to teaching practice but they also put the main emphasis on science content in designing new teaching and learning sequences. Frequently, a balance between science orientation and orientation on student needs, interests, ideas and learning processes is missing. On the other side, the group focussing on empirical research on teaching and learning often orients itself on general education and the psychology of learning barely considering the domain and context specific perspectives of the science topic. A significant number of conceptual change approaches (Vosniadou, 2008; Treagust & Duit, 2008) seem to fall into this category. The two positions may be characterized by calling them *science-oriented* and *student-oriented*. Clearly analytical research on a particular science content (like evolution or energy), which is often carried out by science-oriented science educators provides an essential basis for teaching and learning the content. However, it seems that progress in student understanding and learning may only be achieved if there is a balance between the two perspectives. Successful design of science teaching and learning sequences needs to merge the two positions.

Fensham (2001) points to the necessity of research on teaching and learning to rethink science content, to view it also as problematic (see also Fensham, Gunstone, & White, 1994), and to reconstruct it from educational perspectives. These considerations may also be discussed by contrasting the European Didaktik tradition and the Curriculum tradition (Hopmann & Riquarts, 1995). Whereas the Curriculum tradition is very much in line with the above Jenkin's (2001) *empirical* side, the Didaktik tradition aims at a balance of key features of the *science-oriented* and *student-oriented* science education research. This is the above position of the interdisciplinary nature of science education research as outlined in Figure 1 which is also a key concern of the Model of Educational Reconstruction discussed below.

THE GERMAN TRADITION OF BILDUNG AND DIDAKTIK

It is essential to point out first that traditional German pedagogy was strongly embedded in hermeneutical epistemological views as established by Wilhelm Dilthey (1833–1911). It appears that this tradition is a major reason that behaviourist ideas had a much smaller impact on the educational system in Germany as compared to the predominance of the view in the USA.

The German terms *Bildung* and *Didaktik* are difficult to translate into English. A literal translation is *formation*. In fact *Bildung* is viewed as a process. Bildung denotes the formation of the learner as a whole person, that is, for the development of the personality of the learner. The meaning of *Didaktik* is based on the notion of *Bildung*. It concerns the analytical process of transposing (or transforming) human knowledge (the cultural heritage) like domain specific knowledge into knowledge for schooling that contributes to the above formation (Bildung) of young people. Didaktik should not be interpreted from the perspective of the English expression *didactical* which denotes a rather restricted instructional method (Hopmann & Riquarts, 1995; Fensham, 2001).

Two major conceptions of German Didaktik are presented in the following. The first conception is Klafki's *Didaktische Analyse* (Educational Analysis) published in 1969. His ideas rest upon the principle of primacy of the aims and intentions of instruction. They frame the educational analysis, at the heart of which are the five questions in Table 1.

Table 1. Key questions of Klafki's (1969) Educational Analysis (Didaktische Analyse)

(1)	*What is the more general idea that is represented by the content of interest? What basic phenomena or basic principles, what general laws, criteria, methods, techniques or attitudes may be addressed in an exemplary way by dealing with the content?*
(2)	*What is the significance of the referring content or the experiences, knowledge, abilities, and skills to be achieved by dealing with the content in students' actual intellectual life? What is the significance the content should have from a pedagogical point of view?*
(3)	*What is the significance of the content for students' future life?*
(4)	*What is the structure of the content if viewed from the pedagogical perspectives outlined in questions 1 to 3?*
(5)	*What are particular cases, phenomena, situations, experiments that allow making the structure of the referring content interesting, worth questioning, accessible, and understandable for the students?*

The other significant figure of thought within the German *Didaktik* tradition is the fundamental interplay of all variables determining instruction proposed by Heimann, Otto, and Schulz also in 1969 (Figure 2). In this model students' learning processes are of key interest and not the contribution to *Bildung* as is the case in Klafki's *Educational Analysis* approach. The aims and intentions of instruction form the most significant frame for the process of designing instruction; however, they are given the role of primus inter pares (the first among equal partners). The *interaction* of intentions and the other variables shown in the first line of figure 2 is given particular attention. Students' intellectual and attitudinal as well as socio-cultural preconditions significantly influence the interplay of these components. They allow asking the four key questions that shape the process of instructional planning: Why – What – How – By What.

Intentions (aims and objectives)	**Topic of instruction** (content)	**Methods** of instruction	**Media** used in instruction
Why	**What**	**How**	**By What**
Students' intellectual and attitudinal preconditions (e.g., pre-instructional conceptions, state of general thinking processes, interests and attitudes) **Students' socio-cultural preconditions** (e.g.,norms of society, influence of society and life on the student)			

Figure 2. On the fundamental interplay of instructional variables.

The most important issues of the German Didaktik tradition as outlined are the following. In planning instruction (by the teacher or curriculum developers) the science content to be learned and students' cognitive and affective variables linked to learning the content have to be given equal attention. The science content is not viewed as "given" but has to undergo certain reconstruction processes. The science content structure (e.g. for the force concept) has to be transformed into a content structure *for* instruction. The two structures are fundamentally different. In the first step the *elementary ideas* with regard to the aims of instruction have to be *detected* by seriously taking into account student perspectives (e.g. their pre-instructional conceptions). Hence, it becomes, obvious that key ideas of the later constructivist perspectives of teaching and learning science were already part of the German *Didaktik* tradition.

An additional key figure of thought within the German Didaktik tradition is called "Elementarisierung" (see Nipkow, 1986, for the use of this term in German pedagogy). The literal English translation *elementarization* is not commonly used in pedagogy and science education literature. It includes three major facets (Bleichroth, 1991; Reinhold, 2006). Educational analysis according to Klafki's (1969) first question in Table 1 aims at identifying the *elements*, i.e. the elementary lfeatures (basic phenomena, basic principles, general laws), of a certain content to be taught. The search for the elements has to be guided by the aims and objectives of instruction in such a way that students may understand them. The term *element* as used in considerations on *elementarization* clearly has a metaphorical meaning. It is a search for the entities of a complex content domain (e.g., a complex science theory) that may be viewed as *elements* in a similar way as the elements that allow explaining the composition of all substances. For the science concept of *energy* the following elementary features have proven fruitful: Energy transformation, conservation, degradation, and transfer (Duit & Häußler, 1994). Energy degradation is among the elementary features as understanding this feature is essential for allowing students to understand energy conservation. All processes in the real world display primarily energy degradation. Energy conservation usually may be "observed" (illustrated) only in particularly designed experiments not in daily life processes.

The second facet included in the use of the term *elementarization* is the process of reducing the complexity of a particular science content in such a way that it becomes accessible to the learners. This facet should not be interpreted in terms of merely "simplifying" science content because the purpose is not necessarily to make science simpler but to find a way to introduce students to the elementary features of a content that have been constructed in the search for the elements as outlined above. The process of elementarization often is a delicate task of finding a balance between correctness from the science point of view and accessibility for students. Frequently, it turns out to be a course between Scylla and Charybdis.

There is an additional facet included in the term elementarization, namely to plan student learning processes as a series of elements of instructional methods that allow to guide students from their pre-instructional conceptions towards the science concepts (Bleichroth, 1981).

THE MODEL OF EDUCATIONAL RECONSTRUCTION

The Model of Educational Reconstruction (MER) draws on the German Didaktik tradition outlined above. In particular, it addresses the need to bring science related issues and educationally oriented issues into balance when teaching and learning sequences are designed that deliberately support understanding and learning science. It also addresses the above gap between science education research and science instruction practice by explicitly linking research and development – in much the same way as, for instance, Design Based Research (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003).

Introductory Remarks

The model has been developed as a theoretical framework for studies as to whether it is worthwhile and possible to teach particular content areas of science. Clarification of science subject matter is a key issue if instruction of particular science contents (such as evolution, photosynthesis, or energy) is to be developed. Often issues coming from the structure of the referring science content primarily or solely inform this clarification process. Educational issues then are regarded only after the science subject matter structure has been clarified. Initially, the focus was on studies on educational reconstruction of *science content*. More recently, it became clear that also *science processes* and *views of the nature of science* need to undergo this process in order to allow efficient learning and teaching of issues *about* science.

The MER closely links research on the science content structure[3] and the educational significance of parts of it, and also includes empirical studies on students' understanding as well as preliminary trials of pilot instructional modules in classroom practice. It is, for instance, a key assumption of the model that the curriculum developers' awareness of the students' point of view may substantially influence the reconstruction of the particular science content. The results of the research already conducted within the framework of Educational Reconstruction clearly show that intimate knowledge of students' conceptions may provide a more adequate understanding of the referring science content by the curriculum developers. The MER has been designed primarily as a frame for science education research and development. However, it also provides significant guidance for planning science instruction in school practice.

The model has been developed in close cooperation of members of research groups on biology education in Oldenburg and physics education at the IPN in Kiel (Kattmann, Duit, Gropengießer, & Komorek, 1995, 1997). The model provided the framework for a project on the "*Educational Reconstruction of key features of non-linear systems*" (Duit, Komorek, & Wilbers, 1997; Komorek & Duit, 2004; Stavrou, Duit, & Komorek, 2008). It was also used as a key facet of the theoretical framework for instructional planning within the quality development projects "*Physics in Context*" (Duit & Mikelskis-Seifert, 2010) and "*Chemistry in Context*" (Parchmann & Schmidt, 2003; Schmidt, Rebentisch & Parchmann, 2003).

Colleagues at the University of Oldenburg initiated a large series of studies on educational reconstruction of key biology concepts like evolution, vision, cell and the like in German biology education in general (Frerichs, 1999; Gropengießer, 1998; Kattmann, 2001; Hilge, 2001; Brinschwitz & Gropengießer, 2003; Baalmann, Frerichs, Weizel, Gropengießer, & Kattmann, 2004; Lewis & Kattmann, 2004). They also started a "*Graduate School Educational Reconstruction*" that allowed investigating the power of MER not only in science but also in various additional school topics.[4] More recently, in a subsequent project teacher professional development based on the MER is given particular attention.[5] In general the model became a key figure of thought in German science education. It has also been adopted by science educators elsewhere – especially in Europe, i.e. in countries with a deliberate Didaktik-tradition.

Epistemological Orientation

The model is based on a constructivist epistemological position (Phillips, 2000). This epistemological orientation concerns the understanding of students' perspectives as well as the interpretation of the scientific content (Gerstenmaier & Mandl, 1996). We stress the point of view that the conceptions the learners develop are not regarded as obstacles for learning but as points to start from and mental instruments to work with in further learning (Driver & Easley, 1978; Duit & Treagust, 2003; Treagust & Duit, 2008). We further assume that there is no such thing as the "true" content structure of a particular content area (Abd-El-Khalik & Lederman, 2000). What is commonly called the science content structure is seen as the consensus of a particular science community. Every presentation of this consensus, including the presentations in the leading textbooks, is viewed as an idiosyncratic reconstruction of the authors informed by the specific aims they explicitly or implicitly hold. Thus academic textbooks are regarded as descriptions of concepts, principles and theories and not as accounts of reality itself. Certainly in most cases the scientific knowledge is of higher inter-subjective validity than everyday knowledge but – like the latter – it is still a system of mental constructs. Clearly, these considerations also hold for issues of science processes and the nature of science (i.e. issue *about* science). However, it has to be taken into account that the consensus about the particular features of science processes and the nature of science is far less well established as with regard to science content (Lederman, 2008).

Overview of the Model

Figure 3 illustrates that the MER consists of three closely interrelated components; figure 4 provides details of the process of educational reconstruction.

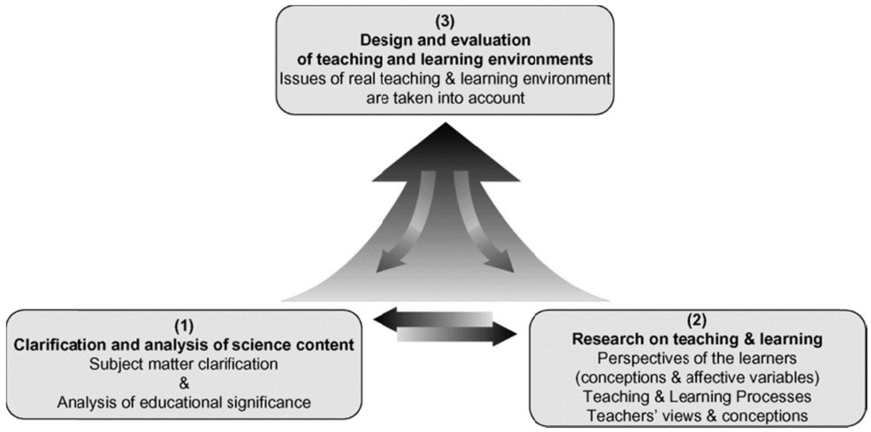

Figure 3. The three components of the Model of Educational Reconstruction.

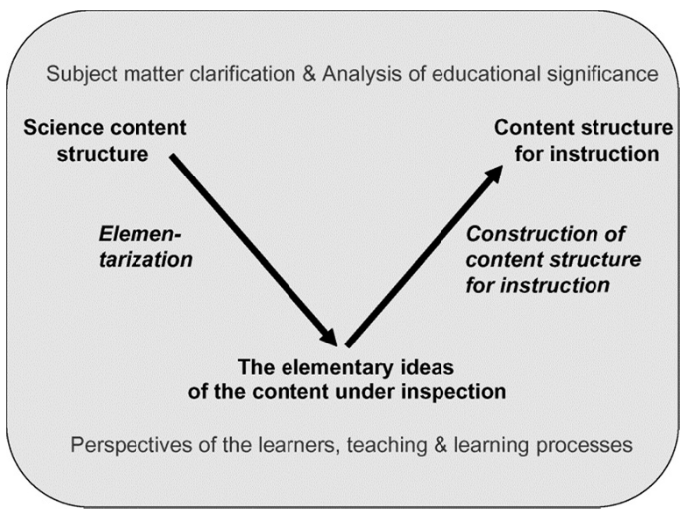

Figure 4. Steps towards a content structure for instruction.

The model concerns the analytical process of transposing[6] (or transforming) human knowledge (the cultural heritage) like domain specific knowledge into knowledge for schooling that contributes to student scientific literacy. Briefly put, the content structure of a certain domain has to be transformed into a content structure *for* instruction (see figure 4). The two structures are substantially different. The science content structure for a certain topic may not be directly transferred into a content structure for instruction. It has to be *elementarized* to make it accessible for students but also enriched by putting it into contexts that make sense for the learners.

Many teachers and also science educators think that the content structure for instruction has to be “simpler” than the science content structure in order to meet students’ understanding. Accordingly, they call the process of designing the content structure for instruction *reduction*. However, this view misses the point. In a way the content structure for instruction has to be much more complex than the science content structure in order to meet the needs of the learners. It is, therefore, necessary to embed the abstract science knowledge into various contexts in order to address learning potentialities and difficulties of the learners.

Component (1): Clarification and Analysis of Science Content

The aim of this component is to clarify the specific science conceptions and the content structure from an educational point of view. Two processes closely linked are included, *clarification of subject matter* and *analysis of educational significance*. Clarification of subject matter draws on qualitative content analysis of leading textbooks and key publications on the topic under inspection but also may take into account its historical development. A critical analysis of a particular science content from the standpoint of science education is necessary, because academic textbooks address experts (e.g. scientist and students to become scientists). Scientific knowledge is often presented in an abstract and condensed manner. Usually, neither preconceptions nor circumstances of the research process, the research questions and the methods employed are given. We even find linguistic expressions of old and outdated thought in academic textbooks. In a scientific community this may not hamper understanding too much. To learners at schools and informal learning sites this kind of science content is not accessible and sometimes misleading. We also attend to science terms that might be misleading to learners, especially words of different meaning in science and everyday-life.

Interestingly, taking students’ pre-instructional conceptions into account that have often proven not to be in accordance with the science concepts to be learned (Driver & Erickson, 1983) also contributes to more adequately understanding the science content in the process of subject matter clarification. Experiences show that surprising and seemingly “strange” conceptions students own may provide a new view of science content and hence allows another, deeper, understanding of the content clarified (Kattmann, 2001; Duit, Komorek, & Wilbers, 1997; Scheffel, Brockmeier, & Parchmann, 2009).

As mentioned previously, the key idea of educational reconstruction includes the idea that a certain *science content structure* has to be transformed into the *content structure for instruction*. According to Figure 4 two processes are included: *elementarization* which lead to the elementary ideas of the content under inspection (see additional remarks on this process above) and *construction of content structure for instruction*. In both processes science content issues and issues of students’ perspectives (their conceptions and views about the content as well as affective variables like their interests and science learning self-concepts) have to be taken into account. Figure 4 provides a somewhat simplified impression of these processes. Usually, the procedure is not as linear as depicted but a somewhat complicated recursive procedure is needed to re-construct an appropriate content structure for instruction (see Figure 5 below).

As mentioned already, traditionally, science content primarily denotes science concepts and principles. However, recent views of science processes (science inquiry), the nature of science and also the relevance of science in daily life and society should be given substantial attention in science instruction (Osborne, Ratcliffe, Millar, & Duschl, 2003; McComas, 1998; Lederman, 2008). All these additional issues need to be included in the process of educational reconstruction, i.e. also they need to be educationally reconstructed.

Component (2): Research on Teaching and Learning

Figure 3 indicates that the process of clarification and analysis of science content on the one hand and the process of construction of content structure for instruction on the other need to be based on empirical research on teaching and learning. Empirical studies on various features of the particular learning setting need to be regarded. Research on students' perspectives investigates their pre-instructional conceptions and affective variables like interests, self-concepts, and attitudes. But many more studies on teaching and learning processes and the particular role of instructional methods, experiments and other instructional tools need to be taken into account. Furthermore, research on teachers' views and beliefs of the science concepts, students' learning and their role in initiating and supporting learning processes are essential.

The research literature on teaching and learning science is extensive (Abell & Lederman, 2008; Duit, 2009). This is by far the largest research domain in science education. A wide spectrum of methods is employed ranging from qualitative to quantitative nature, including questionnaires, interviews and learning process studies in natural settings.

However, for a number of new and also traditional topics little to no research at all is available. In these cases, research on teaching and learning and the process of educational reconstruction are closely interrelated (Baalmann et al., 2004; Duit, Komorek, & Wilbers, 1997). Here qualitative methods like interviews or small scale learning process studies prevail (Komorek & Duit, 2004).

Component (3): Design and Evaluation of Teaching and Learning Environments

The third component comprises the design of instructional materials, learning activities, and teaching and learning sequences. The design of learning supporting environments is at the heart of this component. Hence, the design is, first of all, structured by the specific needs and learning capabilities of the students to achieve the goals set. Key resources of the design activities are research findings on students' perspectives (e.g., their potentialities, learning difficulties as well as their interests, self-concepts and attitudes) on the one hand and the (preliminary) results of subject matter clarification on the other hand. Both resources are regarded as equally important for designing instruction.

Various empirical methods are used to evaluate the materials and activities designed, such as interviews with students and teachers, e.g. on their views of the value of the desired items, questionnaires on the development of students' cognitive and affective variables, and also analyses of video-documented instructional practice. Development of instructional material and activities as well as research on various issues of teaching and learning science is intimately linked.

Interview studies primarily provide guidelines for the rearrangement of learning sequences and design of learning environments (Baalmann, Frerichs, & Kattmann, 1999; Frerichs, 1999; Gropengießer, 1998, 2001; Hilge, 2001; Komorek, Vogt, & Duit, 2003; Osewold, 2003; Baalmann et al., 2004; Schwanewedel, Hößle, & Kattmann, 2007; Fach & Parchmann, 2007). In teaching experiments (Steffe & D'Ambrosio, 1996; Komorek & Duit, 2004; Scheffel, Brockmann, & Parchmann, 2009) carried out with a few students each, learning processes are investigated. The learners' "pathways of thinking" are inferred and linked to the learning activities. The effect of carefully designed learning environments on the students' conceptions is investigated (Komorek, Stavrou, & Duit, 2003; Komorek & Duit, 2004; Schmidt, 2011). In the studies by Brinschwitz and Gropengießer (2003), Weitzel and Gropengießer (2003), Groß and Gropengießer (2003), Riemeier (2005) as well as Niebert and Gropengießer and Riemeier and Gropengießer (2008) the interpretation was framed by experiential realism and a cognitive linguistic theory of understanding (Lakoff, 1990). Further studies in natural settings of science classrooms are conducted (Duit, Roth, Komorek, & Wilbers, 1998). Limitations and the particular shaping of learning processes within the conditions of real classroom settings are to be taken into account in theses studies (compare Brown's, 1992, approach of *design experiments;* for a similar approach: Knippels, 2003; Verhoeff, 2004).

The Recursive Process of Educational Reconstruction

Figure 3 points out that there is a fundamental interaction between the three components of the Model of Educational Reconstruction. However, the three components do not follow strictly upon one another but influence each other mutually. Consequently the procedure must be conducted step by step recursively. In practice, a complex step by step process occurs. Figure 5 presents this process in a project on educational reconstruction of limited predictability of chaotic systems (Duit, Komorek, & Wilbers, 1997).

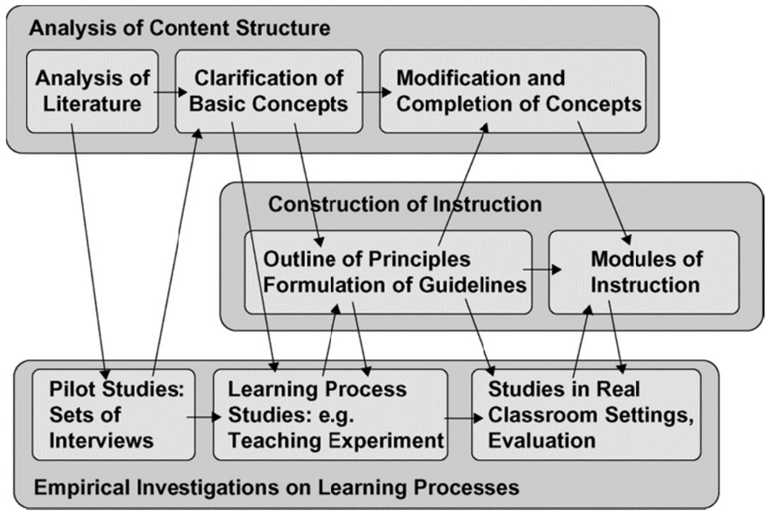

Figure 5. An example for the recursive process of Educational Reconstruction (Kattmann et al., 1995).

The Model of Educational Reconstruction and Other Models of Instructional Design

The MER presented here shares major features with other models of instructional design that aim at improving practice. First of all, the model is explicitly based on constructivist oriented views of efficient teaching and learning environments. In this regard, the model meets the mainstream of the wide spectrum of contemporary attempts towards constructivist oriented instructional design (Vosniadou, 2008; Tytler, 2007; Widodo, 2004). However, the model does not favour a particular variant of this kind of design. Actually, in the many studies explicitly based on the model partly substantially different epistemological variants are used and varying constructivist oriented instructional methods employed depending on the aims of the particular learning settings.

The cyclical (recursive) process of educational reconstruction i.e. the process of theoretical reflection, conceptual analysis, small scale curriculum development, and classroom research on the interaction of teaching and learning processes is also a key concern of the conception of *developmental research*[7] presented by Lijnse (1995).

As mentioned, in the field of educational psychology there has been an intensive discussion on whether results of research on teaching and learning are suited to improve instructional practice, i.e., to bridge the deep gap between research and practice (see above). *Design Experiments* (Cobb et al., 2003) and other design based research approaches have been developed as a means to address this problem. They intimately link research and development, and also take instructional practice explicitly into account. Further, they may lead to the development of content-oriented theories (Andersson & Wallin, 2006) – in much the same way as the MER.

It seems that this model also shares some major features with the approach of *Learning Progressions* that has been developed the past decade, primarily in the USA (Duncan & Hmelo-Silver, 2009). Learning progressions describe "*successively more sophisticated ways of reasoning within a content domain that follow one another as students learn*" (Smith, Wiser, Anderson, & Krajcik, 2006). The major shared issues of the approaches concern that science content structure features and students learning pathways in a long term perspective both are given significant attention.

Clearly, the MER shares a significant number of features with other frameworks for science education research and development, e.g. constructivist orientation, development of content-oriented theories, recursive process of research and development, and aiming at improving instructional practice. The particular contribution to the international state of discussion seems to be the idea that science content structure has to be reconstructed on the grounds of educational issues, namely the aims of instruction and student perspectives. The processes depicted in Figure 4, namely the *elementarization* leading to the key basic ideas of a certain content domain and the adjacent *construction of the content structure for instruction* indicate the special contribution of the model. The more general contribution of the MER can be seen in providing a framework of relevant components for science education research and development and thereby shaping its trilateral relations. The three components are mutually related to each other in a systematic way.

CONCLUSIONS – ON THE ROLE OF THE MODEL OF EDUCATIONAL RECONSTRUCTION IN SCIENCE EDUCATION RESEARCH AND DEVELOPMENT

The MER presented above initially was developed as a model for instructional planning – in school practice and in curriculum development groups. In the following we attempt to illustrate that the model has been also proven fruitful beyond the initial focus.

The Model of Educational Reconstruction as a Framework for Science Education Research

The model integrates three significant lines of science education research: (1) The clarification and analysis of science content, (2) research on teaching and learning with a particular emphasis on the role of student pre-instructional conceptions in the learning process, and (3) the design and evaluation of learning environments (Figure 3). Briefly summarized (for more details see Duit, 2007) there are the following characteristics of these three lines:

(1) *Clarification and analysis of science content.* As outlined more fully above there are two processes closely linked, *subject matter clarification* and *analysis of educational significance*. Not only science content but also science processes and views of the nature of science are included. Research methods for subject matter clarification are analytical (hermeneutical) in nature, and methods of content and text analysis prevail. History and philosophy of science issues are also taken into account. Analysis of educational significance is analytical in nature as well, drawing on pedagogical norms and goals. However, in a number of projects also empirical studies on the educational significance were included, e.g. by employing questionnaires to investigate the views of experts (Komorek, Wendorf, & Duit, 2003).

(2) *Research on teaching and learning.* This is by far the largest research domain in science education (Duit, 2009). The major sub-domains comprise: Student learning (cognitive and affective variables); teaching; teacher professional development; instructional media and methods; student assessment. A large spectrum of methods on empirical research has been employed ranging from qualitative to quantitative and including studies in natural settings. Various epistemological perspectives have been used with variants of constructivist views predominating (see above).

(3) *Design and evaluation of learning environments.* There is no doubt that much development work (e.g., regarding new experiments, new multi-media tools) still is not linked with research but draws on beliefs and "experiences" of the developers. The position underlying the MER points to three significant issues: First, development needs to be fundamentally research based and needs serious evaluation employing empirical research methods. Second, development should be viewed also as an opportunity for carrying out research studies. Third, improving practice is likely only if development and research are closely linked.

The MER provides a model in which primarily features of the particular teaching and learning situation are addressed. The wider context of the learning environment, comprising features of the educational system however, are not taken explicitly into account. *Research on curricular issues and science education policies* which is an additional major science education research field therefore is given only rather limited attention.

As argued above (Figure 1) science education should be seen as a fundamentally interdisciplinary scholarly discipline. The MER is based on this position and paradigmatically takes into account that science education research integrates research traditions from various disciplines, namely the sciences, philosophy and history of science, pedagogy, psychology, and additional disciplines like linguistics, ethics, and sociology.

Conceptual Reconstruction

Student learning processes are taken carefully in account in the MER. The major term to theoretically frame learning processes within constructivist oriented approaches has been *conceptual change* (Duit, Treagust, & Widodo, 2008). Unfortunately, the term invites several misunderstandings as the daily life meaning of change also includes exchange. However, research has clearly shown that a simple exchange of the new science conception for the old student conception usually does not happen in actual learning processes. In order to avoid misunderstandings of the term conceptual change several terms like *conceptual growth* or *conceptual enrichment* have been proposed (e.g., Strike & Posner, 1992; Vosniadou, 1996). Kattmann (2007) argued for using the term *conceptual reconstruction* in analogy to the processes of educational reconstruction (Figure 4). This term indicates that students need to *reconstruct* their pre-instructional conceptions. Mental processes are included that may be described as revolutionary (discontinuous) if conceptions are fundamentally re-organized, or as developmental (continuous) if conceptions are modified or linked in a new way. Furthermore, *conceptual reconstruction* also theoretically frames learning processes in which learners develop their mental structures by forming new conceptions on the grounds of their own imagination and experience. C*onceptual reconstruction* shares major features with the term "*reconstruction of model knowledge*" as introduced by Dole and Sinatra (1998).

The Model of Educational Reconstruction as a Model for Teacher Professional Development

The MER presented in Figure 3 provides a theoretical frame for instructional planning. A significant number of competencies of the science educators using the model to develop instruction are essential. In principle the same set of competencies is needed if a teacher uses the model for instructional planning or intends to enact an instructional unit designed, e.g., by a curriculum development group. Hence, the MER also provides a theoretical frame for teacher education (van Dijk & Kattmann, 2007; Komorek & Kattmann, 2009) as will be briefly outlined in the following.

The way teachers think about key characteristics of instruction has proven an essential part of their PCK – their Pedagogical Content Knowledge (Shulman, 1987). As van Dijk and Kattmann (2007) thoroughly argue, the Model of Educational Reconstruction allows identifying these characteristics. PCK is seen as a unique knowledge domain denoting the blending of content and pedagogy into an understanding of how particular topics, problems, or issues may be organised, represented, and adjusted to the diverse interests and abilities of learners. Teacher thinking in terms of the PCK in this sense seems to be basically in accordance with teacher thinking in terms of the German Didaktik tradition as outlined above and therefore also with the key features of teacher thinking in terms of the MER.

Duit, Komorek and Müller (2004), drawing on the MER, developed a set of key features of teacher thinking on planning and analysing instruction. They distinguish three key domains of teacher thinking:

(A) *Constructivist views of teaching and learning*. Teacher thinking about science teaching and learning is based on constructivist views. Teachers are aware that students interpret everything presented to them from their private perspective. They also take into account that knowledge may not be simply passed to students but that their role is to sustainably support students in constructing their knowledge themselves. Further, teachers should embed science topics in contexts that make sense to students.

(B) *Fundamental interplay of instructional variables.* Teachers should be aware of the interplay of the variables composing instruction, namely *Aims & Objectives*, *Content*, *Methods*, and *Media* (Figure 2), i.e. take into account that for instance the choice of a particular method is also a choice for emphasising certain aims. They should further be aware that a rich spectrum of aims, contents, methods, and media needs to be applied in instruction. With regard to Content they should consider not to restrict themselves to science concepts and principles but to take into account also science processes, views of the nature of science and issues of the significance of science in technology and society. Finally, they should provide learning opportunities that allow students to construct the knowledge intended themselves.

(C) *Thinking in terms of the processes of educational reconstruction.* This kind of thinking concerns the features provided by the MER (Figure 3). Significant features included in the model are already taken into account in the above two domains. Here the process of clarification science content as outlined in Figure 4 is in the foreground. Teachers need to be aware that science content knowledge may not be taught in a somewhat simplified version of the content structure of science. The content structure for instruction has to be adjusted to student pre-instructional conceptions and needs to be embedded into contexts that make sense for students.

Komorek and Kattmann (2009, 179) provide the following set of questions based on the MER that allow reflection on teaching and learning in school lessons:

(1) What were the most important student conceptions occurring during the lesson?
(2) Did the science conceptions provided support understanding of the subject?
(3) Did the students have opportunities to acknowledge and reflect about their conceptions as well as their learning progress?
(4) Were the teaching methods and student activities suitable for learning and understanding the subject?
(5) What conceptions (concepts, notions and principles) were used by the students in the scientific context offered?
(6) What correspondence between student alternative conceptions and the offered science conceptions can be identified?

(7) Were the students aware of inherent scientific and epistemological positions concerning the subject?
(8) Did the students apply the acquired knowledge in other fields and did they reflect on it critically?

The Model of Educational Reconstruction for Teacher Education

In analogy to the MER (Figure 3) a model for designing teacher education settings may be constructed as shown in Figure 6 (Komorek & Kattmann, 2009).

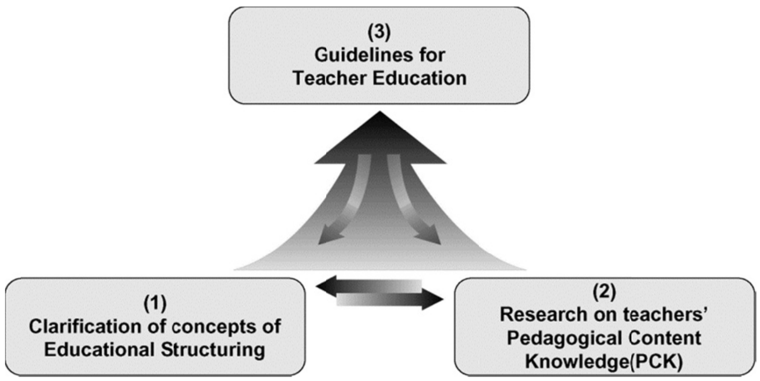

Figure 6. Educational Reconstruction for Teacher Education (ERTE).

Van Dijk and Kattmann (2007) developed this model. Figure 6 shows a slightly modified version. The basic idea of the ERTE Model is that teachers usually (Borko, 2004; Abell, 2008) hold idiosyncratic views about teaching and learning that are only partly in accordance with the position included in the MER. Component (1) in Figure 6 comprises the major ideas of the MER. In order to design efficient settings for teacher education addressing the kind of thinking in terms of the model it is necessary to investigate teachers' views (their PCK). Further, it is essential to critically clarify and analyse the conceptions of teacher education in the literature. As is also the case for the MER, the process of developing the guidelines (component 3) is recursive. The following set of questions may guide this process (Komorek & Kattmann, 2009, 181f):

(1) What subject matter knowledge for teaching do teachers have at their disposal?
(2) What do teachers know about students' pre-instructional conceptions on the subject matter and about their learning processes?
(3) What conceptions do teachers have of educational structuring (design of instruction, subject matter representation)?

(4) What conceptions do teachers have about the interrelation of subject matter knowledge for teaching, students' pre-instructional conceptions, and the influence of this interrelation on the process of educational structuring?

CODA

The Model of Educational Reconstruction is a theoretical frame for research and development in science education. It draws on the German Didaktik tradition. The key message of the model is that science subject matter content (including concepts and principles as well as conceptions about science and the scientific inquiry processes) may not be presented in a somewhat reduced or simplified manner in science instruction. The science content structure for instruction is somewhat more elementary (from the science point of view) on the one hand but richer, on the other hand, as the elements of science content of a certain topic need to be put into contexts that make sense to the students and may be understood by them. The tendency of many approaches towards more efficient science instruction to put the major emphasis on efficient instructional methods falls short. It is also necessary to change the traditional content structure for science instruction. Also science content and not only instructional methods should be seen as problematic (Fensham, 2001).

A model like the MER may not be tested empirically in a strong sense. Such a model needs to be based on sound theoretical foundations. In addition the consequences drawn on the grounds of these foundations need to be sound. We think (or at least hope) that this is the case for the arguments we presented above. Experiences gained in the many studies carried out within the framework of educational reconstruction have shown the usefulness of the model and appear convincing to us. The MER has become the major theoretical perspective in science education research in the German speaking area. It has also been adopted in various science education groups in Europe. This seems to be due to a certain general agreement on key issues of the Didaktik tradition which is a common way of thinking about instruction in – at least – continental Europe. It is, however, still a challenge to convince science educators from different traditions in thinking about science instruction that the model has much to offer. Further, the application of the model for theoretically framing and designing teacher professional development settings still needs serious additional work.

Clearly, the model and surely also the kind of consequences we draw need to be critically analyzed in order to further develop our perspective. This holds, especially, for the application of the model in designing learning settings explicitly addressing issues of science processes and views of the nature of science and in teacher education. To incite a discussion on the significance of the model is what this chapter intends.

NOTES

[1] This chapter draws on previous overviews of key features of the Model of Educational Reconstruction, especially on the following publications: Kattmann, Duit, Gropengießer, & Komorek (1995), Duit, Gropengießer, & Kattmann (2005), Duit (2007), Parchmann & Komorek (2008), and Komorek & Kattmann (2009).

[2] s. Duit (2007) for a more elaborate overview.

[3] The term "science content structure" may need clarification. *Structure* points to the fact that the content elements of a certain content domain (like energy) are intimately linked and that this structure is essential in the process of educational reconstruction.

[4] http://www.diz.uni-oldenburg.de/20512.html (June 2012)

[5] http://www.diz.uni-oldenburg.de/44743.html (June 2012)

[6] In French science and mathematics education the concept of *transposition didactique* (Chevallard, 1994; Perrenoud, 1998) is used. It seems that major ideas of the MER are included in this concept.

[7] The term, developmental research" as used in Lijnse's (1995) approach concerns the intimate link between instructional development and research in basically the same way as in "design experiments" (Cobb et al., 2003). It should be taken into account that in the field of educational design the term "developmental research" may also denote research in a developmental perspective, i.e. research investigating long term progression of instructional interventions (Richey, Klein, & Nelson, 2004).

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3. TRANSCENDING SCIENCE: SCIENTIFIC LITERACY AND BILDUNG FOR THE 21ST CENTURY

OVERVIEW

This chapter starts with an overview of the formation of scientific literacy historically and its relation to the concept of *Bildung*. A critical background is given of the main arguments and definitions of scientific literacy over the years. The review covers three main themes that have emerged more recently in Europe and internationally in discussions of a scientific literacy that transcends the learning merely of scientific concepts and scientific inquiry methods. These themes are 1) the dimension of normativity in human lives and the significance of values in learning science, (2) approaching science content primarily through various activities and learning science as the transformation of actions and habits, and 3) the significance of language use and communication in learning for a transcending science subject.

INTRODUCTION

Reviewing the literature on scientific literacy for the European community is an insurmountable task, considering that more than 25 national languages are spoken and that most texts on education are published in these tongues. As Swedish authors we have only access to a limited part of these publications and our nation traditionally is mainly part of the Scandinavian, German and English-speaking contexts of education with France also playing some role. This delimitation should be held in mind when reading this chapter.

The term Scientific Literacy originates from the U.S.A. In a recent review of education for scientific literacy (or sometimes science literacy) in Western Anglophone countries Douglas Roberts (2007a) traced the term back to the 1950s and 60s when it first appeared. According to Roberts scientific literacy was first introduced as a slogan due to worries about recruiting new scientists and the low level of scientific knowledge among citizens and public officials. The remedy for this condition, was to develop the scientific literacy of the general public, and such calls soon became part of curriculum reform efforts (Roberts, 2007b) and eventually also in the EU (e.g. European Commission, 2002; 2007).

With these reforms followed what Roberts (2007b) referred to as a deluge of definitions for the concept in the English speaking literature. A number of related concepts also appeared, as for example Public Understanding of Science, which

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came to be a catch word in Britain (Solomon & Thomas, 1999). An important thread of the discussion concerned to what degree school science education should be for producing a future work force of scientists or for science literacy among the general public. Fensham (1988) called theses two foci of science education for "induction into science" and "learning from science". Here we will reserve the term scientific literacy to mean that the objective of science education is "learning from science", i.e. how science can be of use to students in their private life as well as citizens, regardless of whether they are going to pursue careers in science or not.

Bildung

In Europe generally the concept of scientific literacy is quite new. In Sweden there is no direct translation. Instead there is a related concept known as *bildning*, which stems from the German concept *Bildung*. Today it is often referred to as *allgemeine Bildung* (general *Bildung*), which is the kind of education that is assumed to be needed by every citizen. Through German philosophers, the concept of *Bildung* has spread to many Western languages. Many of John Dewey's thoughts on education and the idea of liberal education have been traced to this origin (Lövlie & Standish, 2002). The idea of *Bildung* stems back to a word that means "formation" and has a medieval theological origin. Its modern usage to a large extent was influenced by the education reformer Wilhelm von Humboldt (1767–1835) and the philosopher Georg Wilhelm Friedrich Hegel (1770–1831) (Biesta, 2002; Smith, 1988). Bildung means both a process of formation and a state of being. Bildung in this sense entails becoming human by realizing ones dispositions in interaction with the world and, at the same time, positively contributing to the development of society. During the 1800s *Bildung* came to have strong aesthetic and moral connotations, and does not merely entail being a well-informed citizen, but also one of taste and good manners. However, *Bildung* was eventually associated with the humanities rather than with the natural sciences and with the education of certain social classes and Latin schools. Hence, science as a subject traditionally does not belong to the sphere of *Bildung*, but was part of vocational and practical education and the so-called *Realschule*. *Bildung* to a large degree was restricted to the upper classes and linked to conservative political ideals. Hence, traditionally the emphasis for science education in Europe is induction into science rather than learning from science.

Vision 1 and Vision 2

With the democratisation of Europe after the Second World War and the growth of the knowledge intensive sphere of production, a general renaissance of *Bildung* as *allgemeine Bildung* or literacy is evident. Science to an increasing degree has become a subject that every citizen needs to be able to cope with, in decision making and in becoming more environmentally aware (Osborne & Dillon, 2008). Science simultaneously has come to be formational in a more general sense of the word. Paradoxically this has often meant that science education has become less practical and separated from the engineering sciences. It has been divorced from practical concerns and primarily oriented towards learning scientific concepts and explanations as known by scientists. When practicals and lab-work are used, it is mainly to produce the correct explanations, theories or facts (Welzel, 1998). After the last World-War modern science education has come to look inward to science itself as a model for what students should learn in compulsory school. There is a strong belief that science itself is formational of character and that *Bildung* mainly means knowing scientific concepts properly and how to do a controlled experiment with the purpose of producing the right explanations. Roberts (2007a) has referred to this vision of Scientific Literacy as Vision 1. To use Lyotard's (1984) language, such a science subject could be said to mainly answer the question "Is it true?" Proponents of this vision generally suppose that if such scientific conceptual knowledge is modelled on that of the scientist, the capacity of applying this knowledge to various private and societal problems can be practiced later (see Claxton, 1991; Solomon, 1992 and Layton, Jenkins, Macgill & Davey, 1993 for early discussions about the problems of such an approach).

During the late 1900's Vision 1 as the route to scientific literacy has come under attack. Roberts (2007a) refers to the alternative as Vision 2, which maintains that science should be learnt as part of the various contexts in which students in their daily life encounter problems involving science. Such a science education could with Lyotard's (1984) rendering be said to be more than that of the post-modern condition in that it primarily aims to answer the question "Is it useful?" regarding knowledge. These two visions that Roberts describes are reminiscent of the two ways of knowledge production suggested by Gibbons et al. (1994), viz. Mode 1 and Mode 2. Mode 1 is academic, scientist-initiated and discipline-based production of knowledge, whereas Mode 2 is context-driven research in the sense that it is more focused on solving specific problems, and invokes interdisciplinary knowledge as needed. A similar distinction between academic and post-academic science has been made by Ziman (2000).

Transcending Science

Vision 2 can be said to transcend science and to start from questions that are already around in society and which need to be solved by invoking science as one among other resources. Vision 2 springs from recent research on the situated nature of learning, i.e. the finding that transfer of knowledge can never be understood on simple rational terms, but rather that content has to be learnt as part of different situations (Marton, 2006) and that science education also needs to deal with values (Corrigan, Dillon & Gunstone, 2007; Östman, 1994; Wickman, 2006) This review starts from a Vision 2 stance and asks what a *transcending science subject* for the 21st century would look like. Doing this, it looks at the situated nature of learning. However, at the same time it has to ask what a more generally formative science education looks like. In a learning society there are increasing demands for school education generally to transcend not only the academic subjects, but students need to transcend also their idiosyncratic backgrounds and look beyond specific situations to be able to communicate with people with different backgrounds and aspirations, and to be positively critical, creative and innovative in the multiplicity of circumstances and contingent constellations of a shrinking world (Biesta, 2002; Fensham, 2007; Peukert, 2002). Scientific literacy in the European sense could be seen as contributing to an understanding of what *Scientific Bildung* beyond self-realization means in a global and pluralistic post-modern society without degenerating into an either-or relativism (Zembylas, 2000; Schultz, 2007).

In this review we will deal specifically with three themes that have been highlighted by recent research with a focus on a transcending science education. These deal with the normative dimension of human lives and understanding, the situated nature of learning as action, and the role of language in science education for scientific literacy.

THE DIMENSION OF NORMATIVITY

There is one central difference between Vision 1 and 2, namely in the way the normative dimension (world views, values, interests, power) of human lives is approached. Vision 1 represents a perspective where the normative is seen as irrational or possible to rationalise – to become objective – with the help of scientific knowledge and reasoning. Vision 2 represents a view where the normative is seen as something natural, unavoidable and non-reducible in human lives and something that can and should become an acknowledged part of science education.

Within Vision 1 one can thus find two different positions regarding the relationship between what Hume referred to as "is" and "ought" judgements (see Putnam, 2002, pp. 7–64). According to the first position "is" and "ought" are perceived as a dichotomy. "Ought" judgements are irrational (subjective, non-cognitive), devoid of meaning and therefore not suitable to become an educational content: they are not possible to systematically reflect upon. We need to stay away from the non-cognitive and it is the role of education to give the students knowledge and a way of reasoning that can substitute a value-based/irrational decision-making. Scientific knowledge and scientific reasoning are the cures for the irrational. This way of approaching the normative dimension in human lives has a long history, but it is explicated very clearly in the idea of the science subject in liberal education: by appropriate training in the scientific method the students automatically will be imparted with the skills to objectively take a stance in controversial issues (Waring, 1979, p. 41). One can with the words of Fensham (1988) say that induction into science becomes not only something that is suitable for a science elite education but also for empowering the mass.

This approach towards values is sometimes used when environmental issues are dealt with in science education and the media. It was for example very common in Sweden during the 60s and 70s. Environmental problems are seen as caused by lack of knowledge or as unforeseen consequences of human actions in the environment. In accordance with this view it will be natural scientists that are interviewed in radio and TV and it will be knowledge and skills from natural sciences that form the content of teaching. The idea is thus that if people get informed and learn the knowledge from natural sciences they will automatically behave environmentally friendly. Questions of values are omitted here: facts are enough. This manner of teaching can be called *Fact-Based Environmental Education* (see further Öhman, 2008).

The second position within Vision 1 is the belief that it is possible to come to rational decisions regarding normative issues, i.e. it is possible to "objectify" values through true knowledge. This view is contrary to Hume's classical doctrine that one cannot infer an "ought" judgement from an "is" judgement.

Thus, within this second position it is possible to include science-technology-society (STS) content in science education, since the normative dimension is approached as an outcome – as a decision about what one ought to do. This outcome can either be irrational or rational: it is rational if it is built upon true knowledge; it becomes subjective if it is not founded on proven knowledge.

This way of dealing with values is at the core of the most common way of approaching environmental issues within science education in Sweden, and it is probably also common in other parts of the world (Jickling, 1992). This manner of teaching, which can be called *Normative Environmental Education*, started at the end of the 70s as a reaction towards the fact-based approach and became institutionalised in the national curricula of 1980 in Sweden. In this teaching tradition the idea is that students should not only learn knowledge but also how this knowledge leads to a certain "oughts" as certain ways of approaching nature in thought and action, i.e. the ways that are ecologically friendly as established by science (see further Öhman, 2008).

Hence, on a philosophical benchmark Vision 1 seems to include two opposite views on the relation between facts and values, although Rorty (1982) shows that both hold within a positivistic culture:

> The culture of positivism thus produced endless swings of the pendulum between the view that "values are merely 'relative' (or 'emotive' or 'subjective')" and the view that bringing the "scientific method" to bear on questions of political and moral choice was the solution to all our problems. (p. xliii)

While researchers clinging to Vision 1 are not particularly interested in researching the normative dimension – except as something we need to keep away from or make rational – other researchers have this dimension as their main focus, since they believe that science education and choices (individual and collective) are discursive in their character. This interest can be channelled towards different aspects:

- Moral/ethical
- Political
- Norms
- Aesthetics
- Transformation

Moral/ethical

When it comes to the moral dimension one central focus is on judgements connected to responsibility and students' ethical reflection. In dealing with for example environmental issues in science education ethical theories are sometimes used as tools. An example is the exercise called "The hot seat", which is designed with the purpose that students should learn and practice an ethical form of reasoning. The teacher introduces ethical rules – for example "It is always wrong to kill animals. Animals and humans have the same value" – and the students are supposed to take a stance and argue, with the help of knowledge in science and ethics, for their opinion. The reasons to bring in ethical reasoning into science education are that it is perceived as an important aspect of human life (for example in relation to controversial issues) and that this form of reasoning cannot be reduced to a scientific argumentation. This is one of the reasons why for example Zeidler (2003) does not perceive all forms of STS-teaching (i.e. within Vision 1) as equal to what he and his colleagues call socio-scientific reasoning, which apart from evidence-based argumentation contains ethical reflection as well. In Öhman and Östman (2007) an approach for analyses of moral meaning making is presented and illustrated that takes into consideration students earlier experiences as well as the educational situation at hand.

Political

Research into the political dimension involves a diversity of questions. One question concerns distribution of power and authority, i.e. who will be given the voice and who will be given the role of listener in for example issues concerning the environment, health and sustainable development in science classrooms and in society. In Munby & Roberts (1998) and Östman (1996) the distribution of authority within the classroom discourse and within different teaching traditions is analysed. Geddis (1998) studies students' ability to learn to identify interests in controversial issues in society.

Many researchers looking into the political aspects raise questions regarding whose knowledge, perspectives, values and so forth are included and excluded. Here questions of gender (Sörensen, 2007), race (Willinsky, 1998), indigenous knowledge (Aikenhead, 2006), etc. become crucial. Issues of social justice and citizenship are other important aspects in relation to the process of inclusion and exclusion (see further Reiss, 2007 and Roth & Désautels, 2002). With inspiration from Chevallard's (1991) work Tiberghien (2007) shows how it is possible to research into the transformation processes when educational content is formed and how questions of legitimacy arise in the processes. Another set of questions concerns decision making and argumentation in relation to socio-scientific issues (Kolstø et al., 2006) and evaluation of these skills (Ratcliff, 2007).

Norms

A whole body of research perspectives – all unified by viewing language use as discursive – is approaching scientific literacy as learning a secondary discourse-practice which includes the idea that learning to participate in a specific practice includes learning certain values, norms and ways of being in the world. Some of these values and norms are explicitly talked about some of them are taken for granted and learned as ways of acting in the specific practice at hand, a phenomenon that Dewey named collateral learning and Schwab for meta-lessons. The Santa Barbara Classroom Discourse Group (Kelly, 2007) and the research approach of Companion Meaning Analyses covers investigations of norms in text (Roberts & Östman, 1998; Östman, 1995; Östman & Roberts 1994; see also Knain, 2001) and the teaching and learning of norms (Lundqvist, Almqvist & Östman, 2009).

Aesthetics

To both John Dewey (1934/1980) and Pierre Bourdieu (1984) it was clear that education also involves learning aesthetic values and a transformation of taste. There is a strong continuity between learning a specific taste and discursive, normative aspects about what to include and exclude in an activity, and hence for students possibilities of participating in science related activities. Bourdieu (1984) pointed out that education and up-bringing do not only mean acquiring a certain taste, but also learning to see your own taste as superior. People who have learnt to appreciate classical music tend to see people that like popular music as less clever. The importance of such social aesthetic norms for learning science has only recently begun to be examined (Szybek, 1999; Wickman, 2006; Jakobson & Wickman, 2008). These studies suggest an alternative route to study interest in science as a discursive taste rather than as an internal motivational state.

Transformation

One central aspect to Visions 2 is the transformational dimension that is included when using knowledge learned in one context in another activity, governed by other purposes and norms. Jenkins (2002) and Layton, Jenkins, Macgill and Davey (1993) illustrate and argue that in making scientific knowledge useful in everyday actions (including to be citizen) the canonical scientific knowledge must be put into interaction with economical, social and other value positions. If we want to take this interaction seriously in science education we will also need to include a new epistemology, according to Jenkins, an epistemology that is both objective and participatory: "This will allow "truth within situation" (Jenkins 2002, p. 31). Such an epistemology needs to deal directly with transaction in action not only with learning as an inner conceptual process.

TEACHING AND LEARNING SCIENCE AS ACTION

So how do students learn a transcending science and how can it be taught in a fruitful way? Constructivism and its partisan conceptual change studies have a strong legacy in European science education (e.g. Jenkins, 2001). Although the field has adopted some ideas about using concepts in different domains as an adaptation to socio-cultural critique, concepts are still understood as the structural basis for action (Duit & Treagust, 2003; Vosniadou, Baltas & Vamvakoussi, 2007). To understand people's actions one has to ask what conceptions about the world they hold and try to change or replace them. Conceptual change thus is the prerequisite for change in action. This research tradition typically asks first what concepts the student already possesses to see to what degree they need to be changed or replaced to fit the understanding of a certain domain, as for instance science. The emphasis is either on learning the scientific explanations or letting students have their own alternative conceptions. Only secondarily the question is asked about how these concepts build efficient (in their terminology) action.

Our intention here is not to review this line of research, but rather some recent developments within science education in Europe that have tended to see action and practice as primary or on equal footing with language use in learning science and scientific literacy. Such efforts are based on socio-cultural or pragmatist theories of learning. Typically these schools study conceptual learning as embedded in the activities of certain practices, where purposes and values play an important role.

Situating Science in an Activity

In relation to the question of the significance of the activity for what students learn, Astrid Bulte and her colleagues Hanna Westbroek, Onno de Jong and Albert Pilot (2006) make an interesting case for science education by relating to a curriculum reform program in chemistry education at the secondary level in the Netherlands. They set out from the idea that chemistry is more than its concepts, and they examine the ways in which the verbs and activities associated with scientific practice can help students to make sense of the scientific concepts. Their primary aim is still that of changing the students' conceptual understanding, but their starting point is not one of replacing students' prior concepts, but to give meaning to the new ones through practice. Could chemical understanding for example start from the human practice of synthesizing chemicals of use and ask how scientific concepts are needed to solve such problems? The idea of such context-based science education is not new and the work of Bulte and colleagues (2006) builds on inventions in Germany, Chemie im Kontext (Parchmann et al., 2006) and it has a longer tradition in the Netherlands (Kortland, 2005). In Britain the Salters approach goes back to the 1980s and has been adapted to the curricula of numerous countries (Bennett & Lubben, 2006). In France inter-disciplinary themes called "Travaux Personnels Encadrés" (Tutored Individual Projects) have been developed for upper secondary school, based on the idea that learning needs to be situated in an activity (Chevallard, 2001, 2007). In Norway the web-based concept *Viten* has been developed on the basis of an American counterpart (Jorde & Mork, 2007). What is interesting with Bulte and her colleagues' article is their story about the continued quest to find contexts where it makes sense to students to invoke scientific knowledge.

What may first seem as a scientific problem to a scientist or a science education researcher may be situated in a completely different way by students, or teachers for that matter. Schoultz (1999) for instance gives an instance of a task for students to solve from the National Evaluation in Science in Sweden (NUNA, 9th grade, students 15–16 years old). The question has an illustration of a syringe with the piston half-way down the cylinder. The question reads how much it would be possible to push the piston into the cylinder of the syringe if the opening was sealed with a rubber plug. The question was meant to test whether students knew that gases are material substances that fill up spaces and that their particles can be compressed to a certain degree. In the student interviews by Schoultz (1999) it became evident that students could easily solve this problem by recalling their experience of holding their finger on a bicycle pump and pushing the piston, without drawing on any scientific knowledge about the nature of gases. Hence, to many students this question was not conceptual at all, but could be solved by recalling whole experiences involving bicycle pumps, and seeing the analogy. Hence, any context of activity does not as a matter of course produce a need for students to use scientific concepts to solve a problem.

The Quest for Relevant Activities

Bulte et al. (2006) and Bulte (2007) refer to three consecutive frameworks they used in their quest for activities of scientific relevance. In the first framework students were presented with a problem (e.g.: Is this water good enough for drinking?), then with the theoretical knowledge the science education team thought necessary to solve it, and finally students had to perform the actual inquiry to solve the problem using their acquired conceptual knowledge. The outcome of this framework showed that students dealt enthusiastically with the two first parts. However, they could not apply the theoretical knowledge learnt in the second part to the real inquiry. Bulte and co-workers (2006) argue that the students were not able to judge the usefulness of the theoretical knowledge taught, because it was based on the expert's point of view and not on the students' perspective of relevance and need-to-know (i.e. values).

The second framework introduced the inquiry as interwoven with studying the theoretical concepts, and students had to repeatedly return to the concepts until finding a solution to the problem of the inquiry. Also the question for inquiry was made more motivating and exciting to the students. They now were asked to bring water samples and then ask "Will you drink this water?" This was expected to create a strong need-to-know. The students subsequently had to solve another related problem (e.g.: Is this water good enough for aquarium fishes?) and have to consider what they now needed to know to solve this additional problem. The unit ended by explicitly summing up all the concepts that students had used to solve the problems. However, in this case the activity of finding a way to purify the water disrupted learning about water quality; the teachers and students became involved in distillation and filtration. This reorientation is reminiscent to the one described by Schoultz (1999), and again demonstrates that a certain task, that potentially could be solved by using certain scientific concepts, is not necessarily solved in this way. Why choose a complicated path, when the solution is more easily at hand?

To resolve the problems of the two earlier frameworks, a third framework building on activity theory was adopted (Van Aalsvoort, 2004). This method builds on finding a so called authentic social practice. An authentic practice involves an activity that is needed to reach a specific purpose. In chemistry practices certain procedures are typically used, which are based on certain conceptual distinctions. Hence, such an authentic practice is defined as a group of people or a community connected by three characteristics: 1) common motives and purposes, 2) working according to a similar type of characteristic procedure leading to an outcome, and 3) with apparent necessary concepts about the issue they work on (Bulte, 2007; Bulte et al., 2006). This third alternative awaits to be tested in practice.

A Pragmatist Interpretation

The quest of Bulte and co-workers is interesting in that it shows that in scientific activities that transcend that of explaining scientific concepts correctly, as for example that of judging water quality for different purposes, the concepts need to be transacted. They cannot be used as a ready made set directly from science as argued also by for example Layton et al. (1993) and Jenkins (2002). Bruno Latour (1987) has shown how this occurs in society when scientific results need years of transformation to become useful technology in society. Hence, in transacting knowledge into action, something more than concepts as representations are needed.

From a pragmatist perspective knowing is not merely a correct representation of reality, but rather the development of habits for coping with reality (Rorty, 1991). Such coping always involves a selection of what is relevant and irrelevant for the purpose at hand, and such distinctions also involve dealing with aesthetic and moral values (Östman, 1994; Wickman, 2006). There is no such thing as the absolute quality of water, which could be decided on purely scientific conceptual grounds, but we have to use our values to decide what we mean by "*good enough* to drink" as opposed to "*good enough* for aquarium fishes" and to what details and efforts we want to go in finding out the quality. Students also need to do all the actions in a certain order, and the order in which each step is made has consequences for further action (Wickman, 2004; Hamza & Wickman, 2008, 2009). This applies to any sequence of action involving science, be it dealing with socio-scientific issues regarding sustainable development, learning the morphology of insects or about chemical reaction theory (Jakobson & Wickman, 2008; Lundegård 2008; Sund & Wickman, 2008; Wickman, 2006).

Hence, we need to ask not only how students can develop appropriate scientific concepts through action, but also habits that help them to cope with situations of which science is a part. An important part is to better understand how we can help students in using science to generalize across situations. Sensevy, Tiberghien, Santini, Laubé, & Griggs (2008) suggest one interesting theoretical framework based on Nancy Cartwright, Ludwig Wittgenstein and others to discuss how situations could be constructed that support such generalizations in physics.

Developing Science Activities

Wickman and Ligozat (2011) argue from a pragmatist and Wittgensteinian perspective that the meaning of a concept is to be found in how it furthers certain activities. Learning hence needs to start in such activities in which science is necessary to proceed with them. In using an example from chemistry in middle school they show how learning starts from competent action rather than from correct conceptual understanding. They warn that a science education that starts by teaching the concepts risks rendering science as not relevant in life generally. Conceptual refinement should grow out of reflection about how scientific concepts could be used to better reach purposes that students can see the point with, as advocated also by Bulte et al. (2006). When relevance is lacking, students often turn to their habit: to finish the assignement at hand as quickly as possible without any deeper personal or cognitive engagement (Almqvist & Östman, 2006). Wickman and Ligozat (2011) conclude that to build a progression in science that makes sense not only to students but also to stakeholders in society, we need to develop activities

– where scientific literacy is needed,
– that start from questions,
– that already at the start give competencies to all students in achieving an end in view that they value,
– that introduce new problems along the way that make it relevant to improve concepts and skills in such a way that ends can be achieved even better considering our values, and
– that are identified not because they teach students the correct explanation or correct scientific concepts, but because they help them to deal with nature and the material world in ways that they and society value.

As pointed out by several scholars, developing relevant science activities is not trivial. Apart from developing units that work with both teachers and students in classrooms (Pilot & Bulte, 2006), they also need legitimacy from the relevant stakeholders in society (Tiberghien, 2007) as well as a changed practice of assessing what students learn (Orpwood, 2001). It is also complicated by the central tenet from research on artificial intelligence illustrated here, viz. that there are innumerable processes that may produce the same output (Lycan, 1996). Both mechanical and digital devices may for example be constructed that according to different procedures deliver the correct answers to mathematical problems. And any numerical answer could be generated by countless arithmetic procedures. Shoultz's (1999) study and the findings of Bulte et al. (2006) demonstrate that this is also true of humans. Studies of the development of such units therefore cannot depend simply on output, but we need also to study more closely the communication and material transactions in classrooms through language and action. There are now many such possible methods that can be combined in fruitful ways (Kelly, McDonald & Wickman., 2012; Lidar, Lundqvist & Östman, 2006; Sensevy et al., 2005; Wickman, 2004; Wickman & Östman, 2002). Such an epistemology of learning, paraphrasing Rorty (1991), should not only deal with how people get reality right and establish what is true, but also how people transact values more generally as part of transforming their habits for coping with reality. Such an epistemology has been named a *practical epistemology* and the method to track such epistemologies in classrooms for a *practical epistemology analysis* (Wickman & Östman, 2001, 2002; Wickman, 2004). It should not be confused with the later, restricted conceptual approach by Sandoval (2005), who without reference used the term from Wickman & Östman (2001).

LANGUAGE AND SCIENCE EDUCATION

Apart from values and action, research on the significance of language is a crucial advancement in developing a transcending science subject. The idea of language use could be said to be inherent already in the term literacy. There has been a long tradition in Europe to study language in use and the functions of language use. One important source of inspiration within educational sciences has been the work by Bakhtin and his fellow scholars. The concept of polyphony of the word and the perspective on language as a medium for meaning making have been of vital significance. Another important source is the later work of Wittgenstein and his concept of language games we live by. A third perspective stems from Halliday's and his disciples' work within a social semiotic perspective. Halliday (1978, p. 9) states that "Language is the main channel through which the patterns of living are transmitted to him [the child], through which he learns to act as a member of a 'society' […]". The semiotic systems which we live by constitute a meaning resource from which we choose when we articulate and structure meaning. Certain aspects are consequently foregrounded, while other aspects are put in the background or completely excluded. In that respect, the selected language forms are highly significant and coloured with ideology.

Modes of Communication

During the last decade there has been a growing interest in studies of how meanings are developed through language and other modes of communication in science classrooms (Buty & Mortimer, 2008). According to Veel (1997), it is possible to distinguish between twelve different communicative genres typical of science. These genres are organised by Veel in four domains of meaning making: "Doing science", "Explaining events scientifically", "Organizing scientific information" and "Challenging science". Other modalities than the verbal are also involved in science educational texts and they are becoming more and more prominent (Bezemer & Kress, 2008). Habraken (2004) identifies for example a long term shift in chemistry and biochemistry during the last 125 years from a "logical-mathematical" to a "logical-visuospatial" thinking. The main semiotic resources in science classes are natural language, mathematical symbolism, graphs, and diagrams. These different forms of meaning making are discussed by Buty and Mortimer (2008) in terms of Bakthin's distinction between primary and secondary speech genres. Primary genres are linked to the language of everyday life. The development of secondary genres is a consequence of the "translations" between the semiotic register of natural language and other more specialized semiotic registers such as diagrams, graphics and equations. Switches between these and other kinds of modes in the science class are considered by Knain (2006) in terms of transformations. With regard to scientific literacy, any such transformations must involve also other non-scientific specialised secondary genres of which socio-scientific issues are part of in society, such as those of politics, technology, economics, media etc.

Language Dimensions

On a macro level the meaning making in a classroom is studied as sequences of communicative acts, which are linked to each other in a dialogical relation. The tradition to study science classrooms in terms of teaching-learning sequences (TLS) is discussed by Méheut and Psillos (2004). This term points to the close linkage between proposed teaching and expected student learning. A teaching-learning sequence is in this tradition used as an interventional research activity. The designing of such a teaching sequence is an intricate matter. This is discussed by Buty, Tiberghien and Le Maréchal (2004) by using examples from teaching about optics and conductivity in grade 11. The validation of the teaching-learning sequence is carried out in their work from the educational system and from didactical hypotheses on knowledge and learning. Another type of intervention studies is presented by Mason (2001). An experienced teacher in grade 4 is introduced to a systematically sequencing of collaborative discourse-reasoning and writing. Mason shows how reasoning and arguing collaboratively on different beliefs and ideas, as well as individual writing to express, clarify, reflect and reason on, and communicate own conceptions and explanations are fruitful tools in the knowledge revision process for students. In another experimental teaching programme in primary schools some similar results are shown concerning children's reasoning (Mercer, Dawes, Wegerif & Sams, 2004). Children use talk more effectively as a tool for reasoning and talk based activities can have a useful function in scaffolding the development of reasoning and scientific understanding.

The concept of polyphony of the word developed by Bakhtin (1981) and his fellow scholars plays a central role in many studies of classroom interaction. Buty and Mortimer (2008) discuss for example how a teacher works with students in order to develop ideas and understanding. The teacher's approach can then be characterized along a dimension with two extreme positions: "either the teacher hears what the student has to say from the student's point of view, or the teacher hears what the student has to say only from the school science point of view" (Buty & Mortimer, 2008, p. 1638). Referring to the work of Mortimer and Scott (2003) the first position is called a dialogic communicative approach, where more than one voice is heard. The opposite position is referred to as an authoritative communicative approach, where only one voice is heard and there is no exploration of different ideas. It is important to note that a sequence of talk can be dialogic or authoritative in nature, independent of whether it is articulated individually or collectively. The results of an analysis of a class on optics in grade 11 confirm earlier results that it is difficult to reach a suitable balance between dialogic and authoritative discourse in a science classroom. Furthermore it is pointed out that it is particularly important to deal dialogically with words or expressions that science inherits from everyday language. "That teachers explicitly refer to both everyday and scientific points of view in these matters seems, in a dialogic communicative approach, to be crucial for allowing students to differentiate between the two points of view and to recognize that these words can be expressed and thought about in more than one semiotic register" (Buty & Mortimer, 2008, p. 1657). How to encourage more dialogic classrooms need to be studied further as classrooms still often are authorative. In a study of reading textbooks and student writing in science classrooms in grade 5, 8 and 11 it is concluded that these activities aim at reproducing knowledge in a monological way rather than at producing knowledge in a dialogical way (Edling, 2006; af Geijerstam, 2006).

Another topic of research is practical epistemology analysis of the content constituted through the communicative acts and teaching sequences used in science classrooms (Wickman & Östman, 2002; Wickman, 2004). In a study by Lidar, Lundqvist and Östman (2005) the focus is on acts the teacher uses in order to give the students directions that expose what counts as knowledge and appropriate ways of getting knowledge in this specific social practice. These acts are discussed in terms of epistemological moves. In a chemistry course in grade 7 the research team has identified five different moves: confirming, re-constructing, instructional, generative and re-orienting. Furthermore Wickman (2006) and Jakobson and Wickman (2008) have studied communicative acts derived from the aesthetic language resources such as "cool", "funny", "hell". They show how these expressions are used by teachers as well as students in establishing norms of action, and in talking about what objects, events and actions are to be included and excluded. They also state that aesthetic experiences are intimately linked to the ability of students to participate.

Hägerfelth (2004) has moreover studied how students in secondary high school collectively construct the content in the subject area of science in group conversations. She finds three main patterns of textual constructions. The student groups with so called "skimmers" construct content rapidly and mechanically by means of short recited questions and replies. The "waders" creates a superficial content using a colloquial language. The third group, the "weavers", constructs content in a methodical way moving effortlessly within the subject using scientific language. From the perspective of scientific literacy it would be of interest to further examine how students could move beyond weaving and transcend the canonical science content.

The language dimensions of written texts produced and used in science is yet another area of research. In the earlier mentioned study on students' writing in science classrooms by af Geijerstam (2006), the text analysis indicates a development on the domain levels as described by Veel (1997). But the genre steps in texts written in grade 8 are not more elaborated than in grade 5. The texts in grade 8 are instead characterized by the use of more abstract language and more technical expressions and they show a higher degree of information load than in grade 5. Mason (2001) has in her study in grade 4 investigated one particular type of writing situation which is writing in the service of learning. In these situations the students use writing to express personal ideas on a topic, to communicate what has been temporarily understood or what puzzles, to record any changes of ideas, and to give a final explanation of a phenomenon. In a close study of two students' writing of experimental reports, Knain (2005) discusses students' abilities to master the genres of science. He means that apart from mastering factual knowledge students also have to negotiate what they want to achieve with their texts and their ideas about writing and themselves as writers and science students. Such results support the notion that students need values and a context with a purpose to make sense of science.

In their study of writing in a junior high school Lykknes and Smidt (2008) have focused one teacher's comments on his students' writing of a procedural report. The teacher means that the language should be concise and precise. The text must be coherent, just describing what actually takes place and be independent in relation to the textbook. The writing should also imply a non-specified reader. Mason (2001) as well as Lykknes and Smidt (2008) have interviewed the students who in both studies confirm the important function of writing in the learning process. Crawford, Chen and Kelly (1997) studied two bilingual high school students and how they presented a science project across different audiences such as teachers, classmates and fifth grade students. The presentations and what counted as knowledge depended on the communicative setting. Again the selection of subject content is not simply deducible from science, but the communicative contexts afford students with ways of judging the relevance of various parts of what may first seem to be the same, coherent subject matter content.

The development of students' writing in terms of use of more abstract and technical language is a parallel process to the development of the language used in textbooks. Edling (2006) has studied the use of three types of referents in textbooks: specific, general and abstract referents. When focusing the shifts between the usages of these three types in the texts, she finds that the natural science texts have relatively few such shifts with rather few different functions in comparison with texts in social science. The shifts are foremost used to generalize or to express evaluations and classifications through common or technical abstract referents. Dimopoulos, Koulaidis and Sklaveniti (2005) mean furthermore that parallel to a rise of more subject specialised language there is an increase in the students' autonomy in accessing the textbook material. Dimopoulos, Koulaidis and Sklaveniti (2003) also compare the use of visual images in school science textbooks and in the press. It is showed that science textbooks use ten times more images. They also use more images to familiarise their readers with the specialised techno-scientific content and codes. Moreover they tend to create a sense of higher empowerment for their readers by using the visual mode. In a comparison between Greek school science textbooks and science test items used in the Programme for International Student Assessment (PISA) Hatzinikita, Dimopoulos and Christidou (2008) show that the two types of textual materials are oppositional in nature with regard to both the verbal and the visual mode. They discuss if this discrepancy could be one of the factors explaining the low level of Greek students' achievement in PISA.

If a text or a text assignment is to function as a tool for further learning and development it is essential for the student to have a thorough understanding of the text at hand. This includes being able to express and understand the scientific content as well as the language resources that are used to make scientific meaning. This has been studied by Liberg, af Geijerstam and Folkeryd (2011) in terms of text movability. In this investigation of students in grade 5, 8 and 11 it becomes clear that they show a much lower degree of text movability in science compared to other school subjects. The competence of text movability should be an important asset for scientific literacy and hence to study in further research.

CONCLUDING REMARKS

In order to create a *transcending science subject* for the 21st century we need to start with questions that already have meaning for people outside science, questions that society and students value as important. This means that practices and activities beyond science have to be treated explicitly and that issues of values need to be included in the curriculum. We also need to pay attention to the social aspects of language, spoken or written, as part of genres and that language use also in science depends on who you are communicating with and what the purpose is. These dimensions should characterize an education for scientific literacy and this is also what has been reviewed in this chapter.

Arguments for scientific literacy have been around for a long time, and they were very much on the agenda in Sweden and other European countries after the Second World War. It was clear that all subjects needed to contribute to the building of a democratic Europe, and giving the upcoming generation a chance to appropriate *Scientific Bildung* was seen as one way. However, the vision concerning the best way to achieve this literacy has changed from one seeing the learning of an objective corpus of science and its methods as critical, to one that takes a more holistic although situated stance to learning science. Today we are living in a post-modern and pluralistic society with specific possibilities and restraints, which we must take into account in planning a transcending science education. Central to Vision 2 is the need to take departure in the circumstances and ambitions the students with all their various backgrounds live in and through, which means that there is no general formula for all European countries regarding the content and context that should be included in the science curriculum. At the same time communication and joint action are dependent on shared habits and customs that give meaning to action. Understanding the rationales for finding the most fruitful balance between the shared and locally adapted subject matter content is an important future research area that has to consider both values and empirical results.

Vision 2 is a context sensitive concept, in that it acknowledges that research needs to take this situated nature of learning, people's values and the diverse lingual backgrounds of students seriously in examining the content and procedures of science education. It has been shown that transfer of knowledge never can be understood on simple rational terms, where science is perceived as a ready made set. Concepts need to be transacted as part of activities and different communicative genres; they are so much more than representations. And again, when knowledge and concepts are approached as part of contexts we need to pay attention to the values that are inherent, i.e. the companion meanings that have to be in place in order to make purposeful and fruitful actions possible. It is crucial not to confuse this position with naïve relativism; it builds upon the empirical observation that in order to make meaningful actions possible, both knowledge and values are necessary.

In order to develop a transcending science subject it is necessary to develop knowledge on several issues. We would like to highlight some of these. First of all we would like to underscore the importance of studying learning processes and how content learning is formed through transactions between intrapersonal, interpersonal and institutional dimensions. And when studying learning processes it is crucial that not only cognitive dimensions but also values more generally are included, as for instance morale and aesthetics. This is particularly important when dealing with the transformation process and how meaningful learning is constituted in that process.

According to Brickhouse (2007) the development of critical skills – the skills to handle the political dimension – is very rarely examined by educational research and included in the term scientific literacy. Here much work needs to be done. It is also very seldom examined what conceptions of citizenship and democracy that are envisioned when policy makers and other stakeholders are talking about the goals of science education. The political dimension is of course something that we also need to include in critical reflections about our own research. We should be aware that promoting scientific literacy also means to subscribe to certain norms about who is valued (e.g. the person that is scientific literate) and who is not (e.g. the scientific illiterate person).

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4. HOW RESEARCH ON STUDENTS' PROCESSES OF CONCEPT FORMATION CAN INFORM CURRICULUM DEVELOPMENT

ABSTRACT

Research about students' learning of science is often based on conceptual change theory. Typically, student conceptual ecology is theorized, (mis-)conceptions prior to instruction are investigated and how these conceptions change as a result of instruction are analyzed. However, little research has focused on the processes by which students develop conceptual understanding during instruction: Under which conditions will students employ their (mis-)conceptions? How do students' (mis-)conceptions evolve during learning (or while acting in everyday situations)? Which kinds of teacher explanations are understood by students and when in the process of concept formation? Why is specific instruction effective for some students but not for all? Research reported in this chapter aims to explore how students arrive at a particular conceptual understanding, how students employ their conceptions while grappling with physics instruction and experiments and what kind of instruction promotes or hinders students' processes of concept formation. The chapter draws upon theoretical arguments for this type of investigation, empirical procedures and outcomes as well as upon implications for science teaching.

INTRODUCTION

Researching and theorizing students' learning in science is typically associated with conceptual change theories and empirical approaches towards identifying students' conceptions. Compared with other studies of conceptual research, our research program focuses on detailed descriptions of how students develop and utilize physics concepts – both, "correct" and "incorrect" – while working on physics instruction. In order to motivate our approach in assessing students' *processes of concept formation* we briefly outline why we consider current theoretical accounts of students' conceptual ecology and empirical procedures as being limited, especially in terms of their explanatory power of concept formation processes. Later in this chapter, we describe how we investigate students' processes of concept formation and concept use while working on physics tasks and the kind of descriptive categories such investigations reveal. We then outline

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how the categories identified in students' conceptual development can help to understand how students establish misconceptions and why some science conceptions are more difficult for students. Furthermore, an approach towards the construction of instruction based on our findings is presented.

A BRIEF CRITICAL DISCUSSION OF RESEARCH ON CONCEPTUAL CHANGE

Theoretical Descriptions of Concepts and Conceptual Change

Research on science teaching and learning has focused on students' conceptions and on teaching strategies that promote conceptual change (e.g., Duit, 1999; Duit & Treagust, 2003; Limón & Mason, 2002; Tyson, Venville, Harrison, & Treagust, 1997; Tytler & Prain, 2009). Within such research, tests and interviews are widely used in order to assess students' conceptions prior to and/or after instruction (e.g., Hake, 1999; Hestenes, Wells, & Swackhamer, 1992). Even though the theoretical frameworks differ in some details, most of them share a common body of general assumptions which ahre:

– Most of students' activities and utterances have a theoretical foundation (e.g., knowledge is organized in concepts or in framework theories).
– Students entering a physics classroom will have prior conceptions (framework theories).
– Students' conceptual knowledge will not necessarily match that of scientists, that is, students may hold misconceptions (naïve frameworks).
– Students' conceptual knowledge can change when they are shown contrasting "correct" concepts.

Concepts

Although the notion of "concept" is at the core of the assumptions presented above, the usage and theoretical account of "concepts" has been debated in the literature (e.g., diSessa & Sherin, 1998; diSessa, 2002). Is all knowledge that students can have (and show) conceptual? If not, what distinguishes "simple" knowledge from concepts? It is sometimes argued that conceptual (declarative) knowledge refers to an "implicit or explicit understanding of the principles that govern a domain" whereas procedural knowledge refers to "action sequences for solving problems." (Rittle-Johnson & Alibali, 1999, p. 175). However, even if only knowledge is taken into account that can be expressed verbally, one may still ask whether or not all such knowledge is conceptual in a sense that it considers the principles that govern a domain or a topic (see also diSessa & Sherin, 1998). It probably makes a difference whether a child just repeats that this *particular* object is her/his baby chair (being told by her/his mum) or whether s/he can explain that *all* chairs have an area to sit on and (typically) four legs. Also in physics we can distinguish between knowledge that is tied to particular objects and situations (descriptions, labels) and knowledge which refers to the commonalities of several objects and situations and can, therefore, be considered as conceptual.

From a psychological point of view one may argue that even though students' knowledge does not directly indicate a conceptual understanding, (unconscious) mental activities "behind" the expressed knowledge refer to concepts. At the moment it is impossible to evaluate empirically whether or not this is a valid assumption, however, there are some arguments indicating that such a description is not very helpful to understand (mental) activity and learning. From the acting individual's point of view several activities can take place without knowing about the conceptual grounds. In addition to that stated by Vosniadou and her colleagues (e.g. 2008), we would stress that in order to function in the world, students (all humans) do not necessarily need a coherent *explanatory* framework. There is no need to explain the function of a switch in an electric circuit or how pictures emerge on a screen in order to switch on the light or use a computer. To do the washing up, we do not need to know about surface tension, nor about the role a dishwashing liquid plays in reducing the surface tension which enables fat to dissolve more easily. Furthermore, from an observer's point of view one might argue that even though an individual's verbal activities can be described as if these activities follow a certain concept this does not say anything about the mental reality of these concepts (e.g., Neuweg, 2002). Seeing a concept or a theory in almost every activity or utterance an individual develops reduces the number of interpretations that are possible: "Sentences are taken to represent theories, and words are taken to represent concepts, ignoring the diversity in types of concepts or theories that we would expect." (diSessa, 2002, p. 37).

Conceptual Change

It is typically assumed that students enter science instruction holding specific theories, conceptions, or ontological categories. During formal and systematic instruction students either enrich or change their existing knowledge. In the early years of conceptual change research, "change" was considered as a sudden shift in which students replaced their prior concepts with a new scientific concept (e.g., Duit & Treagust, 2003). During the last years an increasing number of researchers have stressed that conceptual change is a rather gradual and slow process. However, it remains unclear to what scales "gradual" and "slow" refer: changes within minutes, hours, weeks, months, years?

In order to describe students' conceptual change, established scientific concepts usually serve as a "measure" for developing quality. Thus, students' conceptual understanding is compared to that of scientists (or, to be more precise, a researcher's understanding of science concepts). Students can hold misconceptions, everyday conceptions, naïve frameworks, synthetic models, or inappropriate ontological categories (e.g., Chi, 1992, 2008; Vosniadou, 1994; Vosniadou, Vamvakoussi, & Skopeliti, 2008) which need to be reorganized or changed towards a scientific understanding (Vosniadou, 2008). The "nearer" students' conceptions are to those of scientists, the more scientific elements are included, or the more appropriate a categorization is, the "better" is the conception. However, this seems to be a limited understanding of quality, which also limits the way in which conceptual change is investigated. One additional measure of quality would be offered with the distinction presented above between "non-conceptual" and conceptual knowledge focusing on students' increasing ability to describe and utilize explicitly the principles underpinning a specific phenomenon or event. Even if these principles constructed by a student were incorrect compared to scientists' descriptions a student focusing for instance on patterns rather than on "simple" observations could be considered as more knowledgeable. Also, students' understanding of science concepts can differ in terms of the kind of interrelations which are constructed between different concepts. Comparing, for instance, "Simple electric circuits can be described with the Ohm's law." with "An increase of amperage results in an increase of resistor's temperature and, therefore, voltage does not increase proportional to amperage." demonstrates that both descriptions are conceptual and are in accordance with current scientific ideas, but the latter offers a more precise and expanded idea of Ohm's law. Progress is then not just moving towards a more scientific view but also expanding scientific understanding by cross-connecting concepts (e.g., v. Aufschnaiter, 2006; v. Aufschnaiter & v. Aufschnaiter, 2003).

Empirical Approaches towards Investigating Conceptual Change

Typically, students' conceptual change is either addressed with tests (e.g., Hestenes et al., 1992; Liu & McKeough, 2005; Shipstone et al., 1988) or with more process oriented assessment, for instance, interviews (e.g., diSessa, Elby, & Hammer, 2002; Vosniadou & Brewer, 1992; Tytler & Peterson, 2005). During the last roughly 30 years these approaches have led to a large number of documented student misconceptions (e.g. Duit, 2009). Also, using interviews has offered insights into how students apply their conceptions within varying circumstances. Results of student interviews seem to demonstrate that at least for specific physics topics students seem to reason differently in situations that require identical explanations (e.g., diSessa, Gillespie, & Esterly, 2004) and also that students approach phenomena very individually even if there seems to be a similar conceptual ground (e.g., Tytler & Prain, 2009).

Approaches towards identifying students' learning are often restricted to a series of interviews (or tests) at different points in students' learning trajectories, for instance, once a year (e.g., Liu & Lesniak, 2006; Löfgren & Helldén, 2009; Tytler & Prain, 2009). Other studies also focus on differences in achievement for the same topic but different grades (e.g.,Vosniadou & Brewer, 1992; Ioannides & Vosniadou, 2002; Slotta, Chi, & Joram, 1995). Such approaches can be part of research on learning progression (e.g., Duncan & Hmelo-Silver, 2009).

Current studies assess students' progress at least globally but usually do not provide valid hints on what in detail has caused the development identified. Thus, so far a large number of studies addressing students' learning outcomes, the way students approach specific tasks, and *changes* in both have been conducted but very rarely does research focus on how students *develop* new or revised conceptual understanding while working on instruction (over a longer period) (some examples of more learning oriented studies are offered in e.g., Petri & Niedderer, 1998; Riemeier & Gropengießer, 2008). As a consequence, "conceptual change theory has struggled to develop a generally accepted view of how shifts occur" (Tytler & Prain, 2009, p. 4) and also which instruction promotes such shift (or hinders desired progress).

CONCLUSIONS

Within the last two sections, some critical issues on conceptual change where raised which we try to address in our investigations. In summary, these are:

- Focusing on students' *conceptual* knowledge leaves out any (declarative) knowledge which is not (yet) conceptual. Therefore, the description of progress is limited to changes in these concepts and does not include that and how concepts are *established* (either scientific concepts or misconceptions).
- Using interviews or tests to assess students' conceptual understanding limits our knowledge about how concepts evolve while learning and how these concepts are employed into (learning) activity. Therefore, the opportunities to describe criteria of appropriate instruction are also limited.
- Using science concepts as a (the) measure of students' progress in conceptual understanding does not offer enough categories to describe variances in different student activity and an increase in their understanding of science phenomena and events. Furthermore, these descriptions are limited to the science topic for which they are constructed and cannot be used to infer possible learning steps in other topics or domains.[1]

The aim of our research is to understand how students' (mis-)conceptions evolve, with which criteria improving conceptual understanding can be described and what the implications for instruction are.

SAMPLE, PROCEDURES, AND METHODS

Procedures and Samples

Like many researchers we use video documentation to assess students' learning processes. In order to gain detailed information about students' concept formation and concept use we use cameras and microphones which focus on student groups (typically two per classroom). Microphones hang from the ceiling above students' desks. Screenshots from our videos in classroom settings and during teaching experiments are presented in Figures 1a to 1c. We are well aware that a group focus is usually limited to a small number of groups and, thus, to a small number of students per class. Therefore, we do not gain information on *all* students of *one* class. However, we asses about 20% of the students in great detail and receive our information about learning processes from the large number of students incorporated in our different studies (see below). In addition group and individual activity we can usually also assess all teacher and student statements in teacher centered phases. Our cameras remain fixed without any camera person, but in classroom settings we usually have an observer sitting in the back of the room who takes notes on what is written on the blackboard and happening at the teacher's desk.

Figure 1. (a) Teaching experiment with students aged roughly 13 (topic: light and shadow). (b) Classroom-setting with students aged roughly 15 (topic: electrostatics). (c) Position of cameras for Figure 1c (VC: video camera; drawing: J. Hirsch).

During the last 12 years we have investigated more than 150 students from lower and upper secondary (11–18 years old) (e.g., v. Aufschnaiter 2006; v. Aufschnaiter & v. Aufschnaiter, 2003) and from university level (typically about 21 years old) (e.g., v. Aufschnaiter, 2003; v. Aufschnaiter & v. Aufschnaiter, 2007). Even though we have done some classroom studies, our main emphasis within the last years has been placed on laboratory studies similar to teaching experiments. These investigations have the advantage that parameters can be controlled better than in classroom settings which helps to identify relevant criteria. Currently, we turn our focus back to classroom settings in order to investigate whether processes are similar to those in our teaching experiments.

Topics of our investigations cover mainly electrodynamics but also thermodynamics and optics. Students are followed in small groups of two to four students with video typically over several successive lessons or sessions. In addition to video we sometimes assess students' interests and their situated experiences with questionnaires (e.g., v. Aufschnaiter, Schoster, & v. Aufschnaiter, 1999) and document their processes of concept-mapping.

Methods

Video-data are analyzed with a multilevel approach. In order to get an overview about the data and to generate quantitative results, videos are coded in 10 second intervals. These coding procedures focus on general dynamics and distinguish, for instance, between organizational and content-specific student activities or assess different types of discourse or student argumentation. Also, coding of video is used to identify sequences which are interesting for a specific research question. These sequences are then transcribed and investigated in more detail. Coding of the videos and transcription is performed with the software "Videograph" (Rimmele, 2008).

The second step of our analyses are in-depth investigations of the transcript (together with the video data) in order to assess details of individual meaning making processes (e.g., how a student understands tasks or contributions from other students). The notion of "processes" refers to the time scales on which we assume cognitions to change. Humans typically change their clothes on a daily basis, so "processes" here would refer to 24 hour-intervals. Moods in contrast might change very quickly, so that intervals need to be much shorter (maybe on a minute-basis). Research on human cognition indicates that immediate behavior is "always new; always a sensorimotor circuit." (Clancey, 1993, p. 111). From this and other work (e.g., Pöppel, 1994) we assume that a mental image (one cognition) takes up to 3 seconds and a line of thought takes up to 30 seconds (S. v. Aufschnaiter & C. v. Aufschnaiter, 2003). Thus, "in-depth" analyses not only refer to close investigation but also to rather short time scales (utterance by utterance, activity by activity).

In our research, step 1 (coding of videos) and step 2 (in-depth analyses of transcripts) are interrelated. In both steps criteria are used to describe processes or criteria are generated. Thus, the approach is explorative but also tests hypotheses. Which codes are applied or developed depends on our specific research question. We want to stress that this criteria-based approach differentiates between "case stories" and "case studies". For case stories, individual learning (and teaching) processes are described in great detail such as what students do and how they do it. Even though these often result in vivid and interesting descriptions, the implications of these descriptions often remain unclear. However, they often cannot reveal commonalities and differences between different individuals. Here, clear criteria are needed as well as a coding schema (an example is given in Appendix 1) that helps to set-up valid coding procedures (including the calculation of the intercoder reliability). With thorough coding procedures, individual processes can be compared and hypotheses can be formulated (see also Jacobs, Kawanaka, & Stigler, 1999).

EMPIRICAL RESULTS ON STUDENTS' PROCESSES OF CONCEPT FORMATION

Conceptual Qualities

In our earlier work on students' learning processes in physics we have noticed that students fairly often talk about particular situations, phenomena, or objects (e.g., v. Aufschnaiter, 2006). This happens even if students are explicitly asked to generate a rule, such as with the example presented in Transcript 1. Before the question is presented to the students they already realized that the temperature of an object adapts to room temperature if the object remains in that particular room for some time. With the question offered in Transcript 1 we expected students to generate an answer such as "The object will become the same temperature as the warm environment." Rather than presenting an answer like this, the students discuss two different phenomena. First an experience with a snowball is reported and then the student S2 tries to create a specific situation when considering what happens to the temperature of a metal cube.

"Imagine a cold object is brought into a warm environment. Explain without measuring: What happens to the temperature of the object?"	
S3:	*For instance, during summer a friend had a snowball which he took out of the freezer.*
S1:	*If you take it from the cold to the warm environment it either melts or…*
S2:	*Did it melt? How quickly?*
S3:	*That was during summer. It melted within 20 seconds, maybe even quicker.*
S2:	*Ok, if I take this metal cube in a real warm environment. Right now, this cube has about 22.5 degrees Celsius. It would then have about 25, I reckon.*
S3:	*Not more than two degrees warmer, the most.*

Transcript 1. 13 year old male students discuss a question (unit on heat transfer, sequence shortened, duration about 1:30 minutes).

Similar to this example students often report descriptions of particular events or ask for them. They describe their observations or remembered phenomena, for instance: "Look, the metal cube feels cold but it measures 22°C.", "Does this lamp still shine so brightly if you add a second one in this circuit?", or "Last time in the cinema, I could see how the light travelled to the screen." On the other hand, students sometimes explicitly state a rule, for instance: "Even if two objects feel differently, they can have the same temperature.", "If you add a lamp in a series circuit, all lamps will shine less brightly.", or "Light always travels in straight lines." This distinction between concrete events and rules found in our data concurs with the above arguments claiming that conceptual knowledge refers to an "implicit or explicit understanding of the principles that govern a domain" (Rittle-Johnson & Alibali, 1999, p. 175; see also diSessa & Sherin, 1998).

In our data, students only explicitly express conceptual knowledge in less than 20% of the time spent with the instruction. That is, dealing with specific objects or phenomena makes up the majority of students' activities. However, we identified in these activities another distinction which is also present in Rittle-Johnson's and Aibali's quote indicating that an "implicit […] understanding of the principles" can exist (1999, p. 175). For instance, when being confronted with a task referring to a conceptual explanation about the adaption of temperatures between an object and its environment, a group of students do not explicitly express this concept but, rather, focus on the water indicating that they have an idea of the underlying principle (Transcript 2).

S1:	*(looks at task 2.1). We have to explain why these gel-packs all have the same temperature [gel-packs were taken out of a water quench with hot water]*
S2:	*Couldn't we just measure the temperatures? Well, these all have the same temperature because they….*
S1:	*They were taken out of the same water quench.*
S2:	*They were taken out of the same water quench, yes.*

Transcript 2. 15 year old female students discuss a task about thermal equilibrium (unit on heat transfer, duration about 20 seconds).

In addition to distinguishing between activity which does not explicitly refer to conceptual understanding and statements in which conceptual knowledge is explicitly expressed, we, therefore, identify an intermediate level. At this level, students predict specific events or phenomena, they attribute expressions (for instance, physics terms) to events, phenomena and objects or they describe how different aspects relate to each other. However, even though at this level students seem to have an intuitive understanding of the underpinning concepts, their explicit verbalizations refer to particular events. When students use physics expressions these serve as labels rather than as generalizations (concepts). Examples for this intermediate level of conceptual understanding are: "I reckon, you'll measure again something like 22°C", "This is the same electric circuit that we had yesterday.", "The shadow is there, because the light cannot pass this box.", or "Last week, our teacher told us to say 'energy' when talking about this situation." Expressing an intuitive understanding can also occur when students are assumed to "hold" the corresponding explicit concept as well. For instance, before the episodes of Transcript 2 students have expressed the conceptual idea of the adaption of temperatures (thermal equilibrium) but do not show this understanding while working on that particular task. Here, we cannot say whether the students simply do not express the concept, e.g. by saying that the gel-packs have the same temperature as the water quench because the temperature of any object adapts to the temperature of its environment, or that they cannot transfer that concept to the new situation (or that they have forgotten the concept). Focusing on how students *express* their science understanding in varying circumstances helps us to identify how students develop an explicit conceptual understanding and how they utilize this understanding.

Students who are more experienced in a particular topic will more likely act on the basis of an intuitive understanding. In a comparison between students from grade 8 (about 13 years old) and grade 11 (about 16 years old) who were working on an identical unit on heat transfer (see v. Aufschnaiter & Rogge, 2010) the 11th graders developed significantly more ideas which are based on an intuitive understanding (Rogge, 2009; Rogge, 2010). However, we have not yet identified significantly more explicit conceptions with the older students. This result seems to be disappointing because differences between novices in physics and students who have had physics for at least 4 years in school appear to be rather small. It has to be noticed that distinguishing between concrete, intuitive, and explicit conceptual understanding is only one way to characterize the quality of students' understanding. In addition, descriptions can focus on scientific appropriateness, complexity of ideas, or time needed to construct these ideas (e.g., v. Aufschnaiter & v. Aufschnaiter, 2003). Differences between less and more experienced students' knowledge of physics might, therefore, not include more explicit conceptions and/or these being scientifically (much) more appropriate. Rather, differences might refer, for instance, to the amount of different elements of the content integrated and/or the speed with which these are developed (see also v. Aufschnaiter, 2006; v. Aufschnaiter & v. Aufschnaiter, 2003).

From Conceptual Qualities to the Learning of Concepts

In the previous section, three different conceptual qualities were established from the discussion of examples (for a more detailed description of these main categories and related subcategories refer to Appendix 1):

I) Students argue and behave in a way that seems to have no conceptual ground, for instance, while "simply" describing what they observe or exploring what happens when they change something in an experimental set-up. In our research we would label this an explorative approach.
II) Students argue and behave in a way which indicates that they have already grasped some idea about underpinning rules but do not yet explicitly refer to these rules. For instance, they predict purposefully (but not based on explicit generalizations) what will happen next or they have grasped how to describe a particular event with physics expressions. These activities are labeled as intuitive rule-based approach.[2]
III) On the third level students explicitly express conceptual knowledge by generalizing over several events, objects, or phenomena. This is what we label as explicit rule-based approach.

Whereas levels 1 and 2 imply that students deal with particular events, level 3 refers to a conceptual level. Thus, levels 1 and 2 indicate that students either lack any conceptual understanding of that particular topic or are currently not explicitly expressing their understanding. Rather than having "misconceptions", students at levels 1 and 2 may be characterized as having "missing conceptions".

Distinguishing different conceptual qualities is useful to identify at which level students currently behave (see also coding scheme in Appendix 1). However, it does not provide any hints on how students move between levels, whether there is a definite level at which they start their movement, and which learning material promotes or hinders such movement. Our results on students' learning processes indicate that for any new aspect of a topic (new for the students) students start by exploring related phenomena, opportunities to solve tasks, to treat experiments and to verbalize aspects (level I). If instruction offers explicit concepts at this level students either seem to "ignore" the information, express that they are puzzled or develop a concrete understanding of the information (for instance, by describing a specific experience). At this level I, students' activities often seem to follow a trial-and-error-like behavior, especially for open instructions. Teachers then often realize that students seem to not follow the instruction and do not control parameters.

From their explorations students develop an intuitive idea about what will happen next or how they have to work on an experiment or a problem in order to get a specific result. In a similar way, students explore how to express things, which is demonstrated by the following example taken from Rincke (2007, pp. 131f.). Here, a student explores how to use the word "exert":

> *A person exerts a force on a ball and throws it to another person. The other person catches the exerted ball. The other person exerts also a force and*

> *throws it back. The exerted balls are thrown back and forth between the two persons.* [Translation by CvA]

Students who have some experiences on a particular aspect of the topic almost directly start at an intuitive rule-based level when dealing with that aspect. Intuitive rules stabilize while students work on similar phenomena and problems. In these phases, students often explore the learning material again even though they already have an intuitive idea about what will happen. Within this circular movement between levels and also within the same level students are also more and more able to integrate different content elements into their considerations.

Surprisingly, students rarely move to the next level III. Explicit conceptualizations often occur in single sentences but not in long and extensive discussions. Moreover, students typically express a rule after they have already developed an intuitive understanding of this particular rule. However, conceptual understanding is usually expressed only *after* students' explorations of specific phenomena and problems. That is, students very rarely construct a hypothesis which is explicitly based on a conception before they work on the relating problem. While moving from level II to III and at level III explicit (short) information on underpinning concepts seems to be useful. Other than at an early stage of their learning, conceptual explanations offered help students to realize that they are "on the correct way" or have not fully grasped the idea. That is, if instruction wants students to understand a particular concept, these students need to discover this concept at least intuitively *before* they are likely to grasp the related conceptual information. Or, conversely, students are likely to understand any concept that they already "know" at least intuitively. However, it should be noted that establishing a concept once is not enough for a robust understanding. Even though we do see a general movement (for a specific aspect of a topic) from level I to level III, a "robust" understanding at level III requires the opportunity for students to (re-)explore related phenomena and problems, to stabilize their intuitive rules and to re-discover conceptual knowledge after dealing with a specific phenomenon or problem. Students will not (immediately) remember a poorly established concept when being presented with a slightly changed situation. More experienced students will need fewer hints and will also be quicker in re-constructing conceptual knowledge. Establishing conceptual understanding at level III also includes integrating more and more events within one conception and to relate different concepts together.

So far, we have described that our students mainly act and verbalize at levels I and II, that is, they deal with particular events no matter of age or prior experiences. We have also described that in comparison to younger students, students in higher grades with more experiences in physics significantly more often construct an intuitive rule-based understanding (level II). The processes by which students develop from a concrete to a conceptual understanding seems to be circular (see also for example Fischer, 2008), often very slow and requiring several repetitions, much more than are usually offered by instruction. Table 1 shows such a circular pattern for the learning unit on heat transfer where students are supposed to establish an explicit rule-based understanding of thermal equilibrium.

Table 1. Part of a grade 8 (aged 13) student groups' development of the concept of thermal equilibrium (Rogge, 2010) (S: students)

Time	*Context and main student activities (shortened)*	*Level*
0:00:00	Task 1: How warm do the scissors feel?	
	S describe that the blades feel cold and the handle feels warm.	I explorative
	"This [reference unclear] *is what we're discussion in geo science!"*	II intuitive rule-based
0:02:10	Task 2: Describe for different objects whether these feel warm, intermediate or cold.	
	S sort objects depending on how warm/normal/cold they feel.	I explorative
	While searching for a "warm" object: *"No* [it can't be warm]*, that is made of metal."*	II intuitive rule-based
0:12:20	Task 3: What are the temperatures of warm, intermediate and cold objects?	
	S estimate: warm 15 Degrees, cold 0 Degrees, normal 8–10 Degrees.	II intuitive rule-based
0:15:10	Task 4: Measure the temperatures of all objects classified.	
	S measure always about 24°C	I explorative
	"That can't be!" – „Maybe, because we've touched them!"	II intuitive rule-based
0:30:50	Task 5: Compare measured with estimated (felt) temperatures.	
	"Our estimations were completely wrong!"	II intuitive rule-based[3]
0:33:00	Task 7: Measure the room temperature and compare it with the temperatures of the objects.	
	S measure a room temperature of 23.5°C.	I explorative
	"They [the temperatures of the objects] *adapt to room temperature."*	II intuitive rule-based
0:37:00	Task 8: What are the temperatures of different cubes made from different material in a cooler?	
	S estimate: aluminum, iron, and granite cube: 5°C; wooden cube: 10°C	II intuitive rule-based
0:38:20	Task 9: Measure the cooler's temperature and the cubes' temperatures.	
	S measure for all roughly ~4–5°C – S are astonished	I explorative
	"The [cubes] *always adapt to room temperature."*	III explicit rule-based

0:40:50	**Info 1:** Objects which stay together for long have the same temperature: [...] Task: Which temperatures would the objects have if the room were at 30°C?	
	"Well, roughly 30°C" – "A little lower or a little higher."	II intuitive rule-based
0:41:30	**Task 10/11:** Progression of the temperatures of cold and warm water.	
	S measure temperatures and observe heating and cooling down.	I explorative
	"I know why." – "Yes, because it [the water] *adapts to the air."*	II intuitive rule-based
0:49:20	**Task 12:** How does the temperature of a plastic knife changes when taken out of the cooler?	
	S measure the temperature of the knife: *"It increases more and more"*	I explorative
	"Indeed, it is going to adapt."	II intuitive rule-based
0:52:00	**Task 13:** To which temperature will the temperature of the cold water, the warm water and the knife develop? *"It always adapts to the temperature of the air."*	III explicit rule-based
0:52:40	**Task 14:** Temperature of cookies which have stayed in the oven for 30 minutes?	
	"When taken out they'll have 200°C. And when sitting there [at the kitchen table], *then they'll have air temperature."*	II intuitive rule-based
0:53:30	**Task 15:** Temperature of a cold object which is brought into a warm environment?	
	"Well, it [the object] *will be like the environment."*	II intuitive rule-based
0:54:00	**Info 2:** Objects always adapt to the environment's temperature: [...] Task: Evaluate, whether the temperatures of the cold/hot water have converged the room temperature.	
	S holds thermometer into hot water and observes increase of scale.	I explorative
	"Does it increase? Say how much you have!"	II intuitive rule-based
	"33.4 [Degrees]*."*	I explorative
	"33, look, it has decreased much! Before, it had been 50 degrees, last time we measured [tasks 10/11]*."*	II intuitive rule-based
0:55:50	**Task 16:** Spoon put shortly into warm water: From where does the heat come? [Experiment to introduce the notion of heat receiver and heat source later on]	
	S heat spoon and touch it.	I explorative
	"Well, also the water. If an object is put into water, it adapts to the water, that is, if you go into hot water you'll get warmer."	III intuitive rule-based

Results presented so far might be seen as artificial because of our somewhat strange distinction between conceptual and "non-conceptual" knowledge. We would, therefore, like to stress that other researchers seem to arrive at similar descriptions of learning. The following three examples give an idea of how our system of categories can be related to empirical outcomes and theoretical descriptions of other researchers' work.

Example 1. In their work on young children's conceptual development over several years, Tytler and Peterson trace children' understanding and reasoning of scientific phenomena using one interview per year and child (e.g., Tytler & Peterson, 2003, 2005). For Jeremy, grade prep (about 5 years old), the following dialogue on how whirlybirds fly is given (coding for Jeremy added in [ ]):

Jeremy:	*I have an idea…. Why don't we try it with this one? [I explorative]*
SP:	*What small and big?*
Jeremy:	*Yeah, small and big (he predicts the big one will be slower, and tries) [I explorative or II intuitive]*
SP:	*Oh yes, you were right. Can you come and tell me how this works? How does one of these work?*
Jeremy:	*Um, because it's got longer fins and then it's got longer air and it can catch lots of air, and this one's only got little fins and it can't catch much air, and this can catch lots and lots and lots and lots and lots of air. [II intuitive]* (Tytler & Peterson, 2005, p. 82)

In their description of Jeremy's approach, the authors ascribe a level 3 which indicates that "Children carry out focused observations or interventions which involve trying out an idea, or following up a prediction with some conceptual basis. Explorations have a recognizable hypothesis driving them." (Tytler & Peterson, 2005, p. 72 and p. 82). Even though the authors describe Jeremy's approach having at least some theoretical basis, the theory is not given explicitly in the excerpt but an intuitive understanding of the rules that make different whirlybirds fly is recognizable. (From the introducing description of the excerpt it can be concluded that Jeremy has already had some experiences with whirlybirds before the excerpt episode.) From an observer's point of view the theory that could be used to derive Jeremy's arguments might be inferred. However, there is no indication that Jeremy arrived at his idea from an explicit theoretical understanding of air resistance or similar aspects.

Example 2. The SEPIA (Science Education through Portfolio) project aimed to integrate curriculum, instruction, and assessment practices at the classroom level (Erduran, 2003). Within the project, a curriculum about acids and bases was developed and evaluated through audio recording of grade 7 students (about 13 years old). The verbal data were transcribed and then the teacher-student interaction was studied in detail.

T:	*Ok. Say bromothymol blue. Now you've got to give me some reasons why you choose that. Bromothymol blue. Why did you like that?*
P:	*Because it's like, I like when you put two drops of it, it like changes to a different colour. [I explorative]*
T:	*Different colour change. And what I heard you say? I heard you say different colours. You mean different whether it was an acid or whether it was a base. [III explicit]*

For this excerpt, Erduran concludes that the mismatch between the pupil's and the teacher's understanding is a result of a student reporting a particular observation which is then interpreted by the teacher as "referring to a generality or rule about colour change and acidity-alkalinity" (Erduran, 2003, p. 82). Rather than arguing with a conceptual basis, the pupil describes an observation whereas the teacher focuses on a conceptual-based explanation.

Example 3. Steinle's (2002) research about the historical development of physics concepts results in a very similar description of how scientists make use of experiments to generate theories about the physical world. In one of his recent articles, Steinle introduces the notion of "exploratory experiment" tracing back how scientists used their prior experiences and ideas to explore phenomena and construct physics concepts (Steinle, 2002). Other than presented with our data, their prior experiences enabled scientists to produce a systematic variation of experimental parameters in order to explore which parameters have an effect and which have not. Typically, students of lower and upper secondary lack content specific (and/or relevant) experiences so that their exploration often starts in an unsystematic manner. Or – conversely – the systematic variation, that is, the control of parameters, must be introduced and promoted by the instruction.

Phenomenon-Based and Model-Based Concepts

Even though the amount of explicit conceptions is small in our data, we found a noticeable difference between students' conceptions which also applies to physics concepts. Table 2 indicates two different groups of concepts. The left column refers to concepts that can be derived from experiences (observations on what can be heart or felt, how people express things, how to work on problems). We label these concepts as "phenomenon-based concepts". The right column, in contrast, includes concepts which cannot be inferred directly from experiences. Rather, one has to construct a theoretical understanding of the principles that explain phenomena and phenomenon-based concepts ("why…"). We label this group "model-based concepts" even though this notion may cause some misunderstandings. If students, for instance, observe atomic models which are presented in a picture, on a computer screen or as a real model (e.g., illustrating atomic bonding), and then generalize that atoms are always round and have a color (which is incorrect but conceptual) we would assign this to a phenomenon-based concept as students have experienced (observed) the features over which they generalize.

Table 2. Examples of phenomenon- and model-based concepts

Phenomenon-based concepts	*Model-based concepts*
Whenever my teacher says “Ohm’s Law” he wants to hear $V=R^{x}I$.	Internal energy is the total amount of energy in an object.
If you add a lamp in a series circuit, all lamps will shine less brightly.	In order to see an object light has to be scattered from the object into our eyes.
Even if two objects feel differently, they can have the same temperature.	Sound is transferred by pressure variation.
All force meters include a spring.	Whenever an object changes its movement a force is exerted on the object.

Our data indicate that phenomenon-based conceptions occur slightly more often than model-based conceptions and seem to be less demanding for students (compared to model-based conceptions). However, due to the small number of explicit conceptualizations we still lack clear criteria to distinguish these two types of concepts in students’ verbalizations. For such distinction it is also very important to hold a 2nd order perspective to reveal how a student conceptualizes a particular aspect. Especially, if students know and conceptually apply specific phrases such as “Batteries need to supply enough energy for any electrical device.” we have difficulties identifying whether these phrases refer to a phenomenon-based understanding (a conceptual understanding of how to phrase things) or to a model-based understanding of the concepts involved into that phrase (e.g., the meaning of energy). Our impression from observations in schools is that students fairly quickly grasp explicitly or intuitively how to “say things correctly” without having (fully) grasped the model-based concept that they communicate. Teachers, in contrast, tend to assume that students who express model-based conceptions correctly have also understood their meaning.

Again, cross-reverence to the work of Steinle (2002) is possible: In the early stages of concept formation, scientists were typically not interested in, sometimes even not aware of, model-based reasoning. “Dufay was definitely not interested in microscopic theories about the ‘hidden nature’ of electricity (though he was well aware of the long history of speculations on that question), but rather intended to establish regularities on the level of phenomena and experiments, in a field that he found in an incoherent and unstable state.” (Steinle, 2002, p. 418). Further on, Steinle argues „Closely connected, there is the central goal of formulating empirical regularities about […] dependencies and correlations. Typically they have the form of ‘if-then’ propositions, where both the if- and the then-clauses refer to an empirical level.” (Steinle, 2002, p. 419). Also for students in physics, we found that they intuitively develop and then explicitly establish those concepts and conceptual connections that they can infer from their experiences.

diSessa’s p-prims can be considered similar to phenomenon-based concepts as most p-prims refer to rules or principles but seem to have a strong empirical basis (e.g., diSessa, 1993, 2002). However, it should be noted that, from a physicist’s point of view, phenomenon-based concepts provide systematic descriptions rather than physics explanations. So, teachers and researchers may argue that there is almost no value in phenomenon-based concepts as they are not at the "core" of physics as a discipline. In contrast, issues raised here provide strong arguments about the importance of such phenomenon-based concepts for both the progress of the discipline and the progress in students' understanding. It is then well established phenomenon-based knowledge, reassured and revised via repeated and varying explorations that provides the basis for the need of, the search for, and the understanding of model-based concepts and their interrelationships. It is the model-based concepts that contain explanations of physics phenomena. Model-based concepts cannot be inferred from experiences directly and are, therefore, "discovered" relatively late in both scientific development and individual learning. These assumption concur with Lawson's framework which comprises a five level description of students' increasing competencies using if-then-patterns to reason about content (Lawson, 2003). In his model, it is only stage 5 ("theoretical stage") which relates to model-based reasoning. For that stage, Lawson argues that it is reached in late adolescence and early adulthood. From our empirical results and from Steinle's (2002) description we would rather point out that it is not the age but the familiarity with content that enables learners to reach a model-based understanding. Thus, it is not only in physics research but also in students' learning that model-based concepts require many experiences and are, therefore, established relatively late in the process.

PHYSICS INSTRUCTION

Misconceptions and Demanding Science Concepts

So far, distinctions have been made between different qualities of conceptual understanding and between phenomenon-based and model-based conceptualizations. Furthermore, it has been described how students develop explicit concepts from explorations to an intuitive rule-based and later on to an explicit rule-based understanding. It can be assumed that this process is not only happening while working on physics tasks but also occurs in everyday learning sometimes leading to misconceptions. Thus, the framework presented above can help to understand students' misconceptions and to describe why some science concepts are demanding for students.

Misconceptions as a Result of Generalization Over Classes of (Everyday) Phenomena

Some typical misconceptions are

- In order to cycle, drive, walk, … at steady speed, a force is needed.
- Current is consumed in a resistor.
- In order to see an object, one has to look at it.
- Metals are (always) colder than, for instance, wood.

From a physics point of view, these concepts are either incorrect or at least incomplete. However, focusing on students' everyday experiences, it is obvious that these concepts are a generalization over classes of similar experiences. For instance, in order to cycle at steady speed one has to exert a constant force; it is often said that we pay for the current consumed; no object can be seen if we do not look at and, indeed, metals usually feel colder than wood. None of these experiences is wrong and, therefore, conceptions should not be considered as being incorrect. Conceptions such as the ones presented above also indicate which experiences are not yet (fully) present to a learner. Students have not (explicitly) experienced that there is a force which hinders movement (friction) and which they have to compensate for any object to move at steady speed. There is almost no opportunity to experience that the wording "current is consumed" is wrong or that almost all objects give off light which travels to the eye. Also, students have typically not measured the temperatures of different objects and have compared these to their experience of these objects feeling differently (see also Table 1). Thus, for teaching, several misconceptions provide a very useful resource as these give hints on misleading or missing experiences which have to be established during instruction.

Misconceptions as a result of missing conceptions

Some concepts may simply not be present to learners when they are prompted to construct these concepts. These missing conceptions can either be phenomenon-based or model based. Examples are the concept that shadows not necessarily have the shape of the object, the concept that temperatures adapt to each other, the concept that whether an object floats or sinks requires a focus on mass and volume, or the concepts of electrostatic induction and polarization. Such concepts are not (yet) constructed because students lack prior experiences (or have not focused on these experiences) that enable them to develop at least a phenomenon-based conceptualization about that particular issue. However, in conceptual change research students are intensively prompted to construct concepts about topics with which they are not familiar, which is demonstrated nicely by the following example:

I: What happens when you see this book?
S: I see it with my eyes!
I: The book sits here on the table and your eyes are there. How can you see it?
S: I don't know. I just see it. Now I can't see it any more (I holds a sheet of paper between the pupil's eyes and the book). Now I can only see the sheet of paper.
I: Why can't you see the book anymore if the paper is there?
S: It covers the book, so I can't see it anymore.
I: Now there is no sheet. You can see the book. Is there something between your eyes and the book?
S: Yes, there is air, isn't it, and lots of other stuff. But because it is transparent I can see through it.
I: Seeing, how do you think it works?
S: I don't know how it works.
I: Have you never thought about how we see?

S: No, that is nothing one thinks about often.
Later:
I: How is it possible for you to see the book?
S: Well, I really don't know, I can do it, that's all.
(Wiesner, 1986, translation by CvA)

For these kinds of questions, students are "forced" to make a "guess" which, in turn, may not say a lot about students' understanding as they may not yet have arrived at a conceptual level, let alone a model-based understanding. In order to give an answer that satisfies the interviewer, students try to transfer their daily experiences to the unfamiliar topic. The effort to utilize everyday experiences then creates misconceptions, such as the idea that atoms have similar properties as macroscopic objects.

Why some science concepts are demanding

We conclude from our results that especially only model-based concepts are difficult for students. These are, for instance, force and energy and their distinction as well as the distinction between energy, voltage, and current. None of these concepts can be established solely from experiences except from experiences with specific wording, such as "Never say current consumption, it is the energy that is transformed." So, students can develop a phenomenon-based concept from what they hear but with this alone, no conceptual understanding of, for instance, energy is established. Unfortunately there seems to be no direct way to address model-based concepts. Either students lack any conceptual understanding or they refer to phenomenon-based ideas (such as particles as little balls that have the same color as the macroscopic object). Rather than approaching model-based concepts directly (for example, by contrasting these to students' ideas) we assume that a thorough analysis is needed which phenomenon-based concepts have to be established in advance of corresponding model-based concepts. In order to, for instance, establish some conceptual understanding of the model-based concepts of electric current and voltage students should be exposed to extensive and systematic measurements of something being labeled as current and voltage so that they can discover that there are two different parameters in electric circuits that behave in specific ways. When having grasped phenomenon-based concepts about measures of current and voltage in different circuits and under different conditions it is more likely that students can and will understand (slightly) what these two concepts "mean" and why measures behave in specific ways.

Designing Instruction

For formal instruction, it is assumed that students' conceptual knowledge needs to be taken into account: "Teachers need to be informed about how students see the physical world and learn to take their points of view into consideration when they design instruction." (Vosniadou et al., 2001, p. 392). Nowadays, teachers can access well documented descriptions of students' understanding in specific domains (e.g., Driver, Squires, Rushworth, & Wood-Robinson, 1994). Although these documents give valuable insights into students' ideas, they are also problematic because they turn the readers' (teachers') focus towards concepts instead of experiences. Research reported in this paper indicates that students rarely construct explicit concepts and if they do so, the concepts are often phenomenon-based. It was also stressed that extensive experiences are the starting point of any learning process whereas lacking experiences and some experiences made in everyday life can hinder learning progress. Therefore, as discussed above, concepts documented should be used to infer students' underlying and missing experiences which are one key to effective instruction.

Another reason why solely focusing on students' conceptions is problematic is that these (mis-)conceptions do not say anything about appropriate instruction. Measuring a "gap" between what students know and what they are ought to know gives almost no hints about how to "close" the gap. Research seems to agree about the need to define an appropriate level of demand (e.g., Leach & Scott, 2002), so that students can restructure their knowledge and will not just try to learn the new information by heart or "ignore" what is presented to them. If it is students' missing and existing experiences that are important for their conceptual understanding, instruction systematically needs to focus on experiences with specific phenomena and events (including experiments). Although experiments certainly play an important role in formal instruction, they are often considered and used to *demonstrate* a specific concept (that is, using single experiments that show best what is needed to be seen). Experiments are assumed to generate cognitive conflict or at least dissatisfaction with existing concepts (e.g., Posner, Strike, Hewson, & Gertzog, 1982; Strike & Posner, 1992). However, if students do not yet have a (model-based) concept dealing with the presented content, they are not very likely to "understand" what is to be conflicted and what kind of concept the experiment is about to demonstrate. For instance, an experiment in which tea from a teabag dissolves into water is typically meant to demonstrate molecular movement. However, observable is only that the water slowly turns brown (and gets a specific taste). Thus, if students do not know anything about the particle model and about these particles moving around, the experiment will only "demonstrate" how you can change the color of water (and make it tasty). Overall, the way experiments are often utilized in physics instruction is not very effective because it is assumed that they are important for connecting theory to praxis but not really as a means by which students can develop new knowledge. This kind of "ineffectiveness" of demonstrating experiments can be seen even if these experiments are embedded in very different kinds of instruction. In his project on inquiry settings, Lederman and colleagues trialed, for instance, direct instruction, inquiry-oriented instruction and a mixture of both, revealing that none of the three settings leaded to significantly different effects (Lederman, Lederman, & Wickman, 2008). With respect to our work we would argue that even though at a surface level these settings differed largely (teacher centered vs. student oriented, different ideas of "inquiry"), the experiments in both settings were of the same nature aiming to demonstrate concepts rather than establishing these. Therefore, outcomes of these different settings are almost identical.

It should be noted that teachers sometimes do not realize that their students have not grasped the concept which was demonstrated in an experiment. The reason is that students are able to figure out rules from their teacher's behavior and, therefore, learn what they have to say and when (phenomenon-based concepts). As long as the teacher offers appropriate hints students will respond with the expected conceptual knowledge even if they neither understand the experiment nor the concept. Such behavior, in turn, often results in knowledge that appears to an observer incomplete, as a synthetic model, or a misconception.

We have emphasized so far that for conceptual development it is the experiences that enable and limit students' understanding at the same time. Instead of focusing on concepts, the focus on experiences would enable a teacher to understand better which experiences need to be differentiated further and where it is appropriate to introduce new experiences. However, only if one is well aware about the concepts which are supposed to be established (phenomenon-based and model-based) one can reflect upon students' existing and missing experiences with respect to these concepts. Such a reflection needs to be included in any design. We have further argued that the differentiation between phenomenon-based and model-based concepts is useful as it offers a distinction between concepts that are more likely to be understood by students from those that require extensive effort in instruction (or are simply told so that students can say them but do not (fully) understand them). Therefore, the starting point for the design of instruction is some sort of list of the concepts that are supposed to be established with a special focus on phenomenon-based concepts. Furthermore, a thorough analysis of students' misconceptions and experiences they have already probably made can offer ideas on which experiences need to be created with experiments (or mental exploration).

In order to establish conceptual understanding, students need to have the opportunity to explore phenomena often so that they can develop an intuitive understanding of commonalities and differences before they are able to construct and understand phenomenon-based concepts explicitly. The typical learning trajectory presented above also shows that instruction should allow exploration at any further stage of students' conceptual development so that students can re-discover, re-assure, and revise their intuitive and explicit rules. In more detail, it is the series of coherent (mental) exploration of phenomena with respect to varying parameters that will support students to develop an intuitive and, later on, explicit phenomenon-based understanding. In that, students' prior experiences need to be differentiated further (see also Table 1). For instance, for the concept of buoyancy, students need to explore systematically the effects that (bulk) objects of different volume but the same material, of different masses each with the same volume, or of different shapes but made of the same material have on floating and sinking. Further, students need to be supported to investigate systematically what happens to the water level when objects of different volumes, masses, and material are inserted, and how the water pressure differs depending on the volume that is inserted. Here, new experiences are created which have not yet been in the focus of students' activities. Finally, the mass of the object and the mass of the displaced water can be compared (for such an approach see Möller, Jonen, Hardy, & Stern, 2002). Even though students cannot discover the model-based concept of buoyancy, they will develop an intuitive understanding of which objects float and which will not (most adults have such an understanding developed through their experiences) and may also be able to create a phenomenon-based concept about floating and sinking referring to the interrelationship of the mass of the displaced water and the mass of the object. Focusing on (bulk) objects of the same size but different masses or objects of the same mass but different sizes as well as the behavior of these objects when being displaced in water can help that students develop at least an intuitive understanding of density in a sense that it is the relationship between mass and volume that matters. The concept of buoyancy is nothing students can discover directly from experiments but these prior experiences will help them to understand that buoyancy has not a fixed value but increases with the volume that is displaced into water sometimes leading to a balanced state between the object's gravitational force and the "water-force" (floating) or being lower than the gravitational force leading to sinking.

The instructional approach, very briefly outlined, does not focus (at the beginning of a new content) on scientific concepts explicitly. Instead, it improves, develops, and introduces experiences to students systematically as these are a prerequisite for students to ask for and be able to understand a model-based concept. Such an instruction does not focus (at an early stage) on "good" conceptual explanations but on "good" (systematic) discoveries. From our and other data we would conclude that expanded and differentiated phenomenon-based concepts are a realistic goal for lower secondary physics education. Aiming to improve students' scientific understanding rather than their understanding of what words are most convincing to the teacher, concrete (mental) activities instead of concepts should make up about 80% of classroom activities (including students' debates about what they observe, how their observation relates to other phenomena, completion of worksheets and so on) in secondary schools.

SUMMARY

"Researchers in science education and cognitive science seem to agree that naïve physics exerts a great deal of influence on the way new information is understood and science concepts are acquired, but disagree on how to characterize the exact nature of naïve physics." (Vosniadou, 2002, p. 61). In this chapter, an attempt was made to classify students' knowledge with respect to its conceptual structure. Whenever students describe a phenomenon they have encountered or label a specific situation (maybe by using physics expressions) it was assumed that such kind of knowledge cannot be considered "automatically" as conceptual (even though students may be able to demonstrate an explicit conceptual understanding when being asked). Only knowledge which explicitly comprises (physics) principles, laws, rules, or theory should be considered conceptual. Furthermore, it was argued that explicit concepts can be based upon own (mental) experiences (phenomenon-based concepts) or are a result of theorizing (model-based concepts).

From our process data we have strong evidence that, indeed, conceptual change is a gradual and slow process, occurring in circular rather than in linear modes. Two different types of changes were described:

(A) A development from a non-conceptual (explorative) approach to a conceptual approach requiring an intuitive understanding in-between. Within such a change, students develop from grappling (a high number of) similar situations or objects to an integrated perspective in which they can explicitly abstract from particular features of these situations or objects. This result concurs with results of research on differences between novices and experts. Whereas experts are able to solve problems on the basis of physics laws and theories novices tend to focus on surface characteristics without an understanding of the conceptual basis (e.g., Chi, Glaser, & Farr, 1988).

(B) A development from phenomenon-based concepts to model-based concepts. Students (and researchers) seem to discover those concepts first that can be inferred directly from distinctions and classifications of their experiences (everyday, in school, in a laboratory). Such concepts have the status of generalizations and do not provide explanations of the phenomena they comprise. Concepts such as "objects fall down when not supported" can be grasped easily (in early childhood) whereas concepts such as "gravity is a force between two objects" require an abstraction from several (and varying) concrete (mental) experiences with different objects and their attraction. Thus, one model-based concept can comprise several phenomenon-based concepts. Or, conversely, students need to develop several phenomenon-based concepts before they are able to construct the associated model-based concept.

Obviously, such a description of conceptual change seems to disregard the contents of the concepts themselves. It should be stressed that no decision of the conceptual quality can be made without an explicit focus on the content of the knowledge which is presented by students. Other than with descriptions focusing on the content solely (A) and (B) aim to provide a generalized framework on concepts and conceptual change which can be applied to different topics. As such, the framework is phenomenon-based and not model-based!

When transferring our results to the design of instruction we have argued that the idea that students can be introduced to a new topic by asking them to discuss differences between their (mis-)conceptions and the scientific view does not match the learning trajectories we observe in our data. Students are not likely to understand any conceptual knowledge which is not based on a large number of familiar experiences. Instruction which uses systematically arranged phenomena in order to help students to establish at least an intuitive understanding of relevant rules before concepts are introduced is much more promising. We have also stressed that current instruction does not lack efforts to include inquiry-based approaches and/or hands-on experiments but it is the way that these experiments are used to demonstrate concepts rather than to help students to discover concepts are problematic for effective learning. However, our approach to instruction presented can be criticized as it does claim to reduce the large number of model-based concepts for schooling. Certainly, seeing students mainly arriving at an intuitive rule-based understanding or an explicit understanding of phenomenon-based concepts may sound trivial and not enough for schooling (at secondary level). However, as Steinle points out, the scientific development of model-based concepts is a very complex and difficult process which required several decades in history. "Most prominently, Ampère himself considered, in all his later reasoning on microscopic circular currents, the concept of a current circuit as an unproblematic foundation. Similar observations hold, finally, for Faraday's 'magnetic curves,' though it took, in that case, several decades until the concept appeared acceptable […]. Nowadays, however, we take it up in school. Since those notions now appear as somewhat natural, the very fact that they have been created out of hard labour easily slips out of view." (Steinle, 2002, p. 424).

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NOTES

[1] Not as a surprise, it has to be noted, that this limitation only refers to the learning of science. For the learning about science, progress is usually assessed with categories that can be applied to different topics (for instance, Table 1 in Songer, Kelcey, & Gotwals, 2009, p. 614).

[2] The reason why we are not stating that this is an *implicit* understanding (according to Rittle-Johnson & Alibali, 1999) is our idea of the meaning of the term "implicit". In our understanding "implicit" refers to something that is already "there" and is obvious to an observer. "Intuitive" in our understanding stresses a little more how the understanding is created rather than that it is already located somewhere. However, we are well aware that in some research projects "intuitive" is used for knowledge developed outside school contexts (e.g., Sherin, 2006), which does not match our meaning.

[3] Here, no definite coding is possible as this activity can also refer to reporting an observation (I explorative). We have agreed to code the higher level whenever we cannot decide between two levels.

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APPENDIX 1

Brief coding schema on students' (conceptual) understanding

Main categories	Subcategories *Students…*	Description	Example (heat transfer)
explorative approach	act/ experiment	Students explore phenomena, e.g. carry out an experiment or measure a value. In addition, students can simultaneously describe their activity. [Just watching, reading or writing is not coded.]	(student touches an iron cube) "Touch this iron cube. It's cold."
	describe with visual aid	Students observe objects, events or situations and describe them.	(student looks at the thermometer) "The temperature is increasing."
	describe without visual aid	Students describe objects, activities or situations without observing them. Also: Students make a guess what will happen.	[student remembers:] "The water got colder."
intuitive rule-based approach	assume	Students make an assumption about what will happen. Students emphasize an aspect that is important from their point of view.	"The cold water in the petri dish will certainly reach 22 degree."
	attribute	Students make use of specific linguistic elements (particularly Physics terms) to label and describe phenomena and objects.	"This hot gel pack is a heat source."
	explain	Students explain how different concrete aspects, phenomena or situations relate to each other.	"This gel pack didn't cool down because it's wrapped in a newspaper."
explicit rule-based approach (conceptual)	generalize	Students express a generalization explicitly. They formulate a rule-based relationship.	"Objects adapt to the temperature of the environment."
	explain rule-based	Students use generalizations or rule-based relationships in order to explain a particular or general situation.	"This rod is at room temperature because objects adapt to the temperature of the environment."
	predict rule-based	Students explicitly refer to generalizations or rule-based connections when predicting the progress of a particular or general situation (e.g., the result of an experiment).	"The white sheet of paper won't get that warm because light and bright surfaces reflect thermal radiation."

Note. This schema is a shortened version of the German coding manual (Rogge, 2010). This manual and the schema are still under revision.

GUSTAV HELLDÉN

5. STUDIES OF THE DEVELOPMENT OF STUDENTS' UNDERSTANDINGS OF ECOLOGICAL PHENOMENA

BACKGROUND

Following an intensive debate on the advisability of building a refuse disposal unit in the town of Kristianstad, Sweden, local people started to discuss what would happen to the residue from refuse incineration. From the debate it was evident that there was limited knowledge of what actually happens to refuse in general. Many thought that the matter would disappear, except for a small residue of ash. There was, in many cases, no recognition of the existence of waste gas. Most people found it difficult to realize that all matter still existed after combustion. This became a challenge for us as teachers and teacher educators. Is not this a kind of knowledge that citizens should acquire at school?

Several studies have shown that students initially take for granted that things they cannot observe do not exist and construct their own explanations in order to understand and describe the phenomena (Driver et al., 1994). As a part of the growing process, organisms exchange gases with the environment. When biomass is decomposed, carbon dioxide and water are delivered to the environment as gases. Students at the secondary level have difficulties to give an accurate interpretation, at their own educational level and using their own words, of the process by which biomass builds up and breaks down or where matter comes from and where it goes. The water cycle is another process that contains transformations with gases involved. An appreciation of these processes is fundamental in order to understand important environmental issues (Helldén, 1995).

Some interesting details emerged in the explanations of these processes at different ages among the students. This pattern made the development of students' ideas still more interesting. The following question was formulated: From where do these ideas come and how do they develop? In order to create teaching situations during which students' ideas could be challenged, we need to know more about individual students' conceptual development. If you identify a student's conception at one point in time, it might be helpful to know more about the roots of such conceptions in order to improve teaching at an early age. It might also be interesting to know how the student could develop her/his understanding when she/he gets older. Short time studies cannot capture the whole picture. It is necessary to stretch the duration of a research project and study the same subjects over time. A longitudinal research design makes it possible to follow the

Doris Jorde and Justin Dillon (Eds.), Science Education Research and Practice in Europe: Retrospective and Prospective, 91–113.

development of an individual student's understanding year by year. Such insights can then be used to develop teaching strategies in order more effectively support the development of students' understanding.

It was also realized that insights from such studies can be used in teacher education. Student teachers can identify children's explanations of scientific phenomena during their practice in schools. They came back with children's descriptions of scientific phenomena. With examples from research, it might be possible to provide the student teachers with insights into the roots of children's explanations and of how such explanations develop over time.

Despite these arguments for longitudinal studies, there are very few articles published on longitudinal studies of students' science learning (Arzi & White, 2005). This became a challenge to researchers to start such investigations.

In order to learn how to help students to develop deeper understandings and more scientifically accurate explanations of some ecological processes, a longitudinal study of students' conceptualization of such processes between 9 and 15 years of age was started. The ecological processes comprised (1) conditions for life, (2) decomposition and (c) the role of the flower in plant reproduction (Helldén, 2004; 2005).

Conditions for life and decomposition have to do with how biomass builds up and breaks down. Also the role of flowers was included as teachers and student teachers had found that students at different ages expressed interesting ideas about flowers with a rich variety of anthropomorphic formulations.

Interviews were used extensively throughout the study, beginning at age 9. During the analysis of the interviews, personal themes were identified that appeared year after year in the students' descriptions (Helldén, 2001). These themes seemed to result from personal experiences that were hidden from the researcher. The longitudinal design made it possible to interview the students again at 15 and 19 years of age about their earlier descriptions of the phenomena after they had listened to the earlier interviews with them.

The following three research goals guided the study:

- to describe students' ideas about conditions for growth and decomposition in nature, and about the role of the flower in plant reproduction
- to explore how students' ideas are influenced by experiences of everyday life
- to study students' ideas about their own learning

Ausubel's theory of meaningful learning was used as a framework for the analysis of the interview data and guided the description of the students' conceptual development. According to the theory of meaningful learning, new ideas are integrated into the learner's thinking through a process that Ausubel calls progressive differentiation. This process starts in childhood and continues throughout life. When new ideas are integrated into the learner's thinking, already existing conceptions can change and new meanings can be added to these conceptions. The theory explains the ways learners use current meanings to develop and construct new meanings (Ausubel et al., 1978).

A LONGITUDINAL INTERVIEW STUDY

As a result of a pilot study, and several projects undertaken by student teachers investigating students' conceptions, it was obvious that clinical interviews can give in-depth information on students' thinking about natural phenomena (Duit, Treagust, & Mansfield, 1996).

In order to learn more about the development of students' understanding of ecological processes that concern transformations of matter, an interview study was started focusing on the development of students' understanding of conditions for life, growth and decomposition, and the role of the flower in plant reproduction. The interviews were carried out at a small primary school, and later at a larger lower secondary school with more subject-oriented teaching. Over the course of the study, the same 24 students were interviewed concerning ecological processes from grade 2 (age 9), with a few students added in grade 4 to form a stable population of 29 students thereafter. The timing of the interviews was complex, but generally occurred in cycles of 1–2 years for each phenomenon. All the students belonged to the same class for all that time, an unusual feature that reflects the stability of the population in this area in Sweden. Usually, longitudinal studies suffer from attrition over time (Arzi & White, 2005).

Prior to the beginning of the interview with the students, the class of 8-year-old students was regularly visited during a six-month period. During these visits the researcher talked about what the children had experienced in nature, and listened to their stories about plants, insects and birds. The purpose of these preliminary visits was to become familiar with the students and to show them interest in their thoughts about phenomena in nature. During the interviews the researcher made it clear to them that he was interested in their thoughts per se, not whether the answer was right or wrong. To show the children that the researcher was primarily interested in their thinking, the first question of the interview started with the words: " What do you think…?

To challenge the students' ideas about the conditions needed for life, the students grew plants in sealed transparent plastic boxes sealed with a glass cover. The first question of the interview started with the question: "What do you think the plant needs to be able to grow in the box with the glass lid pasted on?" Another question was: "What do you think will happen to the plant in the box if we plant it there and glue the lid on?" For the interviews about decomposition, there were soil, brown leaves and litter on a table in front of the students. The opening question was in this case: "What do you think will happen to the leaves on the ground in the autumn?" Later during the interview about decomposition, the students were also asked: "What makes the leaves fall from the trees in the autumn?" When the students were 11, 13 and 15 years of age, the interview about the role of the flower started with the following question: "What is the importance for a plant to have a flower with colour?" During these interviews the students had a jar with common wild flowers on a table in front of them. The researcher did not teach the class but visited regularly. Since the main focus of the study was on broad developmental patterns in understanding, there was no endeavour to seek specific links between the school programme and the ideas expressed in interviews.

Already, at an early stage of the research project, there were features in the students' descriptions that reappeared year after year. These features seemed to result from personal experiences that were hidden from the researcher but had become a part of the students' episodic memory. Such features could be of importance for the description and interpretation of the students' conceptual development. Why not ask the students themselves about such features? Therefore, the students were, as 15-year-olds, asked to make comments of what they said in the interviews at 11 years of age, after they had listened to audiotapes and as 19-year-olds what they said at 11 and 15 years of age (Helldén, 2001).

All interviews were tape-recorded and transcribed verbatim before the analysis started. Ausubel's theory of meaningful learning was of great help. In order to support the analysis of the interviews, concept maps were constructed from the transcribed interviews. The development of the students' understanding could be usefully described as a progressive differentiation through which new concepts are subsumed under concepts that already are integrated in the learner's thinking (Novak, 1998).

THE STUDENTS' IDEAS ABOUT CONDITIONS FOR LIFE

Initially the students expressed doubts as to whether the plants would survive in the sealed transparent boxes. Two students were quite upset when the interviewer told them that they should put plants in sealed boxes. One of them took a deep breath herself and said: "Then they don't get any air. The plant can't get any oxygen and it can't grow. You can't, the plants can't breath. And we can't water them." The children compared their own breathing with the plant's breathing and had developed a feeling for the plants' survival. The interviewee promised the children to take away the glass cover if the plants could not grow inside the sealed box.

Many students expected the plants to die in the sealed boxes. The students thought that the plants must take in matter of different kinds from the environment but did not describe the passing of matter from the organism to the environment as a part of a cycle. They had constructed an 'end station model' in their minds to explain how air, oxygen, water and other resources were consumed. A week later, the teacher told me that she had heard the students discussing the water film on the walls and the cover inside the plastic boxes. She had responded to the students' ideas about the mist inside the box and introduced the concept of the water cycle. Many students picked up the cycle and started to discuss the plants' survival from a new perspective. As a result of that intervention most of the students constructed their own ideas about the water cycle. Many students then used their 'cycle models' as prototypes to explain how organisms could survive in the sealed boxes and maintain life-supporting resources such as air, oxygen, carbon dioxide, water and nourishment. That does not mean that their explanations were scientifically correct.

An analysis of the development of 25 students’ ideas about conditions for life and growth from age 10 to 15 can be grouped into the following three categories depending on their description how the plants got oxygen, carbon dioxide or air: a. Alternative ideas about the role of oxygen and air; b. Towards a limited understanding of the role of oxygen and carbon dioxide; c. Towards a more complete understanding of the cycles in the box.

A. Alternative Ideas About the Role of Air and Oxygen.

Students in this category did not talk about the role of carbon dioxide as an important resource for the plants but argued that the presence of oxygen or air were an important prerequisite for life in the sealed boxes together with soil and water.

In order to be able to explain from where the plants got oxygen and air, four students said that all the resources that the plants needed came from the soil. They argued that oxygen and air also came from the soil. Two students mentioned it a couple of times during the interviews, while Stina and Emil mentioned that oxygen came from soil in every interview from 10 to 15 years of age. The idea appears to be strongly consolidated in their thinking. Already at age 10, Emil said that the plants got oxygen from the soil and at age 11 that the plants could grow better in soil than on wet filter paper because they got oxygen from the soil. At age 15 he said: *‘Doesn’t the soil take up the air and then the soil gives it to the plant and the grass?’* This statement indicates that he meant that the plant absorbed the air through its roots.

Ten students also argued that the plant could survive in the box because they required so little oxygen that it never would be used up or that air or oxygen could be available through the water cycle. Hanna stated, at 10 years of age, that the plant could get air or oxygen through the water cycle: *‘We planted those before when there was air and then we poured water on them and then when the steam made some air, so they could breathe and grow.’* At 13 years of age she mentioned that the plants in the box needed oxygen available from the beginning of the cultivation. Hanna stated that the plant needed light in order to become green, which she claimed was a sign of health. She also made the teleological statement that soil was necessary because otherwise, the plants did not have a place where their roots could grow. Two years later Hanna spontaneously mentioned the need for light, water and oxygen. For her the concept of water got a more diverse meaning: - for the plant to grow in the box - for the absorption of nourishment - for the ‘production of oxygen’. She described the role of the water in a way that made evaporation a prerequisite for water to be obtained by the plants.

Even if the students’ descriptions, in most cases, became more developed through the years, it is possible to recognize personal features or core ideas in the students’ conceptions such as in the following segments from interviews with Eric. After the teacher’s introduction of a cycle model, Eric used a ‘cycle model’ to explain why the plants could survive in the sealed box. His ‘up and down' description was replaced by a description in fewer words at 13 and 15 years of age, but he did not differentiate between air and water until he was 15 years-old.

Eric at age 10: 'It is sort of a vacuum in there. The air evaporates but then it goes down again. And there will be air again. Up and down, up and down. The air rises, evaporates and becomes water. Then it falls down again and there is water there on the ground. Then the air comes up again.'

Eric at age 11: *'The air disappears down into the soil and there is more nourishment. Then it goes up again. Then it goes up and down, up and down'*

Eric at age 13*: 'It is shut up sort of… The air in there has become … It is warm so there was steam of it.'*

Eric at age 15: *'It circulates all the time. Before you put the lid on, you water before. Then it evaporates and settles on the lid.'*

Already by age 10 Eric used the cycle idea and continued to do so in every interview to explain how the plants could survive in the sealed box. But he integrated 'an air cycle' with the water cycle only at 10 and 11 years of age. Eric said, at age 11 years, that the air got nourishment from the soil. Like several other students in the class he looked upon the soil as a container of different life supporting resources. Six students in this category of ideas argued at 15 years of age that the plants in the sealed box got oxygen through their own production.

B. Towards a Limited Understanding of the Role of Oxygen and Carbon Dioxide

The four students that belong to this category had a vague idea of the role of oxygen and carbon dioxide in the sealed box. They could not, even at 15 years of age, explain from where the carbon dioxide came. Already, at 10 years of age, Betty talked about the need for carbon dioxide. She also said that plants could transform carbon dioxide to oxygen at age 12 and added that oxygen could be transformed to water. When Betty was asked where the water inside the lid came from, she said: *'Well, it's made of oxygen moving towards the glass lid. Well, there will be water condensation because oxygen is transformed.'* At 15 years of age, Betty declared that the plants got what they needed as result of cycles in the box. Barbara did not talk about cycles but argued through the years that the plants got what they needed because so little was used up. At 15 years of age she included carbon dioxide. Louise talked on the other hand about cycles but mentioned the role of carbon dioxide only at age 13.

At the age of 15, Sofia said that the green plants transformed carbon dioxide to oxygen but she could not explain where the carbon dioxide might come from: *'They give off oxygen. And then perhaps it is transformed to carbon dioxide again. It goes round.'* Before age 15, she did not say anything about that process but described at 12 and 13 years of age how the plant got its oxygen from the soil and through the water cycle. When Sofia explained why the plants could survive in the box, she always described in an illustrative way how the water cycle could provide resources for many plants' needs. Her ideas always included mention of dew as a part of the cycle.

Sofia at age 10 ("I" refers to the interviewer)

S: *'The water rises up through the stem.'*
I: *'And where does it go then?'*
S: *'It becomes dew.'*
I: *'Well, what happens with it then?'*
S: *'It rises up and rains down.'*

Sofia at age 11: *'Well, first you poured in water. Then in the morning, there sort of will be dew on the leaves and the, when it is a little warmer in the box, it rises up towards the floor. And then it is raining down when there is too much.'*

Sofia at age 12: *'Well, first there will be dew on the leaves. Then it rises up here and then it falls down on something down there.'*

Sofia at age 15: *'You had watered the soil before you planted them and had sealed the box. The plants absorb the water. Then there is dew on the plants that evaporates. It rises. Therefore, it is condensation there. And then it runs down back into the soil.'*

C. Towards a More Complete Understanding of the Cycles in the Box.

The seven students in this category could, at 15 years of age, explain where carbon dioxide came from but their conceptual development towards that idea over the years appeared to be different. Sven, Morgan and Thomas developed their understanding step by step from 10 to 15 years of age. Already by the age of 10 and 11, they talked about the need for carbon dioxide and where it came from. Thomas, for example, suggested at 11 that the carbon dioxide came from the worms in the soil. All the students in this category argued that oxygen was transformed to carbon dioxide. They did not talk about a chemical reaction in which oxygen and carbon dioxide were involved. Morgan said: *'The plants use carbon dioxide and then transform it to oxygen. But then when they die and rot, there is combustion when creepy crawlies and sort of eat them. Then all the oxygen is used up and transformed to carbon dioxide. And it goes like a cycle.'* The students used an everyday expression that carbon dioxide is transformed to oxygen which is scientifically incorrect and can be characterized as a transmutation (Andersson, 1991). The other four students in this category did not talk about carbon dioxide at all before the age of 15. Lisa said that there were enough resources in the box because the plants used very little: *'Have you had them at a window? Well, then they got light. They have air that is in there, 'cos it remains there. Then they have a little water and nourishment. A little disappears piece by piece.'*

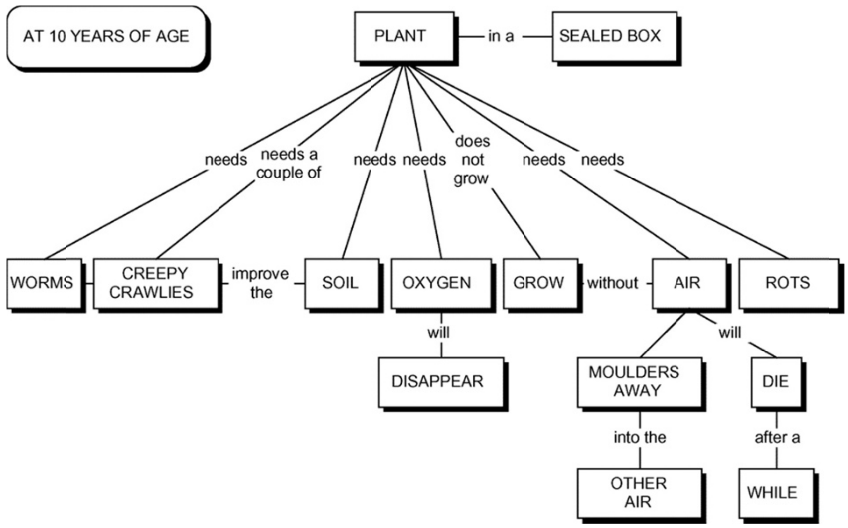

Figure 1. Concept map drawn from Oscar about conditions for life at 10 years of age.

Already at the very first interview with Oscar about conditions for life, he argued that the plants needed creepy crawlies in the soil. He expressed the same argument in the interviews at 11, 13 and 15 years of age (see figures 1–2). In fact this idea helped him to understand how the plants in the sealed box could get carbon dioxide, because Oscar found it difficult to explain from where the plants got the carbon dioxide. He had assimilated that concept to human expiration, probably as a result of teaching. But this could not be the full explanation in this case, as the plants were growing in a sealed box. Later in the interview, he offered the suggestion that carbon dioxide could come from the breathing of small animals in the soil. *'Perhaps somewhere from the soil. There are small animals that perhaps breathe so there will be carbon dioxide.'* An integrative reconciliation had occurred (see figure 2).

Tove, like the other six students in this category, preferred to use cycle explanations when she was asked about plants' possibilities to survive in the boxes as we can see in the following interview segments.

Tove at age 10: *'Water vapour comes from the moisture in the soil. The soil is wet and then it circulates.'*

Tove at age 11: *'They need light. Then they don't need more than the moisture that is in there. If it is sealed there will be a cycle and it goes round.'*

Tove at age 13: *'Well, we breathe out carbon dioxide. We breathe in oxygen and the plant breathes out oxygen to us. I don't understand but there must be a little cycle in there.'*

Tove at age 15: *'The water evaporates and then falls down. It is somehow a cycle. It is like the earth but in miniature.'*

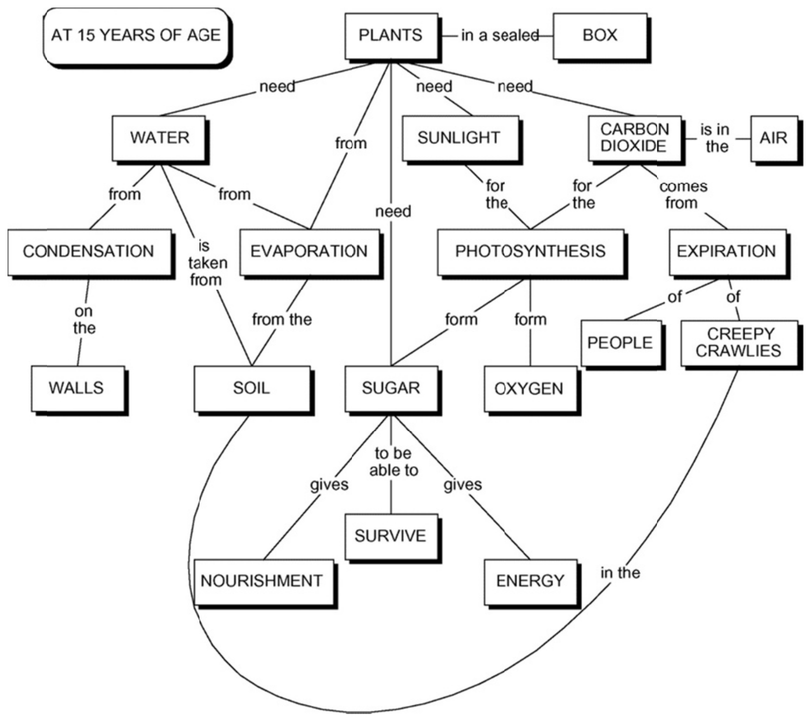

Figure 2. Concept map drawn from Oscar about conditions for life at 15 years of age.

THE STUDENTS' IDEAS ABOUT DECOMPOSITION

All the interviews about decomposition started with the question: "What do you think will happen to the leaves on the ground in the autumn?" Twenty-three students were interviewed about decomposition at age 9. Only one of them mentioned that an organism was involved in the decomposition. An analysis of the interviews at 11, 13 and 15 years of age showed that the 29 students' ideas about decomposition could be grouped into the following three categories: 1) Ideas that do not contain a description of organisms eating the leaves expressed during all three interviews; 2) Ideas about no organism eating at the age of 11 and with organisms involved in ideas at the age of 13 and 15; 3) Ideas about organisms being involved in the process that were expressed in all three interviews.

No Organisms Eating the Leaf

Six students described a process with no organisms involved in all the interviews. Instead, the students mentioned physical factors and age as causing the decomposition of the leaves. Stina described different ways of fragmentation at 11, 13 and 15 years of age. At 11 she described how the leaves were trampled into pieces, at 13 how creepy crawlies could bite them in pieces and at 15 how leaves withered into pieces. In other cases it is possible to identify a personal theme in the students' descriptions through the years. Emil described how the leaves crumbled into pieces and went into the soil during all the three interviews about the leaves on the ground. His idea seems to be very stable and resistant to change.

One boy that only participated in the interviews as a 9-year-old had an interesting answer to the interview question about the leaves on the ground. He explained that the leaves on the ground would become soil. After some seconds he added: *"Well the more there will be the bigger the planet will be."* He then described the consequence of his own statement that the leaves would be soil. He thought that the biomass was conserved as soil and not as a part of a cycle. The repeated defoliation year after year would result in more soil being formed. He could not see the gaseous state of decomposition where carbon dioxide and water leave the ground. The student explained what he could observe and thought that soil was the end point for the decomposition, and drew the conclusion that the planet Earth would grow bigger.

Anders also described the decomposition of the leaves on the ground as fragmentation without mentioning anything about organisms involved in the process. At 9 years of age he said*: 'Quite a lot of soil comes from leaves. Eggshells … Soil comes also from coffee grounds and sort of thing, rots and becomes soil.'* Anders always referred in some way to composting and described this process in a rather detailed way. Here are several segments of the interviews with Anders at 11, 13 and 15 years of age. There seem to be a powerful experience of composting that has influenced Anders' thinking about decomposition. But this experience does not help him to develop a deeper understanding of the decomposition process.

Anders at age 11:' *Well, they have dried. Then they haven't had enough water and then … You put many other things there. You can also put eggshells and so on the compost heap. And they stay there and rot in some way. It takes a long time it takes just about four years to get real and very nice soil. I think there's water and then it rots and then it becomes soil 'cos there is soil underneath that's been there for a long time. And I think it is mixed with that so there will be even more.'*

Anders at age 13*: 'Soil's made of mainly sticks and gravel and that sort of thing. Something else that can dry and become soil can be eggshells and the sort of things you put on the compost. That becomes soil.'*

Anders at age 15*: 'It is like composting. You have some soil on the bottom and then it stays there becoming smaller and smaller bits. It's the same with the leaves, that they are mixed up and then there'll be more and more of it. I don't think that there'll be soil but I think there will be small, small bits that is mixed up with the soil, then you say that it has become soil.'*

Towards a Process with Organisms Involved

As they approached ages 13 and 15, the nine students in this category began to explain how the leaves become soil after being eaten by organisms. At 11 years of age Linda and Ruth described how the leaves rot and become soil by sinking down into the soil. As 13 and 15-year-olds both described how the worm excrements became soil. They also described how the leaves could be soil by crumbling, without any influence from worms. Ralf and Gunnar described in the first interview how the leaves became soil by being torn to rags. At the age of 13 and 15 both of them adopted the idea that animals like worms and snails decomposed the leaves to soil.

While Gunnar and Ralf represent students that as 13- and 15-year-olds have broken with their earlier ideas, Hanna represents a completely different development. Instead of breaking with her earlier ideas she modified them and added new characteristics to the old ideas. At 9 years of age she said: *'Some of them sink down into the mud when it's raining. They dry out in some way and shrivel up. Then when they are completely dry, it is enough for it to rain just once more for them to become just small bit.'* If we compare this answer with the following interview segments, we can identify a theme through the years that concerns raining and drying. At 13 and 15 years of age Hanna included organism activity in her descriptions about decomposition of the leaves but still we can recognize the core idea from earlier years.

Hanna at age 11: *'I think they mould away. The will dry out ... then an animal is coming, trampling them and they become broken. It will become small, small pieces and then the real soil is pressing them down and they will be a lump and then it is raining and the sun is shining and it becomes soil.'*

Hanna at age 13: *'They dry out and perhaps it rains so that they become soft. Then they dry out again. Then in the end they become and animals start eating them. Then you get soil of it.'*

Hanna at age 15: *'It must be when it dries up. Then when it rains, it is mixed up with some mud. Then it dries and becomes soil. Or also some animals come and eat it. Their excrements will become soil'*

Four students described, as 11-year-olds, how animals participated in the processes by making holes, eating the leaves or pulling them down into the soil. It was however not clear that the biomass passed through the animals. As 13-year-olds they declared that the leaves became soil by animals eating the leaves and producing excrements.

Organisms Involved in the Decomposition

In this category, we find students' conceptions of organisms using the leaves as food described in all the three interviews. There was a tendency at the age of 11 and 13 for the students to start their descriptions by saying that the leaves rotted before they went on to describe the process. As 15-year-olds, the students were more willing to talk directly about the animals' activity.

Several students could describe an alternative to decomposition by organisms when they were asked. Mary mentioned every time that the leaves also could rot to soil by being dissolved. She belonged to a group of students that described nearly the same process on the different occasions. Their ideas could be built up round a special factor that caused the decomposition such as insects, water and aging. Such a factor seemed to be so strongly established that it controlled the students' explanations.

Four students at 15 years of age developed their ideas towards the conception of microorganisms causing the decomposition. Let us look at Oscar's development towards a more complete understanding. As a nine-year-old he said that the soil ate the leaves. At 11 he described how the leaves were fragmented by the animals to small pieces, which disappeared down into soil. He seemed to consider that matter of the leaves was conserved as soil: *"Small animals bite and eat the small pieces of it. Then it just disappears. Then the animals do a number two and it becomes soil."* At 13 years of age he also described the alternative that the leaf can be soil by lying and rot. At age 15 he understood that microorganisms took an active part in decomposition: *'Well they are lying there and sort of small animals come, microscopic creepy crawlies. And it will become soil 'cos it is organic material here.'* Later in the interview he explained how the organisms ate the leaves and how the leaves became soil.

In contrast to Oscar, Morgan had the same idea at 11 and 13 years of age that decomposition could take place if the leaf was just lying on the ground. At 11 he completed the basic idea with new knowledge about microscopic activity and with an anthropomorphic view of the process: *'Some of them can just lie and lie. They will be broken down by the nature, 'cos it is the nature itself that built it up. It is bacteria that have broken it down.'* At 15 he explained it by Protozoa, bacteria and worms eating it.

At age 15, Sven and Thomas described the process as a result of an activity of soil invertebrates, fungi and bacteria. Sven said that both a rich soil and a gas were the result of decomposition. He was the only one that described a gas concept when he explained the result of decomposition. At ages 11 and 13 Sven said that the leaves turned to soil by worms eating them or by moisture and rotting. The other students did not present the idea that matter is conserved in the context involving chemical change from solid (soil) to gaseous state (water and carbon dioxide). This was also found during a cross-cultural study about students' interpretation of the phenomenon of decay (Leach, Konicek & Shapiro, 1992).

THE STUDENTS' IDEAS ABOUT DEFOLIATION

The students often talked about different reasons for defoliation when they explained what happened to the leaves on the ground. Explanations of defoliation as a result of physical causation were more common during the earlier interviews. Many students mentioned the wind at the age of 11 and 13 but only two at age 15, when ideas about physical causation were replaced by ideas about lack of resources coming from inside, with nourishment as the most common resource mentioned. All the ten students that mentioned lack of resources at 11 had the same idea at 15 years of age while only seven of the nineteen that explained defoliation as a result of physical factors at 11 years of age had the same opinion at age 15.

There was a tendency during the earlier interviews to describe the leaves as individuals. This could possibly be the reason why many students used human characteristics to describe the defoliation. Several students changed from "leaf-centered" ideas at 11 and 13 to more 'tree-centered' ideas at 15 years of age. Morgan, Sofia and Sven presented explanations at the age of 15 that a biologist would accept. They also expressed 'tree-centered ideas' at age 11 and used anthropomorphic ideas as they developed their understanding. It seemed to be helpful for many students to use anthropomorphic reasoning in order to be able to describe the cause of defoliation. Seven students did not use such reasoning at any time during the interviews. Let us examine some segments from interviews with Oscar which can illustrate changes over time from 'leaf-centered' to 'tree-centered ideas. There is also a change from physical efforts to physiological needs that the students mentioned spontaneously.

Oscar at age 9: *'It doesn't get any water. Or it has no muscles left to be able to stay on the branch'*

Oscar at age 11*: 'They don't have the strength remain sitting there. They must jump off.'*

Oscar at age 13*: 'They fall at autumn and they want much sun. Well, perhaps the tree has not the strength to carry them any longer. It has enough to do getting nourishment themselves, and it drops the leaves.'*

Oscar at age 15: *'Well, it is ...... during winter the tree cannot give nourishment to the leaves and itself, so it drops the leaves. It closes the supply of nourishment to the tree, doesn't it? Then they die and drop.'*

Shortage of nourishment was mentioned as a cause of the defoliation by eight students at all the three interviews. Otherwise very different features in the interviews survived from the first interview to the other two. Very often there seemed to be a core idea in the first interview that can be recognized in the following interviews. It could be explanations about shortage of water, cold weather, blowing, aging or strength to hold on.

THE STUDENTS' IDEAS ABOUT THE ROLE OF THE FLOWER

27 students' were interviewed about the role of colour on flowers at 11, 13 and 15 years of age. The students' ideas can be described in terms of the following four categories: A. Anthropomorphic and human centred ideas; B. Ideas about plants getting protection and resources; C. Towards different ways of mixing pollination and seed dispersal; D. Towards a more or less complete description of pollination.

A. Anthropomorphic and Human Centred Ideas

Three students continued to use anthropomorphic and human-centred ideas during all the interviews compared with six students at the age of 11. Even at the age of 15, Ruth and Stina said that the purpose of the flowers' colours was to make them more discernible and beautiful. Anders had a more detailed description of his ideas which appears in the following segments from the interviews with him at 11, 13 and 15 years of age as an answer to the question why flowers are coloured:

Anders at age 11: *'I think the flowers have ... cos they have colours to make you think they are nice and want to have them indoors. It gives you something to embroider the table with when you have guests. Then the food on the table and then you embroider the table with some brightly coloured flowers.'*

Anders at age 13: *'I think there is a thought behind it just like we as human beings, that I want to look nice and that I don't want ... So if you know to put on something, just as human beings put on things. We comb our hair and so on. So I think they have nice colours so that people and others think they are nice. Just like we want other people to think that we..., that I look nice. That's what I think.'*

Anders at age 15: *'Well, actually I've wondered about that too, but I think it's like a human being, they need all this growing around them and the leaves. Life's a bit nicer and not so boring. It is like human beings. We live in our houses. We plant plants and have other things 'cos it makes it nicer. I think that ... what plays a big part for them to have a flower is that the leaves are not alone. The flower is company for them which makes it nicer for them to grow up. Perhaps it makes them stay on longer 'they're having a nice time.'*

B. Ideas about Plants Getting Protection and Resources

Ellen is one of the three students that are represented in this category. She launched the idea that the flower makes it possible for the plant to get nourishment from the wasp. But by age 13 she also had thoughts that the wasp could do something more. As a 15-year-old she did not say anything about insects.

C. Different Ways of Mixing up the Description of Pollination and Seed Dispersal

All the 12 students represented in this category described, at 15 years of age, how pollen or seeds were transported by insects and dropped down to the ground where a new plant would then grow. Only one of the students in this category talked, at 10 years of age, about insects having something to do with the colour of the flower. Six students expressed, as 11-year-olds, the idea that insects were attracted to flowers and could disperse pollen or seeds. One student said: *'There is something that fastens on them. Then they fly and drop a little of it and then it'll grow.'* Another student said at 13 years of age: *'Such insects come. And perhaps it is so ... , then it perhaps disperses such pollen. It disperses it so new will come.'* These quotations are typical for this category of ideas. The two processes, pollination and seed dispersal, appear to have similar features, that cause confusion for the students. Both the pollen and the seeds develop in a flower. The two concepts are also both involved in plant reproduction.

D. Towards a More or Less Complete Description of Pollination at the Age of 15

Already by the age of 10, six of the eleven students in this category expressed a description of how insects were attracted to flowers because of the colours and how the insects transported pollen from one flower to another. Four students described, at 11 and 13 years of age, how the plants attracted insects but mixed the two processes, pollination and dispersal of seeds. At 11 years of age, Oscar described human-centred and anthropomorphic ideas: *'In order to attract animals that can then suck nectar from inside there so that they can reproduce. Or perhaps they can boast to the other flowers and make themselves beautiful and so on in the same way as women powder themselves and so on. If you have them in a garden, perhaps you water them very much more cos they are so pretty.'* Some anthropomorphic features can also be identified in the interviews with him as a 13-year-old. There were no such features in his description at 15 years of age: *'It's in order to attract the wasps. And then they suck the nectar or something and so the stuff gets stuck, pollinin...... No, I don't know what it is called. Perhaps that is what it is called and then they take it with them and so it goes on to the next flower. The flower can't be fertilized from the same stamen there down in the seed, it must sort of change flowers. These stick to the wasp and are carried on and go down into the seed. And a new embryo is formed in there that falls out or when it withers, it stays there.'*

THE STUDENTS' VIEWS OF THE DEVELOPMENT OF THEIR UNDERSTANDING

About their Ideas

When the students as 15- and 19-year olds had listened to audiotapes of their earlier interviews which laid out for them the history of their thinking, they were asked to make comments on what they said in the interviews and why they said as they did especially concerning the personal themes. The students could in many cases identify personal contexts that continued to persist as themes in their thinking through the years. Nearly all the students appreciated what they had learnt at school about the ecological processes but still they referred to personal out-of-school experiences. They said that such experiences had been of great importance for the development of their understanding. It was possible to identify particular episodes in many of these students' early lives that had an ongoing influence on their explanations of ecological phenomena (Helldén & Solomon, 2004). Here follow some examples of the comments the students expressed after they had listened to the interviews with them.

When Sofia, as a 19-year-old, had listened to her earlier interviews and heard how she referred to the concept of dew in her explanations of conditions for life in the sealed transparent boxes, she claimed: *'It's from childhood. The dew has always fascinated me. It is unbelievable beautiful. There is nothing more beautiful than cobwebs with dew'.* She then described wonderful experiences of dew when she spent a couple of weeks every summer at a relative's summerhouse.

At age 19, Anders could trace back his explanations of decomposition to episodes in childhood. When Anders heard his descriptions on the tape recorder, he smiled and said: *'We had a neighbour who carried out composting in a special* *way. I liked to be there together with him. The man even put eggshells and coffee grounds on the compost. I remember the first time I was there. And he asked me to empty a bucket with coffee grounds and some eggshells on the compost heap. I was confused. I think I was 7 years old.'* The students often related their way of describing the ecological processes to concrete personal experiences that occurred between the ages of 5 and 10. A majority of the students claimed that early experiences have been of great importance for the development of their understanding.

Some students who had used anthropomorphic formulations at any earlier age found this to be a bit strange. Others expressed an appreciation of the way they explained the phenomena. When, aged 19, Anders had listened to the interviews with him at 11 and 15 years of age, he still preferred to describe the role of the flower in an anthropomorphic way when I asked him to make a comment on the earlier interviews with him: 'I think I have the same idea to day. A plant has a soul like us. The plant wants to have the feeling to look nice.'

Oscar clearly expressed anthropomorphic and human-centred ideas to explain the role of the flower and the defoliation in his first interviews. There is continuity in Oscar's accounts from anthropomorphic ideas towards more 'scientific' explanations at 15 years of age. At 19 years of age, after he had listened to earlier interviews with him, he claimed that the anthropomorphic features in his descriptions about defoliation and the role of the flower could be a result of his mother's way of explaining the phenomena to him. She often used anthropomorphic descriptions when explaining different phenomena. He said that he of course knew as a boy that the leaves did not have muscles. It was a way of explaining why the leaves fall down from the trees in autumn, and this resulted in anthropomorphic formulations which are possible to follow as a consistent theme year after year. Oscar used the anthropomorphic ideas as analogies rather than as explanations.

About their Learning

The students were also asked how they thought they had developed their understanding and what had been of greatest importance for this development. At 19 years of age, 12 of the 28 students only recognized a minor change in their understanding of ecological processes between 11 and 15 years of age after they had listened to the interviews with them. They did not correct the answers they gave four years earlier, rather they extended their explanations. Some of them were more aware of the way they talked about things than their understanding of the processes. Even if they did not recognize any change they often expressed positive feelings about learning like Hanna in the following sentence: *'Cos when you were a child you didn't understand that much but learnt still more. You didn't understand anything and were happy to learn.'*

Eleven students in the group expressed recognition of an obvious change in their understandings of the phenomena. Six students in this group had more of a descriptive than a reflective view of learning. They talked more about the addition of new facts than analyzing their thinking. Anders belongs to this group of students. He was fascinated by the recognition of how he described some details about decomposition in the same way as four years earlier: '*I said the same today. It is still several years later. You don't remember what you said and although it is somewhere in the back of your head.'* Although he found himself use the same expressions as four years earlier, he described a change in his thinking about the decomposition of leaves on the ground.

Five students were able to analyze and reflect on their earlier ideas. These students also articulated, as 15-year-olds, a more complete description of the ecological processes. They willingly discussed the reasons why they said as they did in earlier interviews and how they formulated their explanations. More or less, these students made comments on their earlier use of analogies between a plant's need and a human being's needs. Sofia made the following comment on her explanation as an 11-year-old: *'You can often compare them even if the seed hasn't any human thoughts. You can see yourself how you develop. The seed grows too. It's like … the seed grows and I grow.'*

The students in this group emphasized more than the other students the importance of building upon earlier experiences and knowledge. They described an active and constructivist view of the learning process. For them, learning could start with reading a book, listening to others and catching some words. A couple of them described how they caught ideas piece by piece and then put them together.

When the reflective students were asked to say something about the development of their ideas, they easily described thoughts about their personal development with both cognitive and emotional elements as in the following interview segment with Hanna at age 19. Learning has not only to do with thinking. Feeling also plays an important role in conceptual development. Hanna made the following comment when I asked her about the importance of learning in childhood: *'Of course, when you are a child, you are ready to make mistakes. You don't need any knowledge as reason for what you think and claim. The older you are the more weight you want to give in your arguments. All the time, the level of knowledge at is escalated and directs our thinking. When you are a child you dare to speculate. You also have fantasies today … but don't express the out loudly because you can be accused of being ignorant and careless. Children should be researchers because they are willing to come up with new ideas.'*

DISCUSSION

This long-term study describes the ways students developed their understanding of some ecological processes through the years. The interviews with the students showed that the development of the students' understanding depends on prior ideas and concepts. Therefore, the concept development is somewhat idiosyncratic in nature. There are, however, some features that are common to several students' explanations.

About the Ecological Processes

In order to explain what was going on with the plants in the sealed boxes, most students initially presented a 'use-up-model' which meant that the plant was the 'end-point' for the different resources present. This idea was strongly established and retained in some cases up to 15 years of age. It worked well as a way for the students to explain their observations, and was supported by everyday experiences. They had experienced how we water plants without being able to see how water leaves the plants. Some students thought that the plants would eventually die in the closed box environment, because of lack of water, air or oxygen.

When the 'water cycle' was introduced or brought up again, many students used the 'cycle model' to explain the movement of different resources. The 'cycle model' made the processes in the closed box meaningful to the students throughout the years up to the age of 15. They used the idea though the explanations they provided sometimes were incorrect.

An important change of the understanding of the decomposition process occurred when organism activity was assimilated to the students' thinking but for many students, soil was still an 'end-point' for decomposition. When the students assimilated the idea that activity of microorganisms was a part of the decomposition, the process assumed a completely new meaning. It was possible to understand that soil is not the end point of decomposition, but that water, carbon dioxide and minerals are the major end products of the decomposition process.

Reflecting on their Own Learning

When the students, as 15- and 19-year-olds, listened to earlier interviews with themselves, they showed a great interest in their earlier statements, a great ability to interpret what they said – why they said what they said, and to identify key life experiences that shaped their understandings. Most of the students were rather critical of what they said in the interviews and sometimes expressed astonishment over the poor development of their understanding. However, five of the 28 students demonstrated a more reflective, meta-cognitive view on the nature and development of their learning. When they heard what they said in the earlier interviews, they realised that, at that time, they had not possessed all of the language needed for a complete understanding. The students in this group often described their conceptual development as putting together something they had heard, read in a book, or experienced in another way. These reflective students felt that they owned their learning and viewed learning as a process involving active construction on the part of the learner. Johanna, Sven and Oscar belong to this group of students with a more reflective view about learning.

Johanna argued that she used words without knowing what they really meant. She described the development of her understanding in the following way: *'Initially, there are small pieces of puzzle that you put together. And you get a general picture that becomes more and more complete."* Sven characterised himself as an observer and listener when he was younger: *"I collected and absorbed facts uncritically. And that means that understanding came later.'*

At 19 years of age, Oscar claimed that the anthropomorphic features in his earlier descriptions of defoliation and the role of the flower could be attributed to the influence of adults' attempts to explain the phenomena to them. Some of the reflective students said, like Oscar, that they knew as children that plants did not have feelings or that leaves have muscles. The anthropomorphic features were a way of explaining why plants had colourful flowers and why the leaves fell down from the trees in autumn. These comments are in accordance with what Zohar and Ginossar (1998) argue, that anthropomorphic formulations enhance students' empathy toward scientific topics and help students to organise information along familiar lines. They seem to be just formulations, rather than beliefs; language resources students draw on to make sense of the phenomena. The 'reflective' students also showed a greater ability to use language as a tool to support their efforts to understand the phenomena and express their thoughts.

Other students demonstrated a limited ability to reflect on their learning. They recognized that their learning was influenced by their prior experiences but they described the change in their explanations through the years as a process of addition of information. Some students said that they knew more, simply as a result of being older. Others described a learning process by which new facts were fastened to their minds, but not in any way that it changed their thinking. Even if they recognized a change in explanations they gave at age 11 and 15, some students seemed to be unable to trace the change in their understanding to any identifiable experiences. They did not know why their understanding had changed, and they often gave the same explanation to the phenomena as they did four years earlier.

Through the long-term study of students' conceptualizations it was possible to identify personal contexts and continuity as recurrent themes in the students' explanations of the different phenomena. Even if the explanations changed through the years towards more or less complete explanations, it is possible in several cases to identify core ideas that can be followed by an analysis of the interviews with the same child from 9/10 to 15 years of age. These core ideas can be of structural nature, a way of explaining a phenomenon such as Tove's use of a cycle model to explain how the plants could get necessary resources or Oscar's use of anthropomorphic formulations to explain defoliation and the role of the flower. It has also been possible to identify individual themes that concern the content of the students' statements. Sofia always used the concept of dew as a part of her explanations. Anders talked, year after year, about eggshells when he explained composting. The students could, in many cases, trace back such features to experiences that they had made together with teachers, neighbours, playmates or family members. These features became parts of the students' personal biographies through which they saw the world. Even if the students appreciated what they had learnt, they often described concrete experiences outside school, often in the early years, that had contributed to their understanding.

Learning was situated in the sense that the student's learning was related to the context where she/he had made the experience, but what was learnt then became an integrated part of the learner's thinking. As in Hanna's and Sofia's case concerning their ideas about decomposition and the water cycle, many students did not replace one understanding with another one. Instead, they widened their ranges of ideas or increased their repertoires of ideas (Marton, 1998). However, a core idea that developed at an early age seems to have been an important unit in many students' repertoires of ideas. Even if there was a substantial conceptual development, there was also a very strong element of personal context and continuity in the students' thinking about the ecological processes.

CONCLUSIONS

This long-term study shows that early episodes in childhood in many cases seem to have an important influence on students' future learning about scientific phenomena. Therefore it might be successful to create episodes at school where important scientific concepts such as transpiration, evaporation and the role of oxygen and carbon dioxide might be introduced in the early ages at school through interesting experiences, facilitating the development of a deeper understanding later at school. In this study, the early introduction of a cycle concept as an advance organizer supported the students' later understanding of cycles in nature. In developing curriculum for the early ages I think we should trust more in the capacity of young children's ability to learn science concepts (Tytler, 2000).

There was a strong element of personal context and continuity in the development of the students' understanding through the years of the ecology study. When the students listened to what they said about the ecological phenomena in earlier interviews, they could often reveal particular events that they had experienced together with parents, playmates or other persons. These experiences were traced back to social situations, but had become a part of the students' personal context. The students had elements from their personal biographies through which they saw the world.

The students did not simply replace one understanding with another but widened their ranges of possible understandings. Long-term studies of science learning make an important contribution to the discussions about the nature of conceptual change and to the development of a more complete understanding of students' learning in science (Helldén & Tytler, 2008).

Learning science is a long and complex process. A study with a longitudinal design makes it possible to gain insights into students' individual learning. By following the same student over time, we can obtain a series of student's explanations of a phenomenon and characterize individual learning trajectories. If we know a student's conception at one point in time, it might be helpful to know more about the possible roots of such a conception, in order to improve teaching about the phenomenon. On the other hand, it would also be valuable to know where the same conception might lead in the future. Teachers at different levels and teacher students have expressed a great interest in discussing the roots and future development of their students' conceptions, after they have been involved in investigations of students' ideas about a scientific phenomenon. Studies of students' learning trajectories can result in suggestions from teachers about teaching strategies that could support students' learning.

One criticism of this type of study is that revisiting the same phenomenon regularly will tend to encourage similar responses from the students, and that themes may therefore be an artefact of the methodology. Students were usually surprised when they heard their responses from previous years, even going so far as to deny that they had ever said such things. This encourages me to conclude that students construct fresh responses and are not aware of previous explanations.

Experiences from this long-term study have shown that the unique opportunity to listen to previous interviews allowed the students to identify important precursors to their own understanding. Even though the students appreciated what they had learnt at school, they described experiences outside school, often in the early ages that had been of great importance for their future understanding. It is obvious that there is a great potential in utilizing students' reflections as they compare their own previous explanations with their current explanations. Such reflections would also support the students' abilities to learn how to learn science. It is also important to create an atmosphere in the classroom that allows students to communicate their conceptions and reflect over different ways of explaining a phenomenon.

In this six year longitudinal study about students' understanding about ecological processes students were interviewed indoors in a school sitting in front of a table with a closed terrarium, or with brown leaves and soil, or with a bunch of wild flowers. But now a new research project has been started with students studying conditions for life, growth and decomposition outdoors in a forest and in a stream ecosystem as part of biology teaching unit. This research project was started in order to study the development of students' ability to read nature. Reading nature has to do with the ability to recognise organisms and relate them to other organisms and to material cycling and energy flow in a habitat (Magntorn & Helldén, 2007a; 2997b).

In many Swedish families it has been a part of a cultural tradition to spend some time together in nature. And it is obvious that the students in the present study often referred to experiences in nature together with parents or other family members when they talked about ecological phenomena. These experiences were active observations of the natural world with a sense of curiosity and wonder that children naturally have (Carson, 1969). Several students said that such episodes were of great importance both for the development of their images of the processes in nature and for the development of their content knowledge.

In Sweden there is also a deeply-rooted tradition, especially in early childhood and primary education, to introduce children to studies in nature during recurring visits to different biotopes more or less in the neighbourhood of the school. During such excursions the children can follow the development of the environment through the seasons of the year, and there is room for observations including sensitivity, alertness and an awareness of different qualities of the world. In a study of students' early experiences of biodiversity several students referred to such experiences as important the development of their understanding (Helldén & Helldén, 2008). Because of an awareness of the importance of giving children as well as adults possibilities learn outdoor, a network of ninety more or less independent Nature Schools has grown up all over Sweden. They are mostly mobile units of a couple of persons that visit schools and support teachers in their efforts teach outdoor in nature.

In Sweden the purpose of excursions in nature also have to do with the notion that it is healthy for the children to spend some time outdoors. According to the syllabuses for compulsory school (7 – 16 years of age) in Sweden the subject of physical education and health is linked to well-established cultural traditions existing in Sweden concerning the enjoyment of nature. Through outdoor activities and experiencing nature, students gain awareness, knowledge and experiences which can stimulate a continuing interest both in outdoor life and in nature and environmental issues (Swedish National Agency for Education, 2009).

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6. VIDEO ANALYSIS AS A TOOL FOR UNDERSTANDING SCIENCE INSTRUCTION

ABSTRACT

Research on science instruction has revealed complex and nontrivial relations between instructional variables – including school system characteristics, teacher cognition and beliefs, teachers' and students' activities during instruction and last but not least, learning outcomes. To further investigate these relations, the development of respective models as well as appropriate research designs and methodologies are required. This will allow for tracing effects to the instructional level, shedding light on the well-known gap between teachers' demands and students' efforts as well as for the creation of interventions to overcome this gap. To this end, variables of teaching and learning have to be investigated using low- and high-inferent video analyses. Students' and teachers' behaviour holds valuable information for identifying cause-effect relations between what happens in the classroom and targeted outcomes. This provides the basis for describing what characterizes high quality instruction, which in turn can guide pre-service and in-service teacher training. A variety of instruments, including tests, questionnaires and interviews, is required to investigate variables of teaching and learning. Video analysis is a particularly essential tool within this undertaking as it captures students' and teachers' behaviours in the classroom in one package. This will allow complex models of relations between instructional variables to be tested, instructional quality to be enhanced and pre-service and in-service teacher education to be improved.

INTRODUCTION

One important goal of research on instruction is to identify characteristics that affect students' learning outcomes. As an example, socio-economic status (SES) was found to be an excellent predictor for students' mathematics achievement (Prenzel, 2004, p. 251). On average 16.8% of variance in students' mathematics achievement was found to be explained by SES across participating countries in the Programme for International Student Assessment (PISA). In Germany's case, SES accounted for an above-average variance in students' mathematics achievement at 21.1% (Prenzel, 2004, p. 275). However, as instruction itself was not investigated within PISA, little is known if and how different types of

Doris Jorde and Justin Dillon (Eds.), Science Education Research and Practice in Europe: Retrospective and Prospective, 115–139.

instruction influences learning in the classroom. To assess and to improve quality of instruction, instruction itself as a process must be the focus of research. Additionally, it still is necessary to consider other factors, such as SES, political, organizational or institutional conditions, as these may also influence instruction.

This is especially relevant when analysing effects of interventions. The effect of a new teaching method may, for example, be limited by a policymaker's decision to reduce the weekly number of science lessons given at school.

Investigation of instructional quality – that is, searching for a particular pattern of instructional variables and conditions influencing instruction that positively influences students' achievement – requires a model: A model of instructional quality that takes into account variables of teaching and learning in classrooms as well as normative standards and competences and the modalities of their development and assessment. E.g. Fischer et al. (2005) identified four levels of instruction as the basis for a systematic investigation of instruction in general and quality of instruction in particular:

- School system and school organization (e.g., school environment, funding)
- Individual conditions of the learner (e.g., pre-knowledge, motivation and interest, social background)
- Individual conditions of the teacher (e.g., professional knowledge, beliefs, motivation and interest)
- Surface- and deep structures of instruction (e.g., lesson phase, cognitive activation, student-teacher interactions)

This chapter will describe how video analysis of instruction together with investigations of conditions on the other three levels of instruction can guide research on instructional quality and help develop a multilevel model of instruction. Following a brief overview of research on instructional quality, this chapter will detail the research fundamentals as well as provide examples for applications of video analysis as a central investigative tool for instructional quality. The chapter will conclude with a discussion of how video analysis can be used in the development of multilevel models of instructional quality.

Quality of Instruction

Empirical educational research is driven by the aim to reveal what constitutes high quality instruction. Three major paradigms in instructional research can be distinguished: the personality paradigm, the process-product paradigm and the expert-novice paradigm. The personality paradigm focuses on the influence of the teacher's personality (e.g. friendliness) on students' learning (Getzels & Jackson, 1970). However, this approach turned out to not be very successful (Bromme, 1997). In contrast, the process-product paradigm yielded a vast number of studies that identified aspects of instruction such as the clarity of learning goals which correlate positively with output variables like students' achievement, interest and beliefs. These findings were consolidated in a series of meta-analyses that led to extensive lists of instructional characteristics with low to medium effects on instructional outcomes (e.g. Anderson, 1981; Anderson, 1983; Brophy & Good, 1986; Wang, Haertel, & Walberg, 1993). Although these lists shared common characteristics, they did not provide a consistent picture of what would characterize high quality instruction. Accordingly, several researchers have made attempts to synthesize the findings into a model of educational productivity (e.g. Fraser, Walberg, Welch, & Hattie, 1987; Walberg, 1981). Still, further research could not provide a clear picture of high quality instruction. It was instead demonstrated that the effect of particular characteristics such as teachers' behaviours was strongly dependent on the situation in the individual classroom (e.g. students' characteristics). These findings led researchers to more closely consider teachers' cognition in further work (Clark & Peterson, 1986; cf. Bromme, 2008).

Subsequent research integrated the process-product approach with the expert-novice paradigm. Some research focused in particular on teachers' professional knowledge (Shulman, 1987; Shulman, 1986) and its relation to individual beliefs (e.g. Peterson, Fennema, Carpenter, & Loef, 1989; Staub & Stern, 2002). Other research included the instructional process. For example, de Jong and van Driel (2004) investigated the relation of pedagogical content knowledge and teachers' activities in chemistry lessons and identified a positive effect of teachers' pedagogical content knowledge on teachers' activity. The relation between teachers' professional knowledge, instructional characteristics and learning outcomes was also investigated by Baumert et al. (2010) for mathematics instruction. The stronger consideration of teachers' cognition led to a refinement of earlier models of instructional quality, which now include individual characteristics of the protagonists of instruction (i.e. teachers and students), characteristics of the instructional process as well as characteristics of the school environment and system (e.g. Helmke, 2006; Lipowsky et al., 2005). A rather extensive model with respect to the amount of variables considered is the one suggested by Helmke (Helmke, 2006) shown in Figure 1. However, research has not been able to identify consistent patterns of high quality instruction based on these models.

In summary, extensive research exists on the determinants of instructional outcomes such as students' achievement. Numerous attempts have been made to systematize results of this research in order to obtain a theory or model of instructional quality. Such a theory or model has to integrate the various effects of instructional- and other related variables on learning outcomes and consider the complex interdepecies of these effects. It is important to note that learning outcomes in this context does not only include students' achievement, as critized by some researchers (e.g. Einsiedler, 1997; Oser, Dick, & Patry, 1992). Learning outcomes should also cover affective or behavioural aspects (cf. Walberg, 1981) like students' self-concepts, for example (cf. Peterson, Kauchak, & Yaakobi, 1980). It may also include societal aims such as less divergence within a class (cf. Duschl, 2008). However, despite the fact that models which include a variety of instructional and related variables and which incorporate a broader conception of learning outcomes have been developed, little is known about the complex interdepecies of the different effects of the included instructional and non-instructional variables on learning outcomes. This is where further research is needed.

Clausen (2000) stressed three critical points regarding the development of a theory or model for assessing instructional quality: selection of representative constructs (variables of theoretical models), formulation of hypothetical correlations (structure models), and the development of adequate indicators for operationalization (measuring models). Based on this framework, a suitable methodology is needed. This methodology would allow researchers to map the quality of instruction using the measuring models by applying indicators to describe the actual instruction and thus to assess the quality of lessons.

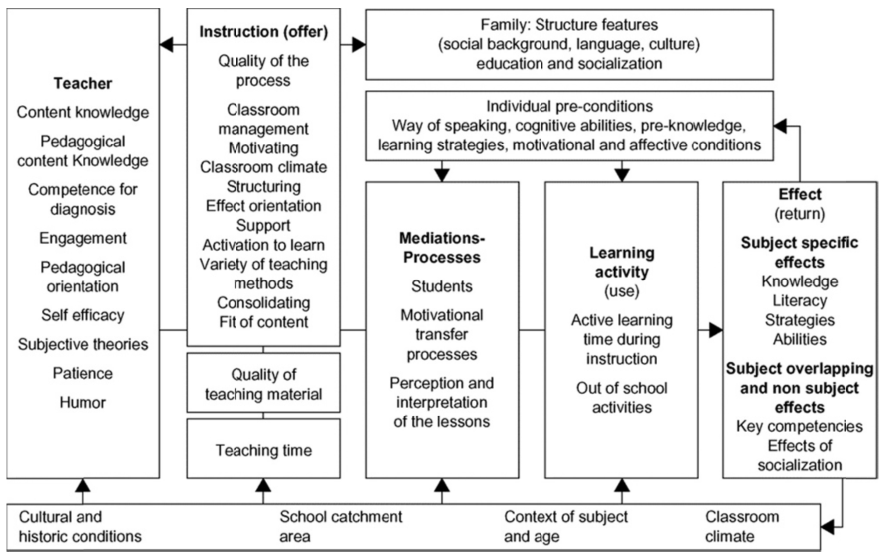

Figure 1: Offer-mediation-use paradigm (Helmke, 2006, translated by the authors).

VIDEO ANALYSIS

One promising method in the range of different methods to assess instructional quality is the method of video analysis. It has been used as a method to investigate instruction since the early 1980s (e.g. Erickson, 1982; Grimshaw, 1982). Since then, video technology has rapidly developed. At the same time, researchers have to this day continued to enhance procedures of recording and analysing classroom videos.

Recording Video Data

The starting point of all related research is the recording of classroom videos. This includes making decisions on the position of the camera in the classroom and training the camera people. Naturally these decisions have to be made based on the underlying theory or model. Even the location of the video camera in the classroom is a matter of the respective research question. Investigation of group work requires different camera locations than the investigation of teacher-student interactions. In addition, the quality of audio recordings is an important issue because verbalizations of teachers and students are mandatory for analysing video data with respect to the majority of research questions regarding science instruction. For the investigation of instruction, a recording arrangement based on the one developed for the TIMSS video study (Jacobs et al., 2003) has proven itself to be suitable. This arrangement includes two cameras and five wireless microphones (see Figure 2). One camera is the so-called action camera. Its role is to follow the action in the classroom. This might be the teacher writing on the blackboard or a student asking a question. The action camera has to be movable, which is best achieved by mounting it on a (stable) tripod. It is convenient although not mandatory to have the tripod be equipped with a remote control to allow the camera person to turn the camera and zoom in or out at the same time. The second camera is the so-called total camera. It provides a wide-shot recording of the whole classroom at all times, so for example, if the action camera is focused on the teacher writing on the blackboard, it is still possible to judge whether students are taking notes themselves. Regarding the audio recording, it is in principle possible to work with the microphones that are integrated into the video cameras. However, given the noise level in a typical classroom these microphones often fail to provide understandable recordings. Therefore, it is highly recommended to use at least directional microphones that can be bought as auxiliary equipment for most video cameras. An even more sophisticated arrangement includes a wireless microphone attached to the teacher as the main protagonist during instruction, three wireless microphones attached to the left and right as well as the rear wall of the classroom, and a fifth wireless microphone attached to one table so that audio can be recorded for at least one group in case the lesson includes a group work phase.

Once the actual arrangement of the recording equipment is decided upon, recording guidelines have to be specified to ensure that the video recordings of different classrooms are comparable to each other. In principal these guidelines aid the camera person operating the action camera in what to record during the lesson. However, these guidelines also have to include rules for a variety of situations that may or may not occur during instruction. This could include what the action camera will focus on during group work, for example. Will the camera follow the teacher while he or she is circling the classroom or will the camera focus on a group of students? What is to be recorded when the teacher addresses the whole class during a group work phase? After finalization of the recording guidelines, camera people have to be trained accordingly. This again is to ensure standardized and therefore comparable video recordings of different classrooms. Training of the camera people is mandatory to ensure familiarity with the recording guidelines but also with the recording equipment itself in order to avoid technical difficulties during the video recordings.

Once the training of the camera people is completed, data collection can start. Depending on conventions in the respective country or region the video recording takes place in, teachers and students may be informed or even instructed about how to behave during the video recording. Also, applicable laws such as the protection of data privacy have to be obeyed. In some cases this includes the collection of consent forms signed by parents or legal guardians or students themselves if they are of age.

Once the data collection is completed it needs to be ensured that the collected data are stored in a reliable and lasting way. This is especially important as most of the cameras use magnetic tapes or flash memory, the storage time of which is somewhat limited.

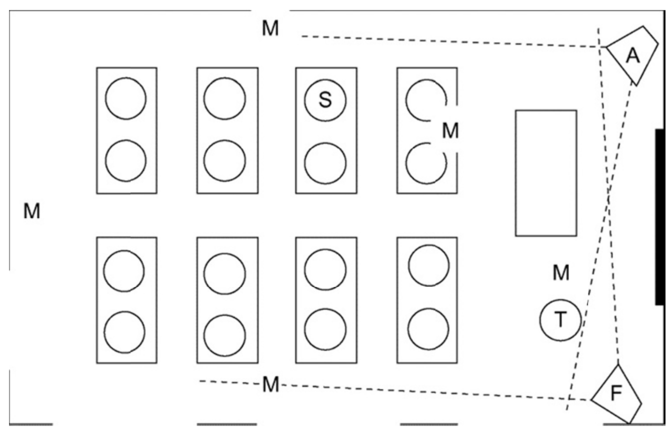

Figure 2: Sample arrangement of a classroom (M denotes the microphones, A the action camera, F the total or fixed camera, S the students and T the teacher).

Analysing Video Data

Video data can be considered as raw data, which once recorded, can be analysed based on different theoretical approaches and research questions. This option is limited only by the requirement that the collected data have to be suitable for an analysis with respect to the research question. It is, for example, not possible to reuse video data that were originally recorded with the aim of analysing the whole classroom to analyse small group processes because both approaches require different camera work. Still, video recordings are flexible data that are rich in detail. So the first step when analysing video data is to decide on the detail level of analysis, which is closely connected to the question of a qualitative or quantitative approach. In the second step, a coding procedure has to be developed and applied to the data. Finally, in the third step quality measures have to be determined.

Deciding on the principle approach Video analysis as such is a qualitative process, as a recorded situation has to be interpreted. However, the investigation of effects of instructional variables on instructional outcomes with the purpose of identifying high quality instruction will require quantification at some point. A common critique is that quantitative analysis alone can hardly grasp the reality of such complex situations as they occur in the classroom (cf. Turner & Meyer, 2000). As a consequence, some researchers exclusively rely on a qualitative approach to analyse video data. But what exactly is the difference between quantitative and qualitative research? *Qualitative* research approaches emerged in the social sciences to study complex and sometimes not very well known social and cultural phenomena. Examples of qualitative approaches would include action research, case studies or text interpretations. Qualitative data sources include observation and participant observation (fieldwork), interviews and (open) questionnaires, documents and texts, and researchers' impressions and reactions (Norman K. Denzin & Yvonna S. Lincoln, 2005). The quantitative research approach originally emerged in the natural sciences to study natural phenomena. Today, it has been further developed for use within the social sciences (including education). Examples of quantitative approaches would include experimental laboratory or quasi-experimental studies. Quantitative data sources include questionnaires and tests, but also interviews or text documents. Most importantly, however, quantitative research embraces a statistical approach to data analysis (cf. Kaplan, 2004).

In research on instructional quality both approaches can be helpful. The qualitative approach classifies elements of a situation using categories based on hypothetically assumed qualities and relations between categories to order the data systematically using certain theoretically based and empirically plausible criteria (Mayring, 2007). Quantitative analysis seeks to provide evidence on hypothesized numerical functions to describe the relations between variables, which represent the elements of a situation. The main features of the qualitative and the quantitative approaches as characterized by Treumann (1998) as well as Hardy and Bryman (2004) are presented in Table 1.

Table 1. Features of the Qualitative and the Quantitative Approaches

Dimensions	*Qualitative*	*Quantitative*
Perception (ontological assumption)	Dynamic	Static
Gaining knowledge (epistemological assumption)	Reconstructive	Rule based
Perspective	From inside	From outside
Focus	Holistic	Partial
Theory	Discovery	Confirmation
Conditions of inquiry	Field	Controlled, xperimental
Generating data	Subjective	Objective
Main type of data	Verbal	Numeric
Units of analysis	Cases	Statistical aggregates
Results	Valid, reliable	Reliable, valid

This comparison suggests that there is no sharp distinction between qualitative and quantitative approaches. Often sample size is taken as a criterion, but there are qualitative case studies as well as quantitative ones with large samples (e.g. Tashakkori & Teddlie, 1998). And as both research approaches can be used with video studies, combining the two approaches for added value in these studies seems promising.

The combination of different data in one study is called triangulation. According to Treumann (1998) triangulation is a strategy used to obtain a gain in knowledge by making use of different perspectives. Treumann (1998) differentiated five types of triangulation which are not necessarily independent from each other: data triangulation, design triangulation, interdisciplinary triangulation, theoretical triangulation and triangulation of methods. A specific version of triangulation of methods, which is also called triangulation between methods, refers to the combination of qualitative and quantitative data (Berg, 2004). Triangulation of methods demands for a common theoretical model for both types of data. Triangulation is difficult to apply for open procedures like the objective hermeneutics described by Oevermann, Allert, Konau, and Krambeck (1979) or the implementation of grounded theory like that of Glaser (1992) or Strauss and Corbin (1998). Thus, qualitative and quantitative data can complement each other by using quantitative results to anchor qualitative ones. However, as video analysis as such is a qualitative process, a procedure is needed to allow for quantifying the interpretations.

Obtaining quantitative data from video analysis requires exact rules on how to observe, secure and categorize the observable features – based on the respective theory or model. This set of rules must be applied to the observation material to obtain quantitative data. This process is called coding. The development of a so-called coding procedure is detailed in the next section.

Developing a Coding Procedure

As discussed above, video analysis is a qualitative process. Even if a quantitative approach is taken, there is an initial qualitative step: the development of a category system. Mayring (1995) emphasizes the importance of this initial step. If the category system is not developed with the greatest care, it renders the obtained quantitative data meaningless. Based on the theory of content analysis, Mayring (2007) differentiates between two approaches to obtain a category system: an inductive and a deductive approach. Whereas the inductive approach is of particular importance for qualitative content analysis, a deductive, theory-guided process is more appropriate for video analysis of instruction. This is because an inductive approach will allow for only a strictly qualitative analysis. A deductive approach on the other hand will allow for either a qualitative or a quantitative analysis as well as a combination of the two. A deductive approach always starts from theory. Based on theoretical considerations and the exact research questions and hypotheses, principal decisions have to be made. Following these decisions a category system is developed and refined until sufficient quality can be established. The amalgam of fundamental decisions combined with the category system is considered the coding procedure.

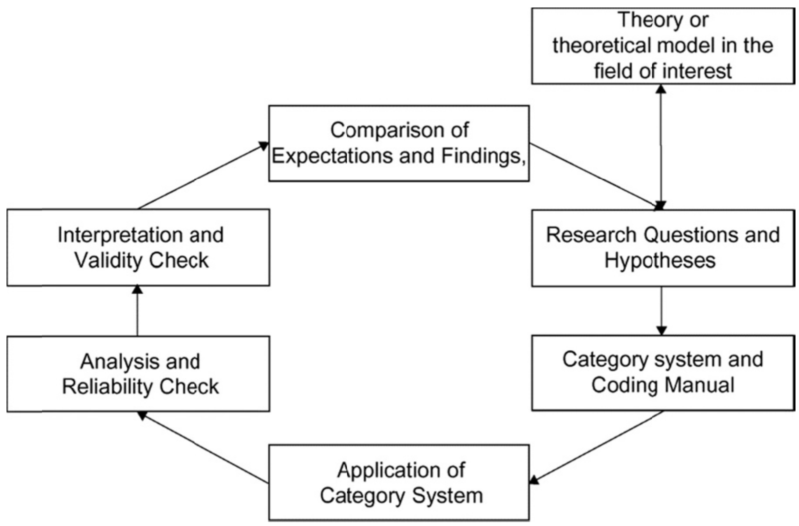

Figure 3. Overview of the video coding procedure.

Based on Jacobs, Kawanaka and Stigler (1999) the process of developing a coding procedure may be described as follows (Figure 3):

1. A theory or theoretical models needs to be identified or developed in the field of interest.
2. Based on the theory or model, research questions and hypotheses should be formulated. Depending on the research questions and respective hypotheses, principle decisions have to be made. This would include, for example, principle decisions about the segmentation of data or further processing of data such as transcriptions of the video recordings. In the case of an analysis of teacher-student dialogs, the raw recorded data would, for example, be segmented into turns (e.g. teacher speaking or student speaking). And as for analyzing time on tasks, segmenting the recording into intervals (e.g. deciding every thirty seconds whether students are on or off task) would be reasonable. A transcript can also be helpful especially when a decision in favour segmenting data into turns is made. In the case of the investigation of teachers-student dialogs, for example, it is easier to identify individual turns. Transcription also requires clear and precise rules as activities of interest, such as gestures and facial expressions, as well as affective expressions, everyday language or dialect would have to be carefully considered during transcription. Examples of rules for transcription are given by Mayring (Mayring, 2007, p. 49). Once the material is prepared accordingly, the development of the category system itself can begin.
3. Development of the category system begins by identifying the theoretical constructs of relevance and operationalizing the constructs into categories. A

construct may be represented by one or more categories. The construct 'teacher use of media' for example may be represented by the categories 'blackboard', 'daylight projector' or 'textbook'. Each of the categories comes with a series of indicators that provide guidance as to whether the respective category should be coded. An example of an indicator could be 'the teacher writes or draws on the blackboard' or 'the teacher asks students to open their textbooks'. The key here is that the indicators have to characterize the related category as precisely and completely as possible – using a potentially extensive collection of examples. Once categories and indicators are found, a coding manual should be written, thoroughly describing categories and indicators. Figure 4 shows an excerpt from such a coding manual.

4. With the coding manual at hand, this initial version of the category system is applied to real data in order to test its practicability and determine quality measures. As this step is still part of the development of the coding procedure and with the quality of the procedure not yet determined, the data used should not be the same data used to test the hypotheses and provide evidence regarding the research questions. However, this so-called test data should be as similar as possible to the original data. The use of an adequate computer program is indispensable in this step (for an example of a suitable program see Seidel, Prenzel, & Kobarg, 2005).
5. In the next step, the data obtained from the coding is analysed. In this step, investigation of the reliability of the coding is of central importance.
6. In addition to analysing the data and determining validity, the data need to be interpreted and the validity of the interpretation needs to be ensured.
7. In the final step, the findings, and in particular, the quality measures need to be carefully examined with respect to the formulated research questions and hypotheses and particularly to the expectations regarding quality measures. If the quality measures do not meet the requirements, that is, reliability remains unsatisfactorily low and validity cannot be established, the coding procedure needs to be refined in a new iteration of the described sequence of steps. A detailed desciption of quality measures is discussed in the next section. It should be emphasized that developing a coding procedure is an intense and demanding process, but for a sound video analysis, it is a mandatory step.

Category/Value	Definition	Description/Indicators	Examples	Differentiation
No Instruction/ Interruption	Refers to sequences in which no instruction takes place. Instruction already took place before and continued later.	The Interruption usually is marked by non-teaching and non-learning activity. Typically such Interruptions take longer than a coding interval.	External event or disruption like an-nouncements or door knocking. Teacher leaves class-room, students remain with-out instructions. Clarification of formal or organizational matter.	Noise or disciplinary problems do not generally count as interruption; the action must be different from what usually happens during instruction.
Pre-Instruction	All intervals are coded in which instruction does not yet take place. The amount of pre-instruction intervals is an indicator for how much time was actually used for instruction.	Teacher did not yet start with instruction. At the most teacher and students prepare for instruction.	Students arrive at the classroom after the bell, unpack their books, wait for the teacher.	Separation from Instruction, Pre-Instruction is coded, until the teacher starts instruction.
Instruction	All intervals are coded in which instruction takes place. The amount of coded intervals is an indicator for how much time was actually used for instruction (time on task).	No specific description: Instruction takes place. Important: All other coding refers only to intervals coded as instruction.	Teacher indicating the beginning of instruction: "Lets start now". Students stand up at the beginning of the lesson.	Mind connection with pre-Instruction and post-Instruction. Instruction only takes place one time and is embraced by pre-instruction and post-instruction phases.

Figure 4. Examples of a category system describing instruction phases on the surface level.

Assessing quality measures To assess the quality of the coding procedure, respective quality criteria have to be assessed. Such criteria have, for example, been suggested by the American Educational Research Association, the American Psychological Association and the National Council on Measurement in Education (2004). These criteria relate to reliability and validity of measurement. That is, in measurement it needs to be ensured that the measurement is consistent across different situations and over time. In addition, it needs to be ensured that what is actually measured is what was, in fact, intended to be measured. These criteria must also be applied to video analysis - the coding of video data has to be evaluated regarding reliability and validity. How these criteria can be applied to the coding of data has already been discussed by Krippendorf (1980) in the context of content analysis (see Figure 5).

Although reliability, in the context of video analysis, is more often the focus, validity is just as important a quality criterion. There exist different theories of validity (cf. American Psychological Association, 51 or Messick, 1989). Krippendorf (1980) differentiates material, results and process-oriented validity. Material-oriented validity includes the adequateness of categories and indicators (semantic validity) and correct sampling of the units of investigation, such as correct data segmentation (sample validity). Results-oriented validity includes the correlation with another measurement of the same constructs or the prediction of classroom observation or field notes (correlative validity) or the ability of the data to predict another measure, such as students' achievement (prognostic validity). Process-oriented validity relates to previous success with similar constructs, models or theories and respective interpretations (Titscher & Jenner, 2000). In qualitative research, validity is often tied to the following demands: (a) enough evidence, (b) an adequate variety in kinds of evidence, (c) constant interpretive status of evidence, (d) empirical measure of evidence and (e) selection of cases adequate to theory (Erickson, 1986).

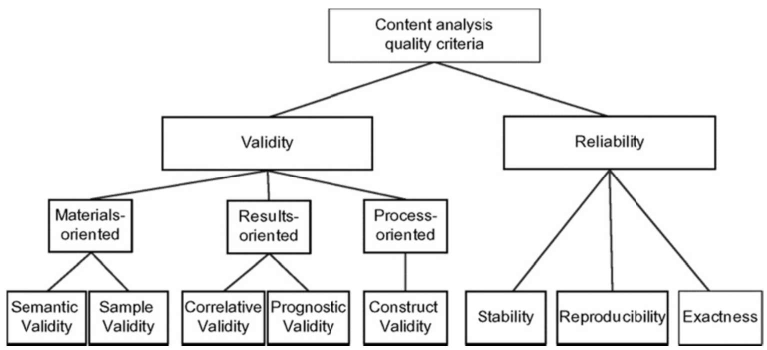

Figure 5. Quality criteria of content analysis (Krippendorf, 1980).

Reliability incorporates the stability of the results when the measurement is repeated (stability), replicability of the results when the coding procedure is applied by a different coder (replicability) and the extent to which the analysis meets a particular functional standard (Mayring, 1995, p. 109). Reliability of the coding procedure depends not only on the size of the sample and its quality but also on the actual coders. They may be considered as the measuring device of the analysis. In the context of video analysis, reliability is usually determined by means of intercoder reliability. To determine intercoder reliability, selected video material has to be coded independently by different coders following the (same) coding procedure. The different codings are compared on a per-unit-of-analysis basis. Different measures may be used to determine reliability. The simplest measure to determine is the percentage of agreement *p*. However, whereas the percentage of agreement *p* is quick to calculate, it unfortunately does not consider random agreements. More sophisticated measures, which are corrected for random agreement, include Cohen's Κ which is suitable in the case of nominal data or Goodman-Kruskal's γ in the case of ordinal data (Goodman & Kruskal, 1979).

However, there are no agreed upon cut-off values that have to be met by the above measures in order to consider intercoder reliability sufficient. Instead, the criterion for sufficient reliability depends on how much interpretation is involved in the coding, that is the level of inference inherent to a particular category. According to Gage (1969) low and high inferent categories may be differentiated. Low-inferent categories relate to directly observable characteristics whereas high-inferent categories relate to categories that require a particular amount of interpretation (see Table 3).

Table 3. Examples of Low- and High-inferent Categories

Surface Structure (Low-inferent coding)	*Deep Structure (High-inferent coding)*
Teacher's behaviour, actions, media Students' behaviour, actions, media Teacher-student interactions ...	Teacher's aims and intentions Teacher's instructional design and methods Students' mental operations and content operations Students' learning path Student-teacher and student-student Interactions Use of language ....

High inference entails a higher influence of a coder's knowledge, expectations and beliefs on the coding. High inference is therefore tied to lower intercoder reliability. For example, when coding the addressee(s) of a teacher's communication, three mutually exclusive categories of addressees may be differentiated: 'individual', 'group' or 'class'. These categories are high-inferent, as asking one student in front of the class does not necessarily indicate communication is directed to one individual only. The appeal, 'Listen please,' which is said in front of the whole class, may be directed towards a smaller group of students. It is important that as many indicators for a given category are formulated as precisely as possible to increase reliability of the coding. Still, compared to low inferent codings, high inference does lead to a lower reliability. Therefore, different cut-off values are needed to determine whether the coding is sufficiently reliable. Table 4 provides an overview of cut-off values depending on the inference of the coding (cf. Reyer, 2005).

Table 4. Reliability Classification

Types	*Value range of Cohen's kappa*				
Fine low-inferent coding:	0.750	$\leq$	κ	$\leq$	1.000
Fine high-inferent coding:	0.600	$\leq$	κ	$\leq$	0.749
Poor high-inferent coding:	0.400	$\leq$	κ	$\leq$	0.599
Non-acceptable coding:	0.000	$\leq$	κ	$\leq$	0.399

Repeated measurement of intercoder reliability during longer periods of the video analysis may help in identifying changes to improve the stability of the coding or rating process. As a rule of thumb, 10% of all data should be coded independently by at least two different coders. Intercoder reliability provides information of the quality of the coding procedure, including quality of video and audio recordings, categories and indicators as well as training of the coders. As a consequence, these sources have to be considered when the coding turns out to be insufficiently reliable.

APPLICATIONS OF VIDEO ANALYSIS

Video analysis can be utilized in many areas of research to obtain empirical evidence: in case studies to investigate learning processes, in experimental studies to check implementation of the treatment, in field studies to describe characteristics of interest. However video analysis may not only be used as a research method but also as a tool in teacher education or even for teachers to critically reflect upon their own behaviour. In the following sections, two applications of video analysis will be discussed in greater detail in order to point out its power.

Critical Reflection

It is an on-going challenge for teachers and teacher educators to improve their teaching. According to Lederman and Latz (1995), a thoughtful planning of instruction, constant monitoring during instruction and a thorough reflection afterwards are a core requirement for constant improvement. Schön (1987) also emphasizes the importance of critical reflection for the change of teachers' behaviour. To engage teachers in reflection – that is, the development of alternative views of the classroom – a framework of their professional growth (e.g. Clarke & Hollingsworth, 2002) and a respective stimulus is needed. This stimulus should not only initiate reflection about teachers' behaviour, but also challenge their beliefs. Video analysis can create and offer the cognitive and emotional conflict required to change teachers' beliefs. According to McCurry (2000), video recordings can also be used as a tool for behavioural training in micro-teaching. Video recordings of classroom teaching allow for a gradual, rich and targeted reflection and opportunities to discuss teaching practices (e.g. Ennis, 1993). Moreover, video recordings of lessons can also provide a rich view of classroom interaction, providing a further opportunity for self-reflection. Wackermann, Fischer and Trendel (2010) utilized video analysis as a tool in a theory-oriented teacher education program. Based on a video analysis of teachers' lessons, teachers were coached in order to better plan students' learning processes. Evaluation of the program suggested that teachers' planning of the learning processes could be improved considerably, which also led to better student outcomes (cf. Wackermann et al., 2010).

In summary, video analysis can be a valuable tool for teachers to critically self-reflect on their teaching practices. However, it cannot be expected that teachers develop their own coding procedures, as this would be the business of science education researchers. Teachers then may use these coding procedures to reflect on their own lessons and to obtain insight on how to improve their teaching. Based on the findings of research on instructional quality, such a reflection could focus on the following questions:

- Do the learning goals become clear?
- Does the structure of the lesson follow the lesson plan?
- Are students cognitively activated?

- Is the sequence of tasks used to structure the lesson adequate with respect to the development of students' learning processes?
- Does the learning climate in the classroom foster learning?

The main issue, however, is that utilizing video analysis for self-reflection is related to reliability and validity. It is important to note that even if reliability and validity have been established during the development of the coding procedure, these criteria would have to be carefully considered for the interaction of the coder (i.e. the teacher) and the coding procedure again. And even if the interpretation of one's own lessons is something very personal, a valid and reliable self-reflection can best be achieved in a team with other teachers. This way, teachers can critically reflect whether their teaching meets the quality criteria identified by research and then improve their teaching where necessary.

Science and Mathematics Instruction

Large-scale assessments such as the Third International Mathematics and Science Study (TIMSS) or the PISA study revealed particular differences in students' achievement – learning outcomes in particular (e.g. Organisation for Economic Co-operation and Development, 2007). However, these studies do not provide evidence of what instructional processes might be held responsible for the differences in students' achievement. For this reason, several field studies have been carried out within the scope of or accompanying large-scale assessments in order to identify high quality classroom practice. In the scope of the so-called TIMSS Video Study, a total of 231 mathematics lessons from Germany, Japan and the United States were videotaped and analysed (Stigler & Hiebert, 1997). To allow for a comparison of the videotapes from different countries, the same procedure was followed in each country: schools and then classes were randomly selected to be representative of eighth-grade mathematics instruction in the respective country. Videos were recorded at different points within the course of the school year to capture the whole range of topics and activities that may take place (Stigler, Gonzales, Kawanaka, Knoll, & Serrano, 1999). Analysis covered the lessons' content and the teachers' aims as well as teachers' and students' manual and verbal activities and the material used. The comparisons provided evidence that there are particular differences between lessons from different teachers. However, the differences between teachers in one country were small compared to the differences between teachers from other countries. That is, in each country a particular pattern of instruction, or a cultural script, exists (Stigler et al., 1999). These results could in general be confirmed by the 1999 iteration of TIMSS Video Study (Hiebert, 2003). The countries in which instruction was videotaped were extended to seven countries and regions: Australia, the Czech Republic, Hong Kong, Japan, the Netherlands, Switzerland and the United States. Altogether data from 638 eighth-grade lessons were collected. Japanese lessons, however, were not videotaped but reanalysed from videotapes of the lessons recorded in part of an earlier study. Hiebert et al. (2003) identified the similarities and differences across the countries with respect to mathematics instruction. But these particular differences could not be related to the differences in student performance across the countries. Within the 1999 iteration of TIMSS, science instruction was videotaped and analysed as well. In five countries – Australia, the Czech Republic, Japan, the Netherlands and the United States – altogether 439 eighth-grade science lessons were videotaped (Roth et al., 2006). Based on a framework developed from research on instructional characteristics, Roth et al. (2006) found that all participating countries besides the United States shared two common characteristics: high content standards and a content-focused instructional approach. High content standards embody different characteristics, such as the density and challenge of content ideas or students being held responsible for their own independent learning. However, these particular differences could not explain the differences among the high achieving countries.

In an effort to further illuminate the complex matter of science instruction, a video study was undertaken by the Institut für die Pädagogik der Naturwissenschaften (IPN) in Kiel, Germany. The scope of this video study of physics instruction was to investigate teaching and learning processes (Seidel et al., 2007). This study investigated teaching and learning processes by taking into account the "complex mediating process from instructional activities to student learning" (Seidel, Rimmele, & Prenzel, 2005, p. 552). Fifty classes from four German states were videotaped and analysed based on a complex theoretical framework with a multi-trait-multi-method approach. The guidelines and procedures developed in scope of the TIMSS Video Study were further developed and elaborated in greater detail for that purpose (Seidel & Prenzel, 2005). In general, the findings were in line with those from the TIMSS Video Study. A more in-depth analysis, however, provided empirical evidence for several cause-effect relations. First, goal clarity and coherence have a positive influence on students' perceptions of supportive learning conditions. Second, interactions in class work were found to be related to motivational affective development (Seidel et al., 2005). Third, students perceived themselves as being more self-determined and motivated in classrooms with high quality classroom discourse (Seidel, Rimmele, & Prenzel, 2003), that is, high cognitive activation.

Another bi-national video study was carried out in the scope of a Swiss German cooperation project "Instructional quality and mathematical understanding in different cultures" (Rakoczy et al., 2007). On the basis of a so-called opportunity-to-learn model of instruction (see Figure 6), mathematics instruction of a total of 40 classes in Germany and Switzerland were video analysed. This time, three lessons (not just one lesson) were videotaped and analysed per teacher or class respectively. Again results confirmed the existence of instructional patterns. A more detailed and systematic analysis identified three patterns (Hugener et al., 2009) of how problems are solved in mathematics classrooms. However, Hugener et al. (2009) concluded that superficial analyses of instruction are not enough to explain the differences in student performance and that a more in-depth view of instruction might provide evidence of cause-effect relations. This was achieved by analyses of the same data set. These analyses revealed that classroom management and cognitive activation in classrooms positively influence students' performance (cf. Lipowsky et al., 2009).

In addition to large-scale or cross-national video studies, a variety of smaller video studies investigated specific details of instruction – using qualitative and quantitative approaches. For example, Mortimer and Scott (Mortimer & Scott, 2003) investigated communication patterns of teachers and students in classroom. Others investigated how students' argumentation relates to their scientific knowledge (von Aufschnaiter, Erduran, Osborne, & Simon, 2008).

In summary, it can be concluded that video analysis has proven to be a valuable tool to investigate instruction in the large scale as well as on the level of individual teachers. Video analysis allows for identification of country-specific patterns of instruction, so-called cultural scripts. It also enables identifying cause-effect relations in different teaching-learning scenarios and allows for in-depth analyses of instructional processes. Given the aforementioned large-scale video studies, building on increasingly refined models of instructional quality, on the one hand, and the sheer number of smaller video studies on the other, it seems promising to establish a connection between these two kinds of research within the same field of video analysis. Theory-based video analysis integrating quantitative and qualitative approaches may achieve this.

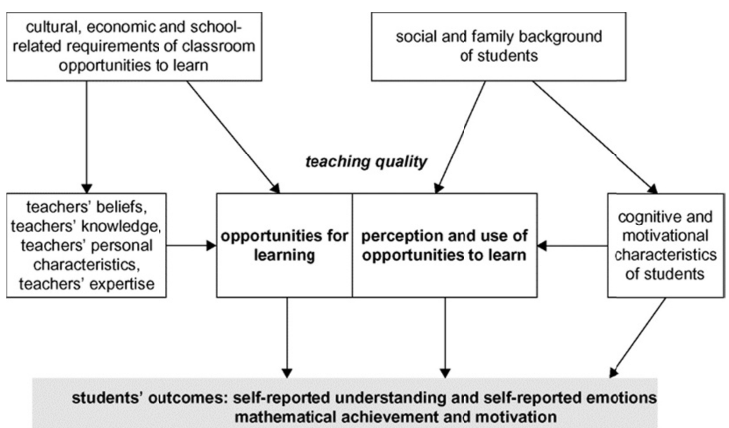

Figure 6. An opportunity-to-learn model of instruction (Lipowsky et al., 2005).

TOWARDS A MULTILEVEL MODEL OF INSTRUCTION

In the analysis of teaching and learning activities in the science classroom, video analysis is an indispensable tool (see also von Aufschnaiter & Welzel, 2001). Nevertheless, the quality of the findings are limited to the quality of the inference processes that take place when analysing video data, as discussed earlier. Video analysis is restricted to a particular perspective, that of the observers. To overcome this limitation, other perspectives need to be included into the analysis. For one, this means taking a multi-method approach to investigate the variables of interest. Data obtained from different instruments can mutually support one another. Also, it is important to consider as many variables that may be potentially relevant in case of the cause-effect-relation at the centre of interest. It is important to note, however, that it is never possible to consider *all* relevant variables. Science instruction is a complex system that requires a respective framework when seeking to describe what characterizes high quality instruction. However, the variables that find their way into the model are not necessarily on the same level. Some of these variables relate to individual characteristics of the learners, like their knowledge or motivation, while other characteristics are specific to a class of learners – the teacher, for example. And still other variables are specific to schools or whole countries, creating even more complex interactions. While some teachers might be better in teaching high achievers, for example, others might make all their students learn something in the same way. To create sound patterns of cause-effect-relations, statistical models that take the multi-level, hierarchical structure of the data into account are required when investigating instructional quality.

Until the late 1980s, a major problem of research on instruction was the lack of adequate theoretical and statistical descriptions of the different levels of analysis. No methodology was available to combine the different levels of instruction: the system level, the classroom level and the individual level. Simple correlations missed out mediating or moderating influences of other variables, and linear models disregarded the particular influence of variables on different levels.

Nowadays, relations between variables on different levels can be analysed by using Hierarchical Linear Models (HLM) or Structural Equation Models (SEM). It is important to note, however, that these methods require a sound theoretical model describing the relevant relations between the variables included in the model. This number is constrained by sample size. The more variables considered on different levels of instruction, the larger the sample required to test the underlying model. Although required sample sizes is a topic of argument, $N = 50$ is suggested as the minimum sample size on the aggregation level (Maas & Hox, 2004). That is, at least 50 classes would be needed when investigating models of instructional quality, for example. Backhaus et al. (2006) and Hair et al. (2006) demanded sample sizes of $N > 100$ or $N = 1.5\ p \cdot (p+1)$ (p = number of manifest variables) for SEM. A general overview on methods and theory is provided by Hox (2002) as well as Snijders and Bosker (1999).

Multilevel methods of analysis have been used in (science) education research for some time. Wong, Young, and Fraser (1997) for example used HLM to identify positive associations between the nature of the chemistry laboratory classroom environment and the students' attitudinal outcomes in Singapore. Based on data from a National Assessment of Educational Progress, Lubienski and Lubienski (2006) found using HLM that the advantage of private school students regarding performance vanished in favour of students' demographics. De Wever, Van Keer, Schellens, and Valcke (2007) focused on asynchronous discussion group transcripts and the impact of role assignments on the level of knowledge construction as reflected in students' contributions to computer-supported collaborative learning. Using multilevel modelling to handle interdependencies between the levels and hierarchical nesting problems, De Wever et al. (2007) found that students' summarizing and focusing on theory leads to significantly higher levels of knowledge construction. In an analysis of 6,150 mathematics and science teachers in 681 junior high schools, Chao and Jen (2007) examined the effect of policy on in-service teacher training on technology-integrated instruction. Multilevel logistic regression was performed and the results were related to the individual and the institutional level. At the individual level, the use of technology-integrated instruction was clearly related to in-service teacher training; and also at the school level, success of schools participating in the training program could be demonstrated. Also using multilevel analysis, Yip, Tsang, and Cheung (2003) compared students of 100 schools in Hong Kong at four different age levels to find relations between academic aptitude and science achievement. They were able to show a synchronic development of academic aptitude and science achievement and negative correlations between science achievement and the use of English to teach science. By differentiating the effects of different variables on science achievement, they found a baseline model for comparing the degree of improvement of students' science achievement in schools adopting either Chinese or English as the language of instruction. Investigating the effects of the academic self-concept and the learning environment on science and mathematics achievement in Australia, Young (1997) found differences between rural and urban high schools. It is remarkable that background effects explained a large amount of variance in the classroom, but little was found to explain student achievement at the school or classroom level of analysis. Most variation in science and mathematics achievement was found at the individual level and not at the instruction level due to missing instruments for describing classroom activities. The development of gender differences in mathematics achievement was analyzed in a longitudinal study by Xiaoxia (2002) correlating achievement with many personal variables like attitude towards mathematics, self-esteem, parents' academic encouragement, mathematics learning, teachers' expectations, peer influence and so forth. The effects did not follow the same direction. Whereas the effect mathematics attitudes had on achievement was stronger for boys than for girls, the mathematics teachers' encouragement varied across schools for boys, but no such effects were found for girls. Krauss et al. (2008) investigated effects of teacher's professional knowledge and its effect on students' achievement in mathematics. Referring to Shulman (1986) the study differentiated pedagogical content knowledge (PCK) and content knowledge (CK). About 200 German mathematics teachers teaching grade 10 students were tested by means of a PCK and a CK test, and the effect of teachers' PCK and CK on students' mathematics achievement was analysed using structural equation models. Krauss et al.'s model could be confirmed, thus showing that it was possible to clearly distinguish between PCK and CK but with a high correlation between both types of professional knowledge. The connectedness of both types of professional knowledge increased with teachers' expertise and ended up merging into one body of knowledge. However, in all the studies described, no direct relation to teaching and learning processes can be established because instruction itself was not analysed. Here, video analyses of instruction could have added additional significance to the findings.

CONCLUSION

Large-scale assessments like PISA and TIMSS carry a particular problem. These studies provide evidence that the average science achievement of students is higher in some countries than in others. However, the studies do not provide information in which regard science instruction in those countries is better than in the other countries. Instructional research, however, has provided evidence about a particular amount of instructional characteristics correlated with students' achievement. Over time, several models of instructional quality were suggested in order to systematize existing findings. These models include characteristics of the protagonists (i.e. the teachers and students) as well as the classroom, the school and the school system. Up to now, however, no coherent picture of what characterizes high quality instruction has been described. This is most likely because the tools to capture the complex reality of instruction had been missing.

With advancements in consumer electronics, video analysis became available as a method in instructional research. Observation of classroom situations by one or several observers using questionnaires or field notes soon became obsolete. Instead video analysis could be used to investigate instructional processes, though certain rules have to be obeyed. For one, video recordings have to be carried out in a standardized way in order to ensure compatibility. For analysis, a valid and reliable coding procedure has to be developed, which is a complex and time-consuming process. However, recent video studies have demonstrated that it is possible to go beyond a mere description of instruction and that it is, in fact, possible to capture the complex reality of a classroom. This requires going beyond video analysis as the single method of investigation and making use of a multi-method approach.

The data obtained by such an approach will be hierarchical in nature. A class of individual students will interact with the same teacher, and these interactions will again lead to individual learning outcomes. Analysis of such data requires the application of specific statistical methods because simple correlations cannot take into account the complex nature of the data. With recent developments in the field of statistics, respective tools have become available to handle this issue, amongst them HLM and SEM. With the help of these statistical tools, more complex designs become possible. More variables can be related to each other and consequently the complexity of the interplay of factors on the individual, classroom, school and system levels can be accounted for in the analysis. This again allows researchers to test more complex theories or models of instructional quality.

Altogether it seems that the ingredients to take science instruction research one step further are at hand: Combining models of instructional quality, video analyses, questionnaires and tests, as well as statistical methods such as HLM or SEM, can help describe what characterizes high quality instruction and, so might be hoped, improve science instruction in the long run.

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ANDRÉE TIBERGHIEN AND GÉRARD SENSEVY

7. THE NATURE OF VIDEO STUDIES IN SCIENCE EDUCATION:

Analysis of Teaching & Learning Processes

INTRODUCTION

The use of video recordings as data in research studies in science education began in the 1970s. After almost thirty years, this use is widespread among researchers; video is included in regular research practice. However as any "new instrument", video has modified researchers' practice to the extent that the nature of information given to researchers is different from that of written data, direct observation and even audio recordings. In this chapter, our aim is mainly to give insight into the characteristics of video data and the complex nature of video. In part one we present specific characteristics, mainly the physical ones, then in part two we discuss to what extent one main characteristic of the video is its analogy with the recorded part of the situation in terms of events kept or transformed in the analyses, and in part three we present an actual research study.

PART 1: CHARACTERISTICS OF VIDEO DATA

Science education publications show that the video's specific roles as data is not analysed frequently even if video data are commonly used. When looking at the papers published in three of the main journals in science education, it appears that in the Journal of Research in Science Teaching, and in Science Education, between 2000 and 2010 respectively eleven and nine papers mention video data in their abstracts, and that in the International Journal of Science Education nine papers mentioned video data in their abstracts in 2009 and 2010; a reduction from those found in 2007–2008. In all these papers, video data are used to study interactive situations, mainly classrooms but also discussion groups, interviews, etc. These numbers under evaluate the use of video data, since we limited the search to abstracts; video use as data has become commonplace and is no longer systematically mentioned in abstracts. The research studies cover various theoretical frameworks involving individual or collective aspects. The specific roles of video are not the focus of these papers; videos seem to be used as other data. Analysis of the role of video may be found from a small number of researchers in the United States (Powel, Francisco & Maher, 2003; Goldman, Pea,

Doris Jorde and Justin Dillon (Eds.), Science Education Research and Practice in Europe: Retrospective and Prospective, 141–179.

Barron & Derry, 2007, Derry & al., 2010) and in France, where the creation of a video database of teaching/learning situations (ViSA) has favoured methodological analysis using video (Veillard & Tiberghien, 2012).

The Main Characteristics of Video Data: Making Communication Visible

In almost all research studies with video data, the recorded situations involve communication between students and/or teachers and/or researchers. In this chapter we do not take into account studies where videos are used as documentation for the student work. Thus more or less explicitly, videos are used for their main characteristics, making communication visible, as Goldman and McDermott (2007) state:

> Analysts should use video *because it makes communication visible* and potentially reveals behavior nested across levels in precarious and contested interactions. (p. 112).

It is not surprising that researchers studying interaction situations, particularly in classrooms, where communication is necessarily implied, favour video as relevant data. To analyse what the characteristics of the video related to the possibility of "viewing the communication" are, we first introduce three main physical characteristics: "density", "permanence", and "length" of the video (Powel, Francisco, & Maher, 2003). Then we discuss two others concerning the relations between the video recording and the situation: "selectivity" and "contingency".

Density

Video captures two simultaneous data streams of audio and video in real time, recording non verbal behaviour and material elements of the situation. This density makes for the richness of the video which, owing to its two streams, can account for the global recorded situation in a multimodal way. Obviously, this multimodality is crucial to understanding communication.

Permanence

As Powel et al. (2003) noted:

> Unlike the ephemeral nature of live observations, with videotapes, researchers can view recorded events as frequently as necessary and in flexible ways such as "real time, slow motion, frame by frame, forward, backward," and attend to their different features (p. 409–410).

This characteristic feature plays an important role in data analyses. The possibility of viewing and reviewing the video files makes possible analyses by different people and their comparison (Goldman-Segall, 1998). This feature is underlined by researchers coming from different theoretical approaches.

For example TIMSS video studies 1999 in mathematics and science (Hiebert & al., 2003; Roth & al., 2006) emphasize the advantage of the permanence of videos:

> Videos allow investigators to view and review *teaching events many times* in order to develop a *shared set of referents for terms and definitions that are linked to images*. This is especially crucial in a study involving multiple languages and countries, especially during the code development phase. In addition, video *facilitates the study of complex processes*, by permitting investigators to parse data analysis into more manageable portions (p. 5) (Hiebert et al. 2003; our emphasis).

This viewing and reviewing enables researchers, particularly in case studies, to modify their theoretical and methodological point of view in the data analysis when the data are already recorded. For example the approach taken by Engle, Conant and Greeno (2007) involved the refinement of hypotheses:

> Specifically, in the process of progressive refinement of hypotheses, an investigator begins with a general question and then decides to collect empirical records in a relevant setting with an initial plan for how to use them to learn more. *Initial analysis of these records informs more specific hypotheses that then may be addressed in other aspects of the data*. […]
>
> […] However, *with the advent of records like video* that both are relatively comprehensive and support multiple re-viewings, it is now often possible to take several steps in the progression *using the same set of records.* Thus, *video records can allow a single study to progress through multiple iterations of hypothesis generation and evaluation*, making the resulting findings more robust than they might have been otherwise." (p. 240, italics ours)

It appears that video reduces the dependence of the observer on *premature interpretation*. The nature of video data is thus deeply different from direct observation. It is easier for a researcher with video recordings to become more flexible in changing ones theoretical point of view than with field notes. A different aspect of permanence, the long-term preservation of video recordings should also be addressed. It implies keeping information available, that is a permanence of storage, of video file readability, and thus rises the question of computer file formats. We do not develop this aspect here, however we would like to make our community aware of this problem, which cannot be solved at the scale of a research team and necessitates collaborative work between teams.

Length

By length we not only mean the length of a single recording but also the total length of video corpus for a research project. Today the length of recording is limited only by the size of the digital memory; it can be from a couple of hours to hundreds. Let us note that this situation is completely different from that less than one century ago where 2 or 3 minutes of film was considered a long recording[1]!

The possibility of a large video corpus is used in educational s research practice. In a given project, researchers can collect dozens and even hundreds of hours of video recordings. For example, these recordings can account for a large sample of classrooms or for the life of the same group (a class) or an individual during a long period of time. It is possible to have “continuous” data over a long period of time comparing to other possible data. Thus the evolution or the emergence of diverse phenomena can be investigated.

These enormous corpora of video data, with the possibility of permanency constitute a richness for research and opens for additional research possibilities. Sharing video corpora among a community of researchers provides the development of new research opportunities as exemplified by Talk Bank (MacWhinney, 2007) in the US and in France with ViSA (Veillard et Tiberghien, 2012). However, such databases necessitate new practices in the research community, in particular that of sharing data between groups which do not necessarily have the same theoretical orientations; we are currently in this evolution of practices.

Selectivity and Contingency

Selectivity and contingency are two main restrictive characteristics of video. Video data are incomplete; they will not be able to portray a complete picture, revealing everything there is to know about an event. The data are constrained by techniques; the space in the place available to put the camera and the camera itself with a limited field of vision. Thus, due to the partial picture, the video recordings can give a false idea of the situation.

Selecting the situation and the ways of managing contingency depends on the researcher’s choices:

> Choices of perspectives and spots from which to record action, choices of the beginning and the end of a recorded segment – which depend often on technical constraints (such as the length of the cassettes, the possibility of placing the cameras in difficult angles and locations, etc.) – and other technical choices – concerning the equipment, its miniaturization, angles and lenses, microphones, etc. – *results from a reflexive analysis of the situation* even before the action takes place. (Mondada, 2006, p. 57)

At the same time, video can capture events in a situation that the observer does not notice or see. As we introduced before, density of the video associated to permanence makes it possible to modify a theoretical perspective. In other terms, the choice of the camera angle depends on the theoretical framework and at the same time should enable the researcher to modify this framework. This point was raised in a famous discussion[2] between Margaret Mead and Gregory Bateson (1976) moderated by Stewart Brand (see also http://www.oikos.org/forgod.htm). The part of the discussion that is focused on films started by a controversy about the use of a tripod for the camera. Margaret Mead (M) defended the advantage of the tripod and Gregory Bateson (B) considered that moving the camera is a better choice, they disagreed (our emphasis):

B: [camera should be off the tripod] to get what's happening

M: What *you think* is happening.

B: If Stewart reached behind his back to scratch himself, *I would like to be over there at that moment*.

M: If you were over there at that moment *you wouldn't see him kicking the cat under the table*. So that just doesn't hold as an argument.

B: Of the things that happen the camera is only going to record one percent anyway.

M: That's right.

Then the discussion is about the Balinese films that Mead and Bateson took when they were working together as anthropologists in Bali. Again Mead reminded Bateson of his use of the tripod and Bateson did not agree on what he did in that case. Mead went on in her argumentation and said:

M: … [To Stewart:] With the films that Gregory's now repudiating that he took, *we have had twenty-five years* of re-examination of the material.

And later on Mead again said:

M: Well, there are other people who don't, do you know? Take the films that Betty Thompson studied[3] That Karbo sequence – it's beautiful – she was willing to work on it for six months. You've never been willing to work on things that length of time, but *you shouldn't object to other people who can do it, and giving them the material to do it*.

There were times in the field when I worked with people without filming, and therefore have not been able to subject the material *to changing theory*, as we were able to do with the Balinese stuff. …

This discussion also illustrates how an apparent technical component of the data collection, here the choice of a tripod, the camera angle, and the length of the film are related to the theory and even epistemology on the role of theory in research. Mead makes explicit that working for a long time on the same films led her to modify her theory. Currently, video technique opens more possibilities; for example in many studies in classrooms, the researchers use two or even more cameras. In these cases, one is devoted to filming the whole classroom and the field of vision of the other(s) camera(s) is usually strongly dependent on the focus of the study. For example a choice can be to focus the camera on two students or on the teacher. The videos from the camera filming the whole classroom could be less theory dependent than the others. It is important to note that this kind of observation is consistent with the viewpoint of neo-realist filmmakers, as Rossellini, or contemporary ones, as Kiarostami. The long shot is a way of enabling the spectators to choose their perspective, without trying to impose a particular way of gazing at the pictures, by trusting his/her intelligence. A long shot of the whole classroom is less theory-dependant for it may give the researcher the freedom to elaborate a specific way of dealing with what is going on in the classroom.

Concerning *contingency*, video recording imposes rather few constraints on the method of analysis in terms of quantitative, qualitative or high or low inferences (Powel, et al., 2003). However, let us note that video data are often insufficient; additional data on the filmed actors, on the situation, the institutions, etc. are necessary. Research studies like TIMSS video (Hiebert et al., 2003; Roth et al., 2006) have a statistical approach whereas many other studies are case studies including a certain number of classrooms or students in classrooms. Moreover, as we analyse below, the treatment can be carried out with coding and counting whereas others can construct patterns of behaviour or characterize specific events. In these different possibilities of analysis, the treatments of video can keep its character of showing behaviour or can become a code or numbers or statistics. In other words either the analogical character of video to the situation is kept or there is a digital transformation. Let us note that the same research can use both treatments. We develop this point below.

Analogical and Specific to the Recorded Situation

When a teacher is speaking with students, the video can capture these exchanges and record them. Most of the elements of the recorded situation, in a classroom for example, are material objects, human beings evolving with time and moving in space. When we look at a video recording we are looking at images and sounds that are *analogical* to the effective situation. The situation is recorded with the same physical time. The events like a teacher's question and a student's answer have the same duration as in the effective situation, the time interval between these two events is also the same and the video recording gives an image of a part of the situation. Thus video makes communication visible.

In the perspective taken here, video is analogical. What do we mean by that? In physics and technology, it is stated that:

> As humans, we perceive the world in analog. Everything we see and hear is a *continuous transmission of information to our senses*. This continuous stream is what defines analog data. Digital information, on the other hand, estimates analog data using only ones and zeros, the difference between analogical and digital signals is the respect of the continuity of the signal in the way of capturing and recording it. (http://www.techterms.com/definition/analog; our emphasis).

Whereas at the physical level, nowadays the video and audio recordings are digital, when we look at and hear the video recordings, we perceive them as a continuous flux of information; thus we consider that, *at our level of perception, video is analogical.*

Thus, video not only is analogical to the real situations in time and partly in space, but also has the characteristics of images and not those of texts and words. We just give some important aspects of these differences without discussing them deeply (Sensevy, 2011a).

As we have already presented, video images are dense, in this sense they include infinity of information, and thus would necessitate infinity of sentences to account of them. As soon as we describe an image with sentences, we select some aspects of images; this is a fundamental difference between the videos and all their analyses in texts, graphs and other representations.

The density of images goes together with the *specificity* of images. Video of classroom is specific of the observed classroom and of the actors, their behaviour. *Interpreting images with words allows the researcher to go from specific to generic*. Telling that the teacher says hello to the students arriving in the classroom at the beginning of the session is more generic and can recovers a diversity of situations, some friendly whereas other more aggressively, etc. Again we emphasize that text necessarily selects information.

CONCLUSION

This short presentation shows technical components; we have distinguished the physical characteristics of the video: data density, permanence, and length, those directly depending on the researcher's choices, selectivity and contingency, and lastly - a crucial characteristic - the analogical character of video to people's behaviour in the material world. This latter embodies the physical properties of video recordings and concerns the relationships between video and the recorded situation. The passage from video or more general analogical situation to texts is crucial to human and social sciences to keep the meaning of behaviour; *video recordings enable the researchers to suspend this passage* that is to keep the analogical character of the situations with its specificity and its infinity of information, and to go back and forth between the analysis in text or other treatments and the video recordings. Finally, we argue that this type of analysis is a way to address the complexity of the communicative situations like classrooms.

These characteristics deeply influence the theoretical and methodological choices; our making video properties explicit aims to help researchers to be better aware of their choices and to clarify the debates between different orientations. With this respect, it is important to emphasize that video data are well suited for the kind of research which focuses on the ongoing concrete actions of people. If theoretical frameworks rest on a conception of action as a communicative action, as we will see below, thus video data enable the researcher to find relevant materials in order to achieve this conception.

PART 2: ANALYSES OF VIDEO DATA: SOME BASIC CHOICES

In this section we focus on the main methodological choices of which the researcher should be aware when studying classroom situations vis-à-vis the specific characters of video presented in the first part. Four main choices are discussed: sampling, two main types of data treatment in terms of narratives and/or coding, and scales. We chose these points to the extent that video data need a specific discussion.

Sampling: What Choices of Space and Temporality?

We take the cases where the studies concern the characterization of classroom practices whatever the approach. Of course the sampling depends on the research questions, thus we focus our discussion on some consequences of two main choices: selecting either one or two lessons by a teacher or a series of lessons over several weeks or months.

TIMSS video 1999 studies is an example of the first choice, one lesson by a teacher is videotaped. The chosen sample aims to be representative of a country; in this process, for each country a sample of schools was selected then a science teacher from each school was randomly selected and each teacher was videotaped once, teaching a single lesson. The authors of this study were aware of the limitation, for example in the case of mathematics, Hiebert & al. (2003) wrote:

> […] taping only one lesson per teacher shapes the kinds of conclusions that can be drawn about instruction. Teaching involves more than constructing and implementing lessons. It also involves weaving together multiple lessons into units that stretch out over days and weeks.” (p. 2)

A single lesson is a short period of time with regard to the duration of a class life; it possibly eliminates many events occurring at a time scale of more than one hour, which however can play a role in students’ learning even if some events relevant for a longer period of time can be acknowledged. Two main positions can be taken.

A position based on the result that most of the teaching patterns are stable ones justified the choice of taking a single lesson by the teacher (Seidel & Prenzel, 2006). The stable teaching patterns highlight the perennial components of teaching practices, like teacher-student interactions and students’ perception of learning conditions (Seidel & Prenzel, *ibid*). Moreover, the results obtained by TIMSS video 1999 in mathematics for the lesson signature of a country shows that certain patterns are similar among the teachers of one country; for example classroom organization (whole class, group work, individual), the way homework is processed in the lesson, the time taken at the beginning of the lesson to review, the type of mathematics problems, the way and the time to introduce new content in a lesson. Let us note that the last category supposes that the way of introducing new content is a perennial characteristic, which eliminates the role of the nature of the new content from this category; it makes it independent of time for a time scale at the level of an academic year for example. It is very likely that these common patterns among teachers of the same country are perennial patterns over an academic year of a class; in other words, this choice supposes that a single session is considered as generic of the teaching practice in a given classroom.

Another position considers that conceptual learning needs a long period of time and that teaching and learning time are not identical. Conceptual understanding of science is constructed through acquisition of elements of knowledge but not necessarily in the rational order of the teaching sequence; complex imbrications of association of elements can happen (Petri & Niedderer 1998; Tiberghien, 1997). In that perspective, *the evolution of knowledge in the classroom over an academic year should be analysed since this is a necessary condition for students' acquisition* in particular for studies that aim to relate classroom practices and students' acquisition. This evolution corresponds to a crucial modification of class life; the teacher's expectations vis-à-vis students are different, they are supposed to know more after each session and to be able to carry out more elaborate tasks. This position does not deny the stable teaching patterns of a teacher but it highlights the evolutionary component of a class during an academic year related to the evolution of the teaching content and students' learning. Clarke, Keitel & Shimizu (2006) take a similar position when they focus their study on "examining the interdependence of teaching and learning as related activities within an integrated body of classroom practice" (p. 12).

The first type of sampling, which consists of units of one or two lessons by a teacher, gives possibility to access to a large number of classrooms; the second type consists of a sampling of a rather long series of lessons by a small number of teachers. These two types of sampling cannot lead the researcher to take into account the same sets of events even if some events are the same. The meaning of the teacher and students' acts cannot be constructed in the same way. For example, class organization (whole class, small groups or individual work) can be considered in all studies whatever their position; however only in studies taking the first position, due to the large sample of classrooms, can the generic aspect be investigated whereas only in the second position can the relationships between the types of classroom organization and the introduction of new elements of knowledge be studied. Thus we should be careful about the conclusions that can be drawn according to the time span of the class life the sampling represents.

In addition to sampling, let us recall a point already made in the first part concerning selectivity and more particularly the dependency of video from theory according to the camera angle. According to the space of the classroom or other situations that are taped, the different temporalities and spaces can or cannot be studied. For example, if the camera is focused on two students without having the rest of the class, the events will be mainly those associated with these students and not with the class, similarly if the camera is focused on the teacher, the students' actions that are missing to study the classroom practices.

Video Analyses in Terms of Narratives

The question of analysing video in terms of narratives or of coding are not exclusive; however these two types of analysis lead to interpreting the video differently; a main difference is about the selection of events and of their context. Goldman & McDermott (2007) state:

> Video records capture what individuals seemingly attend to, talk about, and do with what is at hand, and they allow, more crucially, an analysis of how all this is arranged with the most locally demanding and collectively constructed constraints of time and space. In video analysis, *time is transformed for a simple matter of then and now to a more reticular and reflexive* then in anticipation of a now and now in respect to a then, both occurring simultaneously. *Every moment is a retrospective and prospective advance into the future*; as George Herbert Mead ([1938] 1972:65) confided, "*The unit of existence is the act, not the moment." Space is similarly transformed* analytically from a simple matter of here and there *to a more embodied place for the negotiation of person and social relations*. This is conceptually difficult. (pp 112–113, our emphasis)

Choosing the act as the focus of analysis leads the researchers to make a particular case for the sequence of acts. It means that the researchers keep the video's aspect of being analogical to people's behaviour. The importance of keeping this aspect is emphasized by Bruner (1996) that shows that narratives allow keeping together the acts and their context. The first example of narrative is a story of what happens during a specific session. It corresponds to what Bruner (1991) calls *Narrative diachronicity* in his seminal paper; for him:

> A narrative is an account of events occurring over time. It is irreducibly durative. It may be characterizable in seemingly nontemporal terms (as a tragedy or a farce), but such terms only summarize what are quintessentially patterns of events occurring over time (Bruner, 1991, p 6).

In the following we present examples illustrating two different methodological roles of narrative in a research study related to the specificity of a practice or the typicality of a practice.

In this first example, the aim of the narratives is to construct *intermediary data* to reduce the original ones; these narratives give the plot of what is going on in the classroom during a session and more specifically what is at stake from the teaching perspective; in this narrative:

> [the researcher] acknowledges the space of the classroom as the place where a "story" unfolds, which proceeds from its actors linked together through a plot (Veyne, 1971). It is built over time, and is related to knowledge at stake. This knowledge is developed jointly, and expressed in the interactions between actors (Marlot, 2008, p. 132).

This example comes from a research study at a primary school aiming to characterize the science classroom from the point of view of the communicative interactions involving a transaction of knowledge in the classroom (Marlot, 2008). In this research study, one session by the teacher was collected. Each session is divided into phases:

> PHASE 1: During the first phase which lasts 16 minutes, the teacher, as a first step, asks the class to collectively recall hygiene rules when observing

> living things, the "golden rules". Then he asks students to remember the last session where they had chosen among several questions the two questions to be studied, the associated hypotheses, and the observation device. The two questions relating to how worms go into the soil are: "how do earthworms go into the soil?" and "do worms have strength?" They are written on the blackboard and the three hypotheses, followed by a question mark: do they eat? Pointed head? Do they grow?
>
> PHASE 2 […] At time 48 minutes, the teacher returns to collective work […]) and gives what is at stake "see if you find the same thing or not." Each student who makes the report reads a sentence to the class giving the observation of the group. Apart from group 1, all groups have adopted the initial assumption "the worms enter the soil by pushing", but apparently without relevant observation. The teacher validates the "result of observation". At this time a double event on the initiative of group 1 happens. The teacher proposes to hold a debate on group 1's proposal: "they eat and they spit it back out […]". The teacher tries to define an observation which could be relevant and confirm group 1's result or at least to prove what they observe corresponds to what they propose: to do that the teacher proposes to look at "if soil is missing". This is the first selected event. On the other hand, the teacher asks the question to know if it is possible to accept several answers to a question. When at last he puts in question the reliability of group 1's observation (worms eat and spit soil out) by asking the question "did you see it?", one student of group 1 answers that he disagrees with his group. It is the second event (Marlot, 2008, p. 175).

This narrative accounts for the temporality of selected events at the classroom level in which the teacher or the students are the actors; it does not give the temporality of students' activity when they work in small groups for example. It also gives some information on space like the teacher writing at the blackboard or the students reading their report to the whole class. This extract shows how a narrative is a useful tool for identifying events in the ongoing didactic process. By telling the story of knowledge in this lesson, one becomes aware that the teacher validates some answers without evidence, and asks for evidence for other answers. Acknowledging this kind of managing classroom dialogue enables the researcher to understand the intentional state of the teacher.

The example, phase 2, shows that the intentional state attributed to the teacher by the narrative process (validating "the worms enter the soil by pushing" and challenging "they eat and they spit it back out") may shed some light on the significance of events the researcher identifies. By comparing this narrative to the interviews of the teacher, one may be able to understand that the teacher is dealing with what he thinks to be the misconception of "worms eating the land in order to enter the soil". This narrative accounts for this course of events.

This example raises the question of the interpretive or explanatory roles of narrative discussed by Bruner:

> Narratives are about people acting in a setting, and the happenings that befall them must be relevant to their intentional states while so engaged—to their beliefs, desires, theories, values, and so on. […] But *intentional states in narrative never fully determine the course of events*, since a character with a particular intentional state might end up doing practically anything. […] The loose link between intentional states and subsequent action is the reason why narrative accounts cannot provide causal explanations. What they supply instead is the basis for interpreting why a character acted as he or she did. Interpretation is concerned with "reasons" for things happening, rather than strictly with their "causes," a matter to which we turn next. (Bruner, 1991, p. 7).

More generally these narratives together with other analyses, in particular the synopsis that we discuss below in the part on scale of analysis, are the bases for selecting relevant parts to be analyzed in more depth. *These narratives are methodological tools aimed at giving a global view in a sequential order and selecting a relevant sequence of events*. They may be progressively refined by integrating different kinds of information the researcher gathered in the inquiry process.

This use of narratives as intermediary data first supposes a structuring of the video, like in the example where the didactic phases are the basis of this structuring. At the same time they are themselves one of the bases for selecting video extracts to analyze more deeply. For some orientation of research studies they play a crucial role in the processes of decomposing / recomposing video. In this use, the narratives show the specificity of a practice by focusing on specific events which can provide clues to the researcher's inquiry process.

The following example gives a different status to narratives, they are results of a study. They come from TIMSS Video Studies 1999, one in mathematics and the other in science for the Netherlands showing a typical lesson in these disciplines for this country:

> […] a majority of eighth-grade Dutch mathematics lessons began with a review of previously learned content (64 percent), though a noticeable percentage of lessons began directly with the introduction of new content (29 percent [..]). By the midpoint of the lesson, the percentage of lessons that were focused on review, introducing new content, or practicing new content, were relatively evenly divided (30, 34, and 29 percent, respectively,[…]). […]The midpoint of the lesson is also the time when a majority of Dutch lessons moved into private interaction, wherein students worked individually or in small groups, and focused on sets of problems (concurrent problems) completed as seatwork. (Hiebert et al., 2003, p. 138).

This extract gives a story dealing with the possible sequencing of a lesson and the type of content (previously taught or new) in the Netherlands.

This narrative is an example of account of events, and is based on digital analysis consisting of coding events.

This narrative has a general status; it is not related to what actually happened but to what has the chance of happening in a particular country for a particular taught discipline on the basis of previous coding. They show that one can use narratives to identify what is *typical*. In that case, narratives help in designating didactic patterns.

This corresponds to the difficult question of relation between *particularity and genericness* which characterizes narrative as raised by Bruner:

> Narratives take as their ostensive reference particular happenings. But this is, as it were, their vehicle rather than their destination. For stories plainly fall into more general types… *Particularity achieves its emblematic status by its embeddedness in a story that is in some sense generic*. And, indeed, it is by virtue of this embeddedness in genre, to look ahead, that narrative particulars can be "filled in" when they are missing from an account (Bruner, 1991, p. 7, our emphasis).

Thus narratives can be situated in a kind of gradient between very strong concrete specificity and very abstract patterns, which is a real advantage from the methodological viewpoint. In the first part we emphasized the character of specificity of videos, they allow the researcher to identify specific facts and events. Narratives are a way to go from this specificity of facts, events to their genericness.

With this respect, narratives can be easily linked to video clips; each part of a narrative can be associated with a series of clips illustrating "the generic case". The narrative plays a distinctive and fundamental role of associating the particular (each clip presents a kind of specificity) and the generic (each clip can be viewed as a "sample" of a generic category).

Video Analysis in Terms of Coding

Coding is a practice that is not specific to video data, thus we shall focus our discussion on the similarities and differences between coding video data and coding another type of data like written data. We shall also briefly compare coding video and coding classroom events by an observer in situation.

Similarities between Coding Video, Written Data, and Observing in Situation

In both cases, the researcher transforms the people's acts, written sentences, oral utterances and/or gestures, into a formal code in comparison to a reference. Each code gives the total or partial presence or absence of the event to which it corresponds. Formal treatment of codes supposes that the meaning of the event corresponding to a given coding is considered as equivalent whatever the context, in particular whatever is going on before, simultaneously, or after either in the text or in the video. The coding supposes that events coded in the same way are viewed as the same. In some cases, coding can be automatically done from texts (written text production or transcription of videos). These procedures of coding, that is associating an event to a code is similar for the three cases, video, written data and observing video.

A similarity between only written production and the video is their permanence; the researcher has the possibility to come back to them if necessary; this is a strong difference with observing in situation.

Let us take the cases of coding video at the duration scale of minutes or dozen of minutes like the classroom organization (when the students are working as a whole class, in small groups, individually or when the situation is mixed like when the teacher is speaking to the whole class whereas the students are working in small groups or individually), a code such as a letter or a number is associated with each category. Another element of information can also be associated: the duration of each classroom organization during a teaching session. This coding can be done from video data or from direct observation. In both cases, counting and applying statistics is made possible. For example comparisons can be established in a classroom between the types of session, the taught disciplines, etc. or between classrooms in terms of the number of times a given organization takes place or in terms of the total (or partial according to certain criteria) duration. TIMSS video projects are good examples of video data use showing the differences of class organization between countries (Hiebert et al., 2003, Roth et al., 2006).

Differences between Coding Video, Written Data, and Observing in Situation

A main difference between coding videos and observing in situation in one hand and written data on the other hand is that students' production process takes place in the information from which the coding is done in the first case only.

When coding students' written answers, the researcher deals only with the production of students' written acts; on the other hand when coding student's utterances from video, the researcher has access *to the acts from which the utterances are produced* and not only to the written production. Thus the specificity of video - recording communication - is involved like of course in the situation itself. On the other hand the permanence of video allowing the researcher having access to these acts as often as necessary plays a role in the interpretation and the construction of coding. For example, TIMSS video projects involve people of different cultures devoting time and effort to designing coding of classroom video; in this process the researchers constructed a series of video extracts playing the role of referents or "cases". These references not only involve the events or production to be coded but also their processes. Thus the interpretation involved in the coding process is based on *acts and production*; this can change from an interpretation based only on the production.

This kind of difference is not involved when comparing coding from observing the situation or viewing the video. In both cases, the interpretation is made from acts and production, however two main differences remain. The first one is obvious, the observer in situation can only code what s/he sees and the viewer of the video can only view the part of the situation which has been recorded. The second one is that it is possible to view and review the video and to discuss the interpretations with other people. These video characteristics influence the way of validating coding: the criteria of coding should include some specification of the conditions of the observable to be coded. Sharing coding supposes that researchers share a series of video extracts serving as reference cases (e.g. the Panel-of-Judges method).

Comments on the Risk of Creating Genericness Illustrated with Video Clips

The question of genericness is always present in research studies whatever the methodology. Genericness is based on facts/event observed in the video. The narratives whatever their roles and the coding processes are associated with video clips showing specific cases as relevant events and allowing the researchers to understand and characterize the studied classroom, and/or teaching or learning phenomena. This is a richness of video data but also a risk.

Miller and Zhou (2007) recommend being careful of these uses because of the possible persuasiveness of video clips:

> […] we will argue that video cases can be unusually persuasive because they can function as a form of anecdote, processed differently than are other kinds of data-based reports." (p. 321–322)

> For them it is necessary "… collecting cases in a comprehensive and systematic way, presenting them as well-described samples from a larger domain of instructional experience, establishing their representativeness, and presenting them in a manner that enables viewers to comprehend them. (Miller and Zhou, 2007, p. 329)

In other words these authors raise the question of the theoretical criteria behind the selection of the video extracts. In order to be able to acknowledge that a case is a "sample from a large domain of instructional experience", one needs to use a theoretical viewpoint that establishes their "representativeness". Thus, a major theoretical and methodological issue consists of the dialectic relationship a researcher is able to build up between a narrative stance and the rules constructed on the basis of the theoretical and methodological choices (grammar in Bruner sense). For example, in the case of TIMSS video studies, their set of video coding is the structure or the grammar in Bruner terms and the narrative represents the coding results of the videos by featuring a classroom life; thus their genericness is based on these theoretical and methodological choices

Scales of Analysis

Concerning the scales of analysis we differentiate the researcher's levels of observation from the scale of the events involved in the situation itself. The level of observation of videos is related to human capacities and technical capacities of the instrument of viewing videos. As human beings, the observations of a video extract that lasts for a minute or some seconds or for an hour cannot lead to the same way of understanding and interpretation. It seems that there is an agreement to consider that events and their succession at a short physical time scale (seconds or minutes) are directly observable on videos, they can be viewed and reviewed either at the normal speed or frame-by-frame in the limit imposed by the camera (usually 25 frames per second) even if the transcription helps. On the other hand, the course of events at the scale of an hour can hardly be observed directly globally and in detail. Most of the time, events and the course of events are re-composed from transcriptions and observations at a smaller scale or globally approached with complementary data and/or by analysing the video in a new step. For the course of events at a larger scale than an hour, we consider that the observers are not able to embrace the video directly and need to work on parts and possibly to use complementary data to make sense of the course of events.

Three Scales, the Most Usual Choice

The *question of scales* is central to the study of complex situations like communicative ones even if it is difficult. For example, Ash (2007) studied how families visiting a museum "can take advantages of a number of resources as scaffolds, discontinuously over time." (p. 211). For that she considered:

> To understand scientific sense making over time, we need tools that can track meaning over disconnected dialogic events. *It has taken me years to design methods to frame units of analysis that can capture these discontinuous events*. I have discovered that I need to *focus on three different levels of analysi*s, and to move back and forth among them in order to fully follow meaning making in action. (Ash, 2007; p. 212, our italics).

The three levels chosen are (1) a large grained and holistic one as we present it below, (2) an intermediate one called significant event, which is a specific choice in this research and (3) a microgenetic one that comprises a detailed dialogic analysis. More generally, the macro and micro levels are more easily defined than the meso scale.

The micro scale often corresponds to events the duration of which lasts about a few seconds (or even less) to a minute. More generally, at this scale, the units of analysis chosen by the researchers in science education often are a word, a single utterance or a short exchange, leading to coding or other interpretations (Hiebert et al., 2003; Roth et al., 2005; Fisher et al., [this volume]; Roth et al., 2008).

The macro scale depends on the type of study, that is the duration of the observed teaching for a classroom or more generally of the observed system, a student, a family (Ash, 2007), a group, etc. This duration can be about one hour (one session), dozens of hours (typically the duration of a teaching sequence), or hundreds of hours ranging over one or several academic years. In other words it is convenient for the researcher to take as a macro scale the maximum period of time which the study deals with.

The choice of the meso scale is more open; it is not strongly influenced by the duration of the study like the macro scale nor by the smallest units of analysis like the micro scale. However, an intermediate scale is necessary to take into account one or several relevant units which indicate a level of organization. As we illustrate below, in the case of our studies, this scale corresponds to about ten minutes (from a couple of minutes to about 40 minutes depending on the chosen unit). This time scale is particularly relevant for classroom studies because it corresponds to events characterizing the life of a class as a group like the classroom organization in a whole class, small groups or individuals, or like the didactic phases that are the duration of an activity, an exercise, a debate, a teacher's lecture, etc.

Whatever the choice of scales, most of the time the researcher needs to construct a global view of the set of situations that are filmed in relation to other data: we call it a *synopsis* that often has not only the functions of giving a global view but also those of selecting and giving landmarks.

The Global View: Synopsis

A synopsis gives an overview of the set of situations; this view can be constructed with different goals, in particular *giving landmarks* in order to go to a specific part of videos (or other data) when needed, and/or enabling the researcher to *select significant parts of videos and other data* to be analysed in depth. The synopsis can be a narrative of the story of the studied system like that of a classroom or a student's school life during a period of time. It is a way of organizing the data which makes sense easily, as Bruner (1991) proposed:

> […] we organize our experience and our memory of human happenings mainly in the form of narrative—stories, excuses, myths, reasons for doing and not doing, and so on. Narrative is a conventional form, transmitted culturally and constrained by each individual's level of mastery and by his conglomerate of prosthetic devices, colleagues, and mentors. (Bruner, 1991, p. 4)

Depending on the researcher and the type of study, the global view can consist of making a single construction or a series of constructions with the same model for a given unit of analysis. For example if a researcher studies a series of teaching sessions or any similar unit, each session gives rise to a synopsis and the global synopsis consists of this series.

As introduced before, Ash (2007) constructed a macro level view that she called flow charts for each visit (about one hour) of a family in a museum (table 1). For her, the flow chart is:

> large grained and holistic […] This flow chart provides an overview of one entire visit (typically 40–60 mins), as well as the pre and post interviews (15–20 mins each).
>
> […]
>
> The purpose of the flow chart is to provide a flexible overview of a single museum visit, from which particular segments can be identified and analyzed in more detail … (Ash, 2007, p. 212).

For Ash (2007) the purpose is clearly double: selecting relevant segments and giving landmarks. Table 1 shows the focus of this study: the content themes are involved in the global view. Moreover in other tables they give the structure of the whole research.

Table 1. Example of synopsis [source: Ash (2007, p. 213 legend: Flow chart MBA (Monterey Bay Aquarium' Splash Zone).

Family X, Mother, father, daughter (A, 10), son (8), son (5) Interpreter X & Researcher (Y) June 14, 2001			
Time	*Exhibit*	*Overwiew*	*Content themes*
0-30:00	Pre interview with Splash Zone cards	Lon, rich interview. Mom tells most. She uses the Splash Zone animal cards to start the conversation. […]	Frequent museum goers, Museums are fun, better than flea market, all members have favorite animals.
[…]			
34:50	Whole family is looking at otters	Some talk about otter behavior Dad/kids lead, MBA is crowded	At the otter tank briefly –Is otter asleep? -How would you know?
37:00	Looking at video of whales in the hallways	Family separates; Mom listens attentively & questions Eva	Whale is Eva's favorite animal, because they communicate, Blue whale has smaller flippers

Another method consists of producing a single synopsis for the whole study for a classroom. Ligozat (2008) studied mathematics teaching on measuring during an academic year by four primary school teachers in Switzerland and in France. She constructed a synopsis of the whole year for each teacher (table 2).

Table 2. Other type of synopsis [source Ligozat (2008), p. 241 Legend: "reduced" synoptic plan of observed sessions in the Teacher X's teaching project]

Date of session	Duration of the session ⟶		
Nov 4	Comparing masses [Textbook- measuring quantities] (Grade 4) Working in groups of 4/ plenary sessions where solutions are pooled		
	……		
	….. ··········	··········➝	Geometry
Nov 21	Graduations [Textbook- proportionalities] (Grade 4) Individual work/ plenary/individual work	Graduations [Textbook-proportionalities] (Grade 4) plenary where solutions are pooled	

The rectangles of the second column give the teaching parts corresponding to the studied topic: measurement, the didactic resources (like textbook) the classroom social organization and the rectangles of the last column give the date and the theme of the mathematics teaching which do not deal with the studied topic in the study (measurement).

Such synopses play a major role in this study to the extent that comparisons on the whole academic year can be done on the topics involved in each classroom, on their extent in time, and together on the didactic resources and the class organization. These synopses relate the macro scale (here the whole academic year) and the mesoscopic scale (here the session with the topics and the class organizations). They constitute the reference for the analyses at micro scale. For example, it appears that to analyse the class of a teacher, it was necessary to go to a much finer granularity analysis than for the other class. Ligozat's interpretation is the difference between the social organizations of the class in relation to the use of didactic resources; more globally, the teacher who practises a more individual teaching needs a finer analysis. Such an interpretation is possible because of the synopsis giving the whole academic year at level sufficiently developed that is at a meso scale.

CONCLUSION

In this part we have discussed some methodological aspects of studies based on video data. All of them involve the question of going from the specificity of video data to a necessary genericness of research results. They also involve the way the context of the selected facts/events are taken into account.

In particular we have emphasized that narratives are particularly important for video studies to the extent that, at least partly, they keep the analogical character to the recorded situation, that is some temporalities and spaces of the students' and teacher's acts involved in the situation or in other words, the context. We have also noted that coding is different in the case of video from the cases of many other data to the extent that video gives access to the process of production (oral or written) and not only the production; also for example the clips which serve as referent in video coding processes involve the process of what is coded (for example reviewing, assessing students' learning, developing new content).

Another aspect deals with the selection of video clips that, due to the power of image, can highlight some events which are not representative of the analyses, then we emphasize the necessity of making explicit the relationships between the selected clips and the structuring of the corpus. More generally, the importance of making explicit the theoretical and the methodological choices has been emphasized, even if the video clips could seem giving evidence enough without necessity of proving it. Lastly we have discussed the importance of analyzing a video corpus in terms of scales to the extent that it is a methodological approach relevant to the complex systems that classrooms are. In this case, the level of analysis giving a global view is particularly important because it gives the structure of the analyses.

PART 3: A STUDY BASED ON JOINT ACTION THEORY IN DIDACTICS AND ITS RELATION WITH OTHER STUDIES

In this part we present a specific research study that, in particular, is an example of work at several scales focusing on the act as a significant unit of analysis. In particular, this example shows the role of theory in the video data analysis.

The Theoretical Framework of Joint Action Theory in Didactics and its Compatibility with Video Data

We shall consider the learning-teaching process within the perspective of the Joint Action Theory in Didactics (JATD) where the didactic action includes the two joint actions of teaching and learning (Sensevy, 2007, Sensevy, 2011b). This approach aims to understand classroom practices in order to characterize them. Thus our intention is to be comprehensive first rather than explanatory.

The Joint Action Theory in Didactics (JATD)

In this theory, the main object of study is the classroom viewed as a community of practice where the didactic action involves two joint actions: teaching and learning (Mercier, Schubauer-Leoni & Sensevy 2002). For Sensevy (2007) this statement is taken as a fact:

> Let us take any didactic act, in each teacher's action, the student has a space, even tiny, and there is the same thing for each student's action (Sensevy, 2007, p. 15)

Sensevy includes a note to explain this choice in reference to Quéré (2006) and Descombes (1996):[4]

> For Quéré (2006) a "social act" is "social to the extent that it is distributed among several individuals and demands cooperation; each individual accomplishes his/her part of the whole act and *one individual cannot act without the other*" (ibid, p. 15). […]. Then Quéré following Descombes (1996) shows that, in essence, a social act is linked by a social relation to another complementary social act, and again, he finds the paradigm of teaching: "the teacher cannot teach if s/he does not have a student to carry out the complementary activity of learning" (p. 15). (Sensevy, 2007, p. 15)

The two joint actions, teaching and learning are produced along their duration within the triple didactic relationship between knowledge, teacher and students. These joint actions are based on communication oriented by the instructional goal given by society to the school. In most countries, this goal is made explicit through official texts including standards or an official curriculum. Thus knowledge is at stake in classroom communication. This view of communication as knowledge-oriented is developed with the idea of transactions. This idea is very coherent with that of didactic joint action. In the JATD the finality of classroom transactions is knowledge. These considerations lead us to investigate the didactic action and its evolution within the teaching time by focusing on *knowledge*[5] in the classroom and its progression, or in other terms by focusing on the evolution of knowledge involved in the transactions. Three aspects are involved: (1) who (teacher, students) introduce(s) and/or deal(s) with knowledge, (2) what is the knowledge involved, (3) in what situations (material and communicative) the transactions take place. Another important component of the classroom, which accounts for the whole classroom practice (or the whole didactic action), is about the reciprocal expectations that the teacher and the students may have. This component has been introduced by Brousseau (1998) who called it *didactic contract*. This contract forms a system of norms that one can see as a system of habits, some of which are generic and will be lasting, and others are specific to elements of knowledge and need to be redefined with the introduction of new elements. For example, after the teacher has introduced the concept of force, his/her expectations of the students' interpretations of material situations will be different from before.

Thus the classroom is investigated in terms of the didactic contract and of three notions relative to knowledge considered as the object of transactions. More specifically, three concepts are proposed: chronogenesis, topogenesis, mesogenesis. *Chronogenesis* accounts for the development of knowledge during teaching and involves a relationship between knowledge and time. *Topogenesis* means the places of actors (teacher and students) who take responsibility for introducing/using elements of knowledge, and to what extent their responsibility is recognized by the class. *Mesogenesis* is related to the "milieu," that is the social and material components with which actors construct knowledge and meaning (Sensevy, Schubauer-Leoni, Mercier, Ligozat, & Perrot, 2005; Sensevy, Tiberghien, Santini, Laubé, & Griggs, 2008).

Possible links between JATD and other theoretical approaches Let us note that the concept of didactic contract is close to what Cobb et al. (2009) call normative identity:

> In the case both of classrooms where some students are resisting and of classrooms in which there is no oppositional discourse, an analysis of general and specifically mathematical obligations specifies the role of an effective mathematics student. We call this role the *normative identity* established in a particular classroom because students would have to identify with this role in order to develop a sense of affiliation with mathematical activity as it is realized in that classroom (Cobb et al., 2009, p. 229).

In the same way as the concept of didactic contract, normative identity refers to class phenomena. The notion of a didactic contract emphasizes the specific knowledge at stake, which aims to define precisely the normative identity.

The concepts of chrono-, topo-, mesogenesis and didactic contract characterize class-level phenomena and not the level of the learner or the teacher as individuals. These concepts can be related to other concepts allowing the researchers to differentiate *collective and individual processes*. For example, Engle (2006) proposed:

> [to] determine whether the generalizations or multiple examples became part of the *common ground for the collective*, and then consider this as content available to be potentially appropriated by individuals, with the recognition that content is often transformed during that process (our emphasis, p. 455).

These relationships established with other researchers' work make explicit that our approach includes the view of a classroom as a group and also enables us to analyse individual student contribution to the classroom life. Let us note that this theoretical choice influences the chosen field of the cameras in the classroom.

The importance of knowledge in our studies leads us now to briefly discuss our position on it.

Position on knowledge Our didactic point of view on knowledge is different from epistemological and sociological ones. For example Latour (2005) has studied how actions within social organizations allow the construction of knowledge; its focus is not knowledge in itself but actions involved in its construction. Hacking (1983/2005) has studied what new knowledge is constructed, its evolution but not the social processes that lead to its construction, even if the social context is taken into account.

In our case, we study what and how knowledge, of which some of the main lines have already been decided (official curriculum), is shaped and shared in a classroom considered as a group under the teacher's responsibility. Thus knowledge constructed by this group is partly specific to it. We study the "life of this knowledge" in the classroom, which is "what and how" knowledge is constructed and evolves in its duration within the life of the class group. Even though the official curricula as well as the 'definitions' of science literacy are always elaborated in reference to knowledge and practices belonging to spheres of activity outside the educative system, we study the proper life of knowledge inside the classroom in order to understand the teaching/learning process.

To take into account the relations between knowledge outside and inside school, we call upon the concept of transposition. Following Chevallard (1991), there is a transposition process from knowledge taken as reference and knowledge at stake in the curriculum and another transposition process from the curriculum to the classroom knowledge. The reference knowledge is often that of the discipline of the taught knowledge but can also be that involved in other society practices. The basic idea of this theory is that *the meaning of knowledge depends on the transaction process in which knowledge unfolds*. Consequently the knowledge involved in two classrooms at the same level and with the same teacher is different because the transactions processes are different. We call the knowledge involved in a classroom the taught knowledge.

JATD theory and temporalities and spaces of communication The JATD aims to describe and understand human communicative actions. Thus, video recording that makes communication visible gives powerful data to this theory. More specifically, the three concepts of chronogenesis, topogenesis, mesogenesis account for temporalities and spaces of classroom communicative acts involving knowledge. For example one set of elements of knowledge can be involved in a series of teaching sessions and in a single session several new elements of knowledge are introduced. Then the flow of introducing new elements of knowledge is not linear to the physical time, this chronogenesis has specific temporalities. Topogenesis and mesogenesis account for communicative spaces; for example if in a classroom the teacher always has the responsibility of introducing knowledge and that there is no debate about knowledge whereas in another classroom the students can debate and question elements of knowledge the respective places of the teacher and the students in the communication about knowledge are clearly different; the spaces of knowledge communication for which topogenesis account are different. Even in one class, a moment of a session can be devoted to the teacher's synthesis of a debate whereas at another moment the students can debate a solution to a task proposed by one of them, and thus take the responsibility of the elements of knowledge involved in their utterances. These differences in the responsibility lead us to consider that there are different topogeneses according to the moment of the session but this concept also accounts for the evolution of the teacher's and the students' places vis-à-vis knowledge. Thus the spaces of communication are not limited to the situation of the utterances' production. Moreover, knowledge production by the actors and the way the actors do it depends strongly on their environment. For example an inquiry task where students have to design experiments to test a conjecture, seems very open whereas it could be closed if, to carry it out, the students had to use an imposed set of objects and measurement apparatus. In that case instead of focusing on the question, dealing with the students' environment called milieu, our theory enables us to better characterize the spaces of students' actions and compare to other classrooms where the task statement is the same but the milieus are different.

The didactic contract includes the three concepts to the extent that the teacher's and the students' reciprocal expectations depend on the knowledge content, its evolution, the way the teacher and students process their actions on their environment with it.

This concept accounts for the way the communicative processes are regulated in the classroom for the whole life of the class and thus accounts for the evolution of this life during an academic year. Some components of the contract are norms established for the whole academic year whereas other components like teacher's and students' expectations during a task strongly depend on the task and the precise knowledge at stake.

These concepts allow us to approach the complexity of classrooms and thus to use different scales of analysis. For example, when a student intervenes during a debate, this intervention cannot be only interpreted on the basis of what happens during this moment. Indeed the didactic contract established during the whole year can help understand this intervention. Moreover, the argument involved in this intervention should be interpreted with regard to the elements of knowledge introduced before, including a rather long time ago. This example shows the necessary linkage of scales, the scale of the intervention (micro scale) and a larger scale at the level of weeks or of the whole academic year. This notion of scales is developed below.

Analyses According to the Three Scales of Analysis: Macro, Meso, Micro

As we argue below, the learning/teaching process needs to be understood at different scale-levels. To understand the reality as a process at a given scale level, one has to relate the facts and events selected at a scale to those at another scale. Thus researchers have to identify different techniques in order to describe the reality at different scales, then to network these different descriptions.

Macro scale In our research studies, the macro scale analysis was done for the two observed classrooms during a teaching sequence on a specific topic in physics, mechanics (grade 10). As we have already discussed, the macro view cannot be directly constructed from video data; in our case it means that the effective taught knowledge in a classroom has to be reconstructed from lower scale analyses and from teacher's documents in relation to the official curriculum. Figure 1 presents this reconstruction, the conceptual structure of the teaching sequence in the two observed classes; it appears that the order of presentation of the concepts are different in parts I: in class 1 the concept of force is introduced by the effects whereas in class 2, the notion of action is introduced first and then the concept of force. Let us note that class 1 followed a teaching sequence designed in a group where teachers and researchers work together (Tiberghien, Vince, and Giadioz, 2009; Tiberghien et al., 2011)

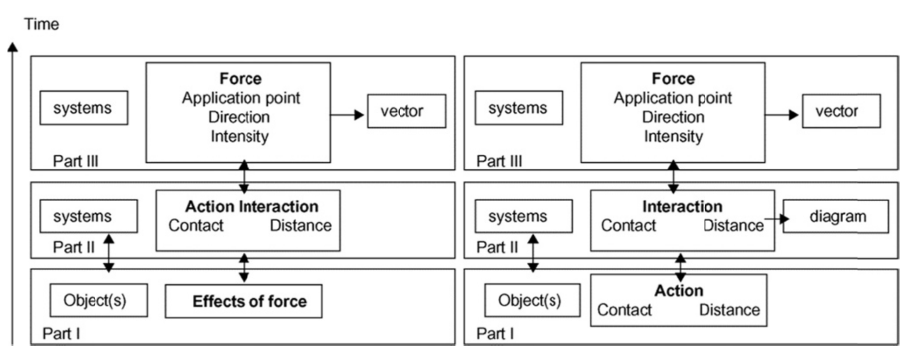

Figure 1. Structure of the taught sequences by two teachers for the introduction of dynamics.

As discussed in part 2, this macro-level corresponds to the total duration during which classrooms are studied. This is a kind of description that allows us to situate lower level events. More generally, the scale at a level N serves as reference to situate events at lower levels. Metaphorically, it is like in language: the level of word, of sentence, of text. Some aspects of the word can be and have to be understood at the word level, but in order to adequately understand the meaning of a word, one has to situate the word in a sentence, etc.

Mesoscale: the Case of Themes

Our study As presented in the theoretical framework, the focus is on what and how knowledge is involved in the transactions; consequently we aimed to account for knowledge involved in the classroom communication during a teaching sequence. This is why we chose a thematic analysis that accounts for the meaning of knowledge that is really staged in the classroom and its temporal evolution (Ash, 2008; Tiberghien & Malkoun, 2009).

A session includes several themes; each theme can be dealt with by the class with different shaped patterns of communication; however going from one theme to another involves an introduction and a conclusion whatever the shape it takes (Cross & al., 2009). The shape is varied, the teacher moves from place to place, erases the blackboard, or gives a summary at the end and explicitly introduces a new theme. We consider that this change should involve observable clues in the classroom communication. Changing themes corresponds to a modification of the object of the transactions between the teacher and the students. Its duration ranges from a few minutes to more than half an hour; the granularity of knowledge is lower than that of knowledge included in the whole sequence and bigger than an element of knowledge given in a single utterance.

A theme can constitute *a unit of analysis*; thus the video recording of the sessions is broken down into different units. Structuring by theme is not coding in the sense of a number associated with the presence or absence (or intermediary scale) of an event according to definite criteria; this is an example of structuring video (figure 2).

At the same time each video extract of a theme is still analogical to the classroom situation to the extent that the relative times of events that take place within the extract are kept. However, this is true only if *the duration of the event is smaller or equal to the duration of the extract*. For example if a whole session is devoted to laboratory work or to the correction of an important exam, these events that give meaning to the whole session are not given by the extract. More generally, the intentionality of human practices means that the behaviour of the teacher or a student cannot be explained by what is going on in the situation. This emphasizes the importance of being aware that going to a smaller scale of analysis cannot give the structuring of the situation at a higher scale (Lemke, 2001).

One may say that there is a kind of over determination of higher levels on lower levels. For instance, it is very difficult to understand how a theme changes without appealing to a higher level structure within which it is possible to understand this change. In a similar way, if one wants to understand some conversational shift at a micro-level, one needs to identify what may explain this shift in the actual theme. We can propose a general rule: at some moments, one necessarily needs a n+1 level structure or higher to understand events situated at level n.

Session	Time (min)	Themes in class 1	Themes in class 2	Time (min)	Session
		………………….			
S 2	6:13	1. Graph representation	(other topic)		
	13:35	2. Interactions for various situations	1. Effects of force on the motion of a object	18	SI
		3. Situations for chosen systems in interactions	*2. Interactions*		
	1:25	4. Introduction of the general theme of the notion of force	2a. Interactions = A acts on B then B acts on A	14:33	
	18:44	5. Determination of phases of motion of an object, direction of action on this object, variation of velocity	2b. Interactions at distance and contact interactions	4: 39	
	10:41	6. Analysis of interactions for different phases of motion of an object (case of a medicine-ball)	1 Revision of interactions	1: 31	S II
	4:41	7. Introduction of the force and its vector representation and of the principle of reciprocal actions	2. Modelling actions by the forces (representation and measurement of forces)	34: 00	
	9:23	8. Using (exercising) force and its vector representation from interactions (use of the full model of interactions)	3. Force and mass	10.26	
S 3	5:14	1. Interactions: relations between a symbolic representation and one or several material situations	4. Lists of forces which compensate or not according to the motion	44:48	
	10:10	2. Representation of force modelling an interaction (not length of vectors)	…..		S IV
	30:31	3. Representation of force modelling a moving object			

Figure 2. Comparison of the development of themes in two classes (grade 10) for the introduction of the notion of force (in class 1 the notion of action has been introduced in session 1 not in this table). The bold line between the cells means a new session, a theme in italic includes several sub-themes. (extract from Malkoun, 2007, p. 80).

With this respect, analyses by themes structure the development in time of the taught knowledge of a whole sequence (figure 2). Figure 2 gives an example of this analysis in two classes (grade 10) for a part of mechanics teaching. It shows that force is introduced differently according to the classroom, and that some parts of knowledge like the vector representation of forces is developed more in class 1 than in class 2. More generally, such a figure gives a representation of the evolution of knowledge in a given classroom. Let us note that the theme title plays an important role in accounting for this knowledge evolution. This title should account for what is effectively involved in the classroom, in particular, all the words of the title should be in the classroom discourse; the title should not come from the titles of the official curriculum. The title plays the role of a short summary, in a synoptic perspective.

This unit at the meso scale is particularly relevant to investigating the students' and teacher's responsibility in knowledge development and in its display (topogenesis). The didactic contract, taking into account the situation, can also be analysed in depth in each unit (Tiberghien & Malkoun, 2007; Malkoun, 2007). We have chosen to use narrative to account for *what* knowledge the teacher and the students introduce and *how* they deal with it during the theme. The narrative is about the "slice of life" story of the class from the knowledge perspective, *it does not dissociate what and how* knowledge lives in classrooms.

We give a short example of this type of analysis. It comes from theme 2 of session 2 in class 1 (figure 2). During this theme, the class is doing homework correction.

> With the help of the model of interactions, draw the system-interactions diagram describing the following situations. The underlined word indicates the object corresponding to the system considered.
>
> 1. a) An object put down on a table.
>   b) A table on which an object is put down.
> 2. The Earth, planet of the Sun and which has a natural satellite, the Moon (the interactions involving the other bodies are neglected).

Figure 3. Extract of the statement of the exercises.

The exercise is given in figure 3 and the student's correction drawn on the blackboard by a student is given in figure 4 part 1, and the right solution figure 4 part 2. Malkoun (2007) analysed this theme as the following:

> The students, who are at the blackboard, make the correction of the exercises and when the diagrams are drawn, in a first step the teacher reformulates with words the diagram and the students discuss the proposals, in a second step the teacher asks the student to correct their errors on their notebook. [These two steps overlap….]
>
> The use of the diagrams brings out students' difficulties on the difference between the Earth and the ground and on the role of the air. The first difficulty leads the teacher to introduce a new element of knowledge, the direction of the action of one object on another, which, in fact, is planned later on in the teaching sequence. For that element of knowledge, the teacher takes the responsibility of its introduction. On the reverse, the students [at the blackboard] who make the correction take the responsibility of introducing

> knowledge in drawing their diagram. The students seated in the classroom take also the responsibility of putting some drawings in question with arguments. Then in this theme, the teacher and the students share the responsibility of dealing with knowledge. (Malkoun, 2007, p. 150)

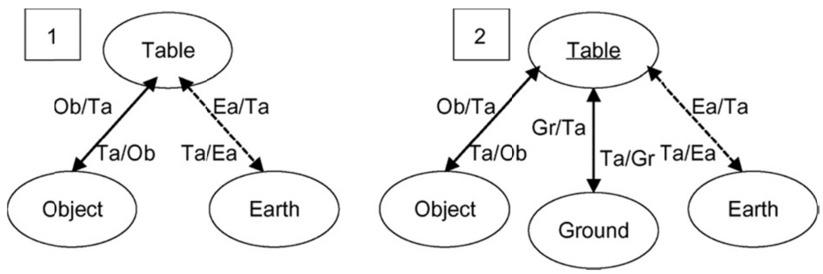

Figure 4. part 1: student's solution, part 2: correct solution (systems are represented by ellipses, and the studied system is underlined, contact interaction between two systems is represented by full lines and distance contact is represented by dotted lines).

Such an analysis is possible because the unit at meso-scale corresponds to a time scale that is relevant to describing and interpreting classroom phenomena. This analysis is supplemented with those at a smaller scale presented below.

General comments This analysis by themes illustrates an important difference between theme analysis and coding. Coding involves categories, like classroom organization or didactic phases, which are formally coded with fixed categories. On the other hand, theme consists of dividing a discourse. It is not a categorisation in which a part of the video is associated with a category chosen among a set. A theme is a narrative unit, giving a part of the story of knowledge as it unfolds in the didactic process. Thus in both cases, videos are divided into parts, but only the coding can lead to statistical analyses.

Micro scale Two different micro scale analyses are presented and discussed.

Coding at micro scale: facets We present one of the types of coding at micro scale used in our studies which combines content analysis and systematic coding called facet coding. Analyses in terms of facet account for the meaning of knowledge at a fine granularity level. The idea of facets comes from Minstrell (1992) and Gallili & Hazan (2000). A facet is a simple sentence which can be an element of a theory or a concept, of a procedure, of an epistemological statement, of a skill, or more generally any component of knowledge whatever it is, scientific, everyday, abstract, concrete, etc. The set of facets constitutes the reference to analysing the classroom discourse.

The set of facets that we have created for this reconstruction is based on an analysis of the 'knowledge to be taught' (curriculum, textbooks) and on the class's production in an iterative approach.

Here is an example of the analysis of the classroom discourse in terms of facets. This example comes from a situation in class 1 during part I of the sequence on dynamics, theme 2 of session 2 (figure 2). The transcription extract corresponds to the part of the exercise given figure 3. The correct solution is given in figure 4 part 2. Let us note that, before this correction in the previous session, the students were introduced to a "model" involving a semiotic system (graphic representation) where an object (the notion of system is introduced later on) is represented by an ellipse and the action of contact between two objects by a full arrow, the action at distance by a dotted arrow.

A student writes his solution on the blackboard (see figure 4, part 1) (In this extract E and M stand for students and T stands for Teacher, inaud. stands for inaudible). Note that, in French, soil and Earth correspond to the same word, "terre".

18 T [...] the ground and the Earth is it the same thing?
19 St no
20 T the action of the Earth on the table how do you imagine it? What does the table tend to do?
21 St1 (inaud.) a force
22 T it is an action that attracts the table towards where?
23 St1 mm downwards
..... [Turns 24, 25, 26]
27 T what does it tend to, what does it do?
28 St it does not move
29 T yes it prevents the object from falling that is it prevents the object from sinking into, on the contrary mm how does the ground act on your feet? Does it attract my feet? No on the contrary the ground acts upward, [...]
30 St the ground
31 T the ground, thus it can be garden soil (terre) but even if it is garden soil (terre) it is not the Earth (Terre) as an object. The action of the ground prevents the table from sinking whereas the Earth attracts towards its centre on the contrary

From our analysis, speech turns 20 to 23 (Teacher and students) correspond to the facet: "The action of the Earth is always downwards"; turns 20 and 22 also involve the facet: "The Earth always acts on (attracts) the object", and turns 29 and 31 involve the facet: "The action exerted by the Earth and the action exerted by the ground are not the same".

When coding an extract with a facet, this facet is associated with the theme in which this extract is situated and is noted as "new" or "re-used". A "new facet" corresponds to an element of knowledge introduced for the first time in the whole class, and a 're-used facet' corresponds to an element of knowledge already introduced at the whole class level. We also group the facets according to the notions or skills, epistemological statements, etc (table 3).

In this study our way of grouping the facets is mainly oriented by the conceptual analysis of the taught knowledge. Here a comment is necessary, this coding could be improved in associating who (a single contributor (teacher, student), several contributors, etc.) says the utterance coded as a facet; and thus contribute more clearly to the analysis in terms of topogenesis at a micro level.

The facets being systematically situated in a theme, their coding is done in relation to the analysis in themes; thus a relation between scales of analysis is introduced (Tiberghien and Malkoun, 2010).

Transaction at microscale: roles of interactions and of knowledge

This analysis does not involve coding, it aims to construct classroom phenomena of transactions where the roles of knowledge and interactions are differentiated and related. It is a further step of our studies on classroom practices (Malkoun & Tiberghien, 2008) which is based on the hypothesis involved in the theory of joint actions in didactics stating that, according to the moments of a classroom life, some types of knowledge will give a particular pattern to interactions, or on the other hand that some patterns of interactions will allow the emergence and the construction for new elements of knowledge. We suppose that specific types of relations between knowledge and interactions can be found; they are called "nodes". Let us give just two examples. The first one illustrates the node where *knowledge which involves rules guides the interactions*. This example comes from theme 2 in class 1 presented above. In this classroom, the rules of the diagram given figure 4 part 2 are shared among the class. The following takes place just after a student drew the diagram given in figure 4 part 1 on the blackboard. (St X and St Y are two different students):

1 T: […] what is missing in the diagram at the blackboard?
2 St X: he has forgotten to underline
3 St Y: underline
4 P: here it is the studied system, that is the object, must be underlined

The teacher asks students to evaluate a representation, the students propose that which she is waiting for and evaluate it on the basis of rules. This is a node where the didactic contract clearly appears. When this type of interaction is involved, *the fact that most of the students know the rules of the semiotic system shapes the interactions*.

The second example shows the reverse in the sense that *knowledge emerges from interaction*. This example comes from the same theme in a discussion just following the previous extract; a student (St 1) proposed another solution:

5 St 1: between the table and the earth there is a contact arrow [full line]
6 T: ah like this
7 St 1: because the earth heu the table is put on it
8 T: (*T goes from the back of the classroom to the blackboard*) do you understand what St1 did? She [St 1] drew a full line [between table and

earth, figure 4 part 1] instead of drawing a dotted line what do you think about it?
[…] [other students intervene]
13 St1: no because if we look at the object it is put on the table and it is the table which is on the soil/earth (terre) therefore it is not direct while the table will inevitably touch something
14 T: ah so St1 says the table will inevitably touch something it touches the earth (terre)
15 St 1: if it is in the garden
16 T: if it is in the garden and if it is here
17 St1+ St2: it touches the ground
18 T: it touches the ground and the ground and the earth is it the same thing?

In this example, a student (St1) takes the initiative to propose another solution with arguments; she opens the focus of the debate, this *focus was not predefined before the interactions*.

This type of analysis at micro level is close to narrative and does not involve coding. However it aims to construct classroom phenomena about the relations between elements of knowledge and shape of interactions. Knowledge can shape the interactions, and the interactions can make elements of knowledge appear where it was not expected. This last case can happen only in classrooms where interactions during which the participants' points of view can be debated and thus the shape of interactions is not predetermined. When in a classroom, some knowledge rules are largely shared, like forms of expression (we should say force of X on Y) or rules of representation of a diagram, and that transactions involved these rules, very likely the interaction will be strongly shaped in such a way that it will involve a call to these rules.

General comments

These two examples, coding in terms of facets and analyses of nodes between interaction and knowledge show several main differences on:

- their relations to meso and macro scales. Facet coding covers the whole sequence and has strong relationships with both meso and macro scales whereas nodes introduce didactic phenomena with typical patterns.
- Their genericness. Each facet is specific of an element of knowledge, a node is straightaway characterized at a more generic level, the emergence of knowledge and its type.
- Their treatment. Numerical treatments are done with facets leading to graph representations, and the proposals of the concepts of density and continuity; these treatments lead to a large distance between each video clips corresponding to a facet and these concepts and consequently classroom analyses. On the reverse, nodes can be easily connected to the video clips themselves.

Relations Between the Different Ways of Analyses

Our way of coding in terms of facets retains the temporality or in other words it keeps the time when the idea given by the facet was involved in the classroom transactions. This coding is carried out in the meso structure of themes. Thus we can introduce the two notions of density and continuity of taught knowledge which incorporates the temporality of taught knowledge, what we call chronogenesis.

The notion of "density" of knowledge informs the dynamics of 'taught knowledge'. The density by theme is the number of facets of one or several types in relation to the duration of a theme; the global density is the number of facets divided by the total duration of teaching (given in minutes) (Tiberghien & Malkoun 2007). Figure 5 gives the density of new and reused knowledge by themes; it shows that *reused knowledge* is denser at the end of the sequence and that almost no new knowledge is introduced during the last sessions in the two classes. It also shows the non regularity in the introduction of new knowledge. For example, in class 1, theme 7 (session II) is very dense in new knowledge; in this theme the teacher presents the model of force (force which models action and force as a vector) during a short period of time.

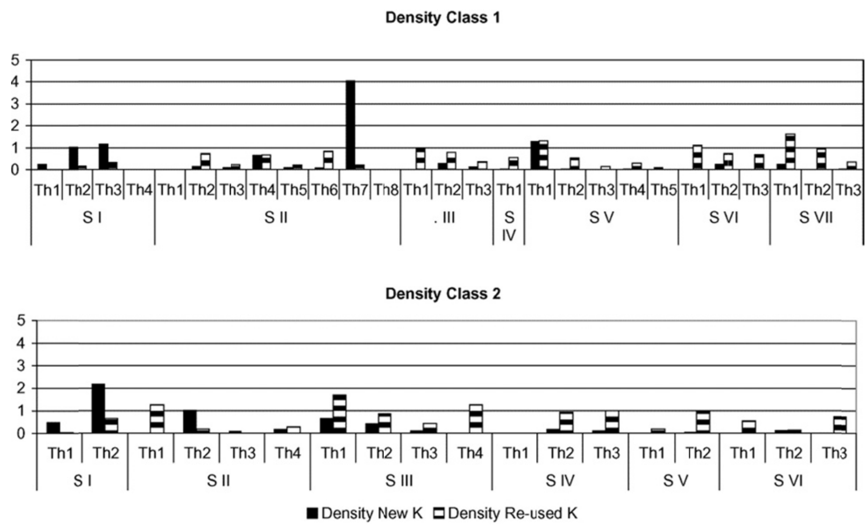

Figure 5. Density of new and re-used knowledge by theme (Th) and session (S) for the two classes.

Another way of representing taught knowledge is to select the facets which are the most reused. It allows us to know which aspects of knowledge are given emphasis in a class. Table 3 confirms the difference between the two classes, in that action (relative action of a system on another – interaction between two systems) plays an important role in class 1, whereas in class 2, only force (relative force – interaction) is involved.

Table 3. Number of times that some of the most frequent facets are reused in the two classes (Malkoun, 2007) (WC= whole class)

Groups of conceptual facets and representation	*Facets*	*Class 1 (WC)*	*Class 2 (WC)*
Action - Interaction	When object A is in contact with object B it acts on it	**20**	2
Force - Interaction	When object A is in contact with other objects, it exerts a force on these objects	1	**12**
Motion	The motion of a point is rectilinear when its trajectory is a straight line.	8	14
Representing	Force	**11**	6

It also shows the importance of representations in class 1, in particular for vector force. It is useful to have a graphic representation of the most frequent elements of knowledge involved during the teaching sequence (figure 6).

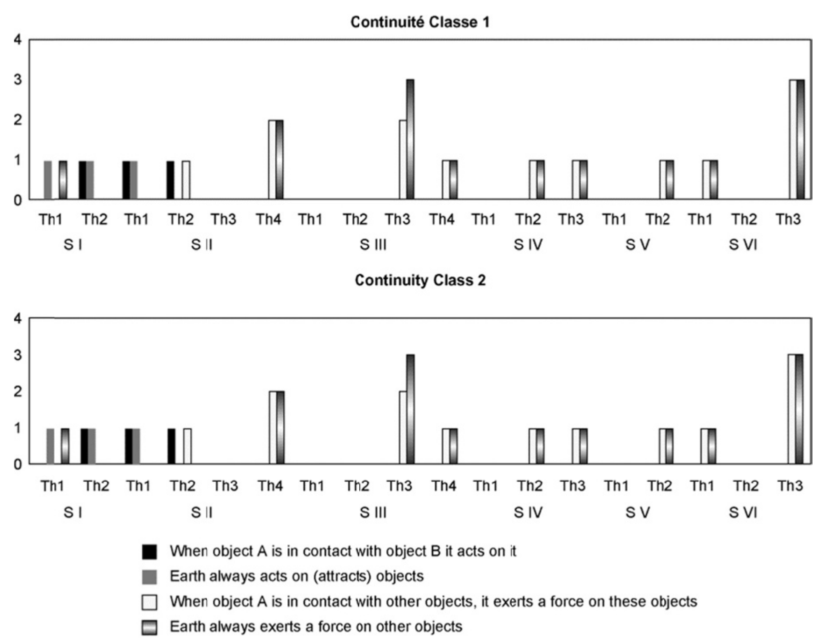

Figure 6. Distribution of the most frequent facets over the duration of the teaching sequence, presented in themes and sessions.

Figures 5 and 6 illustrate relations between macro, meso and micro scales. The whole teaching sequence is represented, and structured by themes, the facets are situated in the theme.

It appears that the theme, which is at meso level, plays a central role for the following reasons:

- A theme is the framework for the microscopic analysis: the facets are situated by theme and at the same time feed the narrative of the theme.
- A theme is used as a unit for the density of knowledge.
- Each theme is analysed in terms of narrative of what happens in the classroom; it *accounts for the life of the classroom in relation to knowledge*; it is a slice of classroom life from the knowledge point of view. It retains *an analogical component to the classroom life*.
- A theme, as an analogical component to the classroom life, enables situating the analyses in terms of facets in the life of the class. These analyses have their autonomy, but they are interpreted owing to the themes that serve as reference in the chronogenesis.
- The set of the themes accounts for the development in time of the conceptual organization of the teaching sequence and this set is in coherence with the macro scale analysis of the conceptual structure of the sequence (example figures 1 and 2).

This importance of themes come from our theoretical choices to include a mesoscopic scale; in particular it allows contextualising the facet with the same perspective focused on knowledge involved in the classroom transactions.

In our studies presented here, the articulation between the meso and micro are made *with a collective perspective*; articulate collective - individual and the different scales would be necessary to better understand the respective roles of the teacher and the students. These roles could be characterized for each extract in which a facet is involved. This perspective goes in the same direction as what Sensevy and his collaborators call “learning games” in reference to language games of Wittgenstein. A “learning game” corresponds to transactions between the teacher and the students where diverse types of knowledge are at stake, involving a change in the contract and in the milieu of the situation (Sensevy, Mercier, Schubauer-Leoni, Ligozat, & Perrot, 2005 ; Marlot, 2008).

General comments We have attempted to represent the complexity of classroom life which videos account for with diverse representations (figures 1, 2, 5, 6 Table 3) and the narratives. A similar approach is shared by Barron (2007) who makes explicit the importance of these diverse treatments due to the complexity of the studied situations:

> In my case, I chose to combine what Bruner (1986) described as a paradigmatic approach (coding and statistical analysis) with narrative approach (that preserved the sequence of interactions). Within the narrative approach, I used three types of representation to convey the complexity of the interaction. First I used *transcripts to illustrate key aspects of dialogue*; second, I provided *behavioural descriptions* that conveyed aspects of the interaction such as facial expression, tone, gesture as they occurred across short periods of time; and third, I used still *frames to further illustrate* the body positioning of the interactions students at key points.” […] *The problems of re-representing the complexity in video are not trivial and we*

> *are in the beginning stages of figuring out field creative ways to do this. We can learn a great deal form one another's attempts to do this well within and across disciplines*. (Barron, 2007, p. 175).

The complexity in our approach has been grasped with multiple scale analyses and with a combination of treatments like coding and narratives. The multiple scales can allow to contextualise an event of a smaller scale into a unit at larger scale. This contextualisation reduces the distance between the analysis and the video data. However, all analyses imply a gap with the video data, which can be more or less large and can appear at different steps of the analysis.

In short, coding video makes a "transformation" or creates a gap since it transform video data which is analogical to the situation into codes or even digits; human acts are transformed into numbers, and acts that can happen in different contexts are considered as equivalent. The approach with narratives that *most of the time involve selection of relevant parts* are close to the video data which are selected first; however gaps are created, they happen at two steps, the selection step and when the analysis goes from the specific to the generic. Thus gaps occur in both types of treatment but not in the same way; in a narrative the passage from specificity to genericness could be less apparent than in coding but it occurs. To be aware of these gaps should help the researchers in their conclusions not to forget that they have selected and transformed components of human actions.

CONCLUSION

In this chapter we intended to propose elements of reflection about the types of analyses that video data of classrooms or other similar situations make possible. In the first part we introduced the main characteristics of video. All these characteristics make that video keeps the analogical character of the recorded situation. Thus video contains an enormous quantity of information and in the same time is very specific to the recorded situation.

These characteristics make that there are strong relationships between techniques of filming and theory. These relations were underlined very early on, in the first uses of film by researchers like Margaret Mead and Gregory Bateson in the thirties. This use of films by anthropologists emphasizes the richness of this type of data; films or videos make communication visible to the extent that they keep an analogical relation to the situation itself in particular with regard to space and time. The succession of events is similar and the relative time of events is kept; the respective places of the actors can also be conserved. This analogical aspect means that video can account for a part of the classroom complexity of the situations. Nevertheless, video cannot account for the whole situation and for its links with school organization, homework, parents, etc.; thus video data should be completed by others.

In the second part, analyses of videos are discussed on three methodological components, (1) sampling, (2) analysis in terms of narrative and coding and (3) the use of multiple scale analysis to approach the complexity of classroom situations.

Concerning sampling, we commented the duration over which video data are taken, for example one or two teaching sessions or a series of sessions over months or years. This raises the question of what the researcher considers a priori as invariant or generic in order to generalize its results. The discussion focused on the treatment type of video data, that is to say on the type of transformations carried out by the researcher. Three main types were discussed. One type of treatment consists of using narratives to account for the events and their succession that happen in the situation shown in the video. To the extent that some events, their context and their evolution with time are taken into account, the narratives have an analogical relation to the effective situation. Coding is another type of treatment that implies selecting an event or a series of events, and associating this selection with a code. The information given by the video being transformed into a succession of codes becomes discrete. Between these two types of treatment there are intermediaries, which consist of sharing the whole video into "clips" depending on criteria that can be diverse. In this case each clip can be treated with narratives; for example if a discussion at the classroom level or between students involves interactions or topics which are particularly relevant for the study, the researcher can create an extract and then analyse it with narratives. Narratives and coding are not exclusive treatments, in many research studies they are used together. They can be two different complementary ways of tackling the complexity of situations like those of classrooms. Another way of approaching this complexity is to analyse videos at different scales with the main idea that the organization at a level n cannot be given by the sum of organizations at a level n-1 (Lemke & Sabelli, 2008).

In the third part we give an example of a research study that involves both narratives and coding and analyses at different scales. It aims at developing the reflection on how to manage different time scales in relation to narratives and coding and the associated representations. This study focused on what and how knowledge is involved in a classroom and evolves during a teaching sequence on the basis of the teacher's and students' actions at three scales of time (weeks, hours, minutes and seconds), and scales of knowledge elements (conceptual organization, theme, facet). It proposes several representations of knowledge evolution with time.

In conclusion, the video of classrooms or similar situations, due to their analogical character with the situations and thus their specificity, accounts for the teacher's and students' practice and can then produce a series of evidence that has no equivalent among the other data in human and social sciences like observation notes, interviews and questionnaires. The challenge is to exploit this richness.

NOTES

1 See Margaret Mead and Gregory Bateson with Stewart Brand (1976, CoEvolutionary Quarterly, June 1976, Issue no. 10, pp. 32–44 (web site: http://www.oikos.org/forgod.htm)

2 CoEvolutionary Quarterly, June 1976, Issue no. 10, pp. 32-44

3 Betty Thompson. 'Development and Trial Applications of Method for Identifying Non-Vocal Parent-Child Communications in Research Film,' (Teachers College, New York, 1970, Ph.D. thesis)

4 Descombes, V. (1996). *Les institutions du sens*. Paris: Minuit.

5 Here the meaning of the term "knowledge" includes the act of knowing, and also covers non scientific knowledge and any knowledge including skills.

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8. TEACHING ACTIVITIES AND LANGUAGE USE IN SCIENCE CLASSROOMS

Categories and Levels of Analysis as Tools for Interpretation

INTRODUCTION

The aim of this chapter is to discuss video studies and new ways of coding, and how coding categories and levels of analyses perform as analytical tools when analysing teaching and learning in science classrooms. Through in-depth analyses of video data from lower secondary science classrooms, we show how different categories and levels of analyses support diversified interpretations and conclusions. By moving between different categories with different levels of functioning, we show how conclusions arrived on the basis of one level of coding might be scrutinized, and challenged, if you use another level of coding as the basis for making interpretations of the data. Within studies of teaching and learning, we argue that scholars often tend to give preference to some authoritative levels or analytic categories in favour of others (often macro level analysis), without any explicit criteria and rationale for these preferences (Nespor, 2004; 2000). In the following analyses, we will elaborate on conceptual categories and functioning levels as lenses through which we explore and analyze teaching and learning opportunities in science classrooms.

Prevalent conceptual categories for analysing classroom activities such as teacher led instruction, individual work and group work document how teaching and learning activities in science classrooms paraphrase a very well known and stable pattern of classroom interaction based upon principles of teacher-centred instruction (Cuban, 1993; Driver, 1983; Goodlad, 1984; Jorde, 1986; Lemke, 1990; Mortimer & Scott, 2003). Despite massive reform efforts encouraging new and student active ways of working like inquiry based learning, teaching for understanding, an enhanced pressure on hands on activities and laboratory work, researchers continue to portray how science teachers reproduce a very stable pattern of interaction and learning in their classrooms based on teacher led instruction, seat work, and (some) practical assignments. In this article, we challenge this picture by critically examining and discussing coding categories and levels. At a first glance, and based on one level of analysis, our findings reaffirm existing portraits from science classrooms. However, substantial in-depth analyses and critical examinations of categories reveal a more complex and nuanced picture of the teaching and learning

Doris Jorde and Justin Dillon (Eds.), Science Education Research and Practice in Europe: Retrospective and Prospective, 181–202.

activities that take place. Contrary to what is portrayed in earlier studies, our analyses suggest for example, that teacher led instruction in the observed classrooms is more dialogic and less authoritarian and rigid than indicated in earlier studies. Although our analyses from Norwegian lower secondary classrooms show that teacher-centred instruction still dominates Norwegian science classrooms, these teacher led, whole-class instruction sessions also include opportunities for student-initiated actions (Bergem, 2009; Ødegaard & Arnesen, 2010). Recent studies of communicative patterns and whole-class interactions from Scandinavian classrooms support these developments of classroom discourses (Aukrust, 2003; Klette, 2003; Sahlström, 1999). Furthermore, dependent on the targeted level and unit for analyses, we see that our science teachers offer ambiguous learning situations. In-depth analyses of classroom discourse reveal how students on the one hand are offered increased opportunities to talk in science lessons. On the other hand, these conversations are often played out in an everyday social language (Mortimer & Scott, 2003) with weak links to scientific concepts and frameworks essential for understanding science as a field of scientific and thematic practice. To design for student engagement and student initiatives is itself no guarantee for extended opportunities for science learning. By moving between different levels and units of analysis, we describe processes, activities and possible changes that are evident in science classrooms, and so give life to a more many-faceted and nuanced picture of the classroom processes that take place.

Video records provide extended opportunities for critically examining and re-examining classroom interactions and classroom events. The production of data within video design allows for nuanced and multifaceted layers of analyses focusing on different levels (macro, meso or micro) with different conceptual coding categories (Klette, 2010; Popkewitz, 2000).

The data highlighted in this chapter is drawn from a video-based classroom study (PISA+) from six science classrooms at lower secondary level in Norway. The video study PISA+ (Pluss: Project on Learning and Teaching Strategies in School, see www.uv.uio.no/ils/english/research/projects/pisa-pluss/index.html) is a project on learning and teaching in schools, including data from mathematics, science and reading classrooms (Klette et al., 2008). The research project was established to pursue and enlighten problematic PISA findings in the Norwegian context in mathematics, science and reading. The main aims of the PISA + project have been to describe and scrutinize the pedagogical processes that underlie the Norwegian PISA results and to attempt to transform some of the PISA findings into concrete suggestions for improving Norwegian education in the perspective of life-long learning.

THEORETICAL PERSPECTIVES

Analytical Framework

Teaching and learning in classrooms take place in complex settings involving layers of actors and meanings. As framework for interpretations, Nespor (2004) uses what he calls scales and analytical categories, serving as contexts and hosts for analytical endeavours. Nespor (2004), leaning on Massey, underscores scales as envelopes for disclosing time-spatial activities and ordering mechanisms in schools and classrooms. Scales demarcate and place limits on interpretations available, and for that reason scholars should be explicit about preferred scales for analyses. Lemke (2000) distinguishes, for example, between time, space, actors, matter, and objects as scales for interpretations and shows how different scales can serve as possible candidates for interpretative ambitions. Within studies of teaching and learning, scholars tend to privilege one preferred scale (often time scales in the favour of others) even though there is often no rationale provided for these analytical preferences. In order to account for these complexities when we are studying classrooms, we suggest making explicit the preferred scales for investigation, whatever they are.

In the following analyses we will use actors, conceptual categories and levels as the analytical framework for interpretation. We specifically focus on three approaches; instructional format, classroom discourse and features of language used in science classrooms for examining classroom processes, and thereby show how these approaches and the analytical framework *together* might enrich our understanding of what is going on in science classrooms. We lean on Lemke's (2000) distinction between micro, meso and macro levels as three levels of time. Macro level analyses often involve teaching sequences covering a longer time scale (thematic unit, a course, an academic year) while meso level often use sequences, sessions and units for analyses. Micro level analyses focus on smaller segments of interaction in the class (i.e. student – student interaction, teacher –student interaction). The distinction between micro, meso and macro as three levels of analyses is however not restricted to time periods. Instructional formats (macro level), classroom discourse (meso level) and scientific features of language used (micro level) could in addition be seen as three hierarchical levels of analyzing classroom talk. Lemke (2000) suggests that it is useful to analyze hierarchies in groups of three levels at once. Call one level of any such group the focal point (N) that all other levels (above and below) would shed light on. The level N is however never the top level, Lemke underscores:

> "…interactions on the focal level are not free to range over all the possibilities afforded them: they are also constrained by being themselves part of longer timescale processes at level N + 1.." (p 277)

In our analyses we have used teachers' instructional formats, features of classroom discourse and language used in science classrooms as three interdependent hierarchical levels of analyzing patterns of interaction and classroom talk in the science classroom. Each layer could be analyzed within its own theoretical framework and preferred unit of analyses. Analyzed together they may however expand and enrich our capacity for interpreting meaning from complex social settings such as classroom learning.

Based on existing studies we are introduced to science classrooms as sites of learning centered around whole class instruction and plenary teaching where the teachers dominate, regulate and monitor most of the classroom talk and classroom interaction. The students are subsequently given little opportunity for talking science and raising their voices. In the next section we expand on this general portrait of science lessons by paying attention to what research tells about instructional format and classroom discourse and language features from science classrooms.

Instructional Format in Science Classrooms

Several studies (Cuban, 1993; Jorde, 1986; Lemke, 1990; Mortimer & Scott, 2003; Nystrand, 1997) document the pervasiveness of plenary teaching; where whole class instruction combined with individual seat work and group work/ laboratory work as the most predominate in science classrooms. Whole class instruction as plenary teaching is not however a very clear cut and definite concept and might imply quite different things. Nystrand and colleagues (1997) distinguish for example between recitation, dialogic instruction and discussion as three features of teacher led whole class instruction. Klette and colleagues (2005) elaborate between lecturing (monologues), dialogic instruction, question/answer sequences and whole class discussion as four different features of teacher led whole class instruction. By calibrating the concept of teacher led whole class instruction into more specified and distinct subcategories, such as the distinction between monologic instruction (i.e. lecturing, recitation) and dialogic instruction, we are able to explore the iterative dynamics and developments of interaction between teachers and students within the rather broad category labeled "teacher led whole class instruction". Many studies continue to use rather broad conceptual categories for describing instructional format in science classrooms and consequently end up with paraphrasing existing 'common sense' in the field of studying classroom learning (Klette, 2009; Popkewitz, 2000). The dichotomized conceptual language available furthermore tends to push the analysts into labeling the activity as *either* teacher centered instruction *or* student centered instruction and with little latitude for transcending these blurred descriptions. If we calibrate whole class instruction into subcategories such as lecturing, thematic dialogic instruction, going over the do now, classroom dialogue and question answer sequences as possible categories for teachers' instructional format we get a more elaborated and updated picture of what constitutes teachers' repertoire of whole class instruction. Barnes and his colleagues showed already in 1969 (Barnes, Britton, & Rosen, 1969) that science lessons gave more space and place for student initiated questions than recognized in other lessons and subjects. Emanuelsson and Sahlström (2008) and Klette and colleagues (Klette, 2003; Klette, et al., 2008) show how whole class instruction still dominates science and math classrooms in Sweden and Norway. These studies also underscore how whole class instruction involves extended possibilities for student initiatives and student responses compared to those described in earlier studies. Prevalent and established categories as scales and devices of interpretation might undermine more sensitive and updated versions of teachers' instructional format in today's science classrooms. In the analysis that follows we therefore calibrated whole class instruction into distinct subcategories (i.e. see figure 2 below for illustration) when aiming to disclose characteristics of instructional format in science classrooms. We distinguish between monologic instruction, dialogic instruction, question/answer sequences, whole class discussion, student presentations, tasks management, comments on misbehavior, and comments as different features of activities at play during teacher led whole class instruction.

Classroom Discourse

Learning is often portrayed as a meaning-making process, where ideas are shaped as they are expressed in language in a social context (Alexander, 2000, 2006; Mortimer & Scott, 2003; Vygotsky, 1978). Meaning is made by gaining an understanding of the substantial knowledge in a conceptual framing mediated throughout language and other artefacts. Understanding dialogues and classroom discourse is subsequently of uttermost importance when we want to understand and improve learning in science classrooms.

Wellington and Osborne (2001) classified research on classroom dialogue and show how the general dilemma of teaching science as an accepted body of knowledge and at the same time as a process of genuine enquiry where students should generate their own understanding of events and phenomenon, may influence and produce conflicts in different areas of science teaching. For instance, in the art of questioning this dilemma is apparent. It is not unusual to experience teachers asking what seems like an open-ended question, but only acknowledging one answer as correct, a so-called 'pseudo-question'(Barnes, et al., 1969) or 'guess-what's-in-my-head' game. Several studies document the pervasiveness of these 'pseudo questions' (Edwards & Mercer, 1987; Mortimer & Scott, 2003; Wells, 1985). Another well documented feature of classroom discourse is the predominance of teachers' talk within the repeated IRE and IRF pattern. Teachers dominate, regulate, define and evaluate all communication and activities in the classroom. The dominant pattern of interaction follows auxiliary a predefined IRF (E) pattern of communication (Dysthe, 1995; Edwards & Mercer, 1987; Lemke, 1990; Mortimer & Scott, 2003) where the teacher poses a questions or initiative (I) followed by a student's response (R) for then being followed up (F) or evaluated (E) by the teacher. The pupils are left with small possibilities for participation and influence within these patterns of communication, following the cited researchers. In a recent study Juzwik, Nystrand and colleagues (2008) underscore however the dynamic exchange mechanisms between monologic and dialogic instructional formats. They show how monlogic instruction formats might change to dialogic formats as the teacher opens the floor to student initiatives and competing ideas and voices.

As indicated above Barnes and colleagues recognised a certain space for student initiated questions in science classrooms already in the 1960's. Interestingly Barnes et al. (1969) show how approximately 1/3 of the questions in science are open-ended, and that compared to other subjects, science is the subject with most reasoning questions and least factual questions (Barnes, et al., 1969). While investigating the question of why students do not actively ask many questions to their teacher, Barnes found that in ‘pupil-initiated sequences’, the most frequent kind of question was about the method of carrying out a task: “What kind of pencil should we use?”. The very few other examples were requests for information for its own sake, for information to confirm an insight and for a theoretical explanation, in addition to statements made by the pupils (Barnes, et al., 1969). Questioning is often part of a general process of guiding or focusing a lesson so that it follows a path, and sticks to limits, which are part of a grand lesson plan. This involves restricting pupil participation to relevant, objective statements and using them to converge on predetermined ideas Barnes et al. argue. Thirty years later Galton – studying primary classrooms in UK – came up with rather similar conclusions. In trying to monitor changes in instructional activities at primary level in UK, Galton and his colleagues document extended possibilities for student initiatives and student questions (Galton, Hargreaves, Comber, Pell, & Wall, 1999). Most of these questions are however what they describe as ritual and practical (“how to carry out a task”). The teachers give minimal and/or restricted response to the substantial issues raised within these questions. From Norwegian classrooms Klette (2003) and Aukrust (2003) report of procedures and social climate favourable for student initiated questions while student initiated questions where the student uses questions to thematically explore a field of knowledge are rare. Examining the relation between procedural and substantial features of student initiated questions provides a strategy for studying how student initiated questions can contribute to students’ learning in science classrooms.

Language in Science Classrooms

As emphasised above the use of language in a social context is of crucial importance for science education. Learning science is learning to talk science, not only understanding science concepts but also learning to use structures and features of the scientific language. Mortimer and Scott (2003) emphasise language as a fundamental tool for learning, and, as Bakthin (1953/1980), Wertsch (1991) and others, they recognize different discipline-based social languages which can be seen as toolkits for talking and knowing. Mortimer and Scott (ibid.) use the distinction between an everyday social language and a scientific social language based on Vygotsky’s everyday and scientific concepts (Vygotsky, 1978) when they study language practices in science classrooms. They also focus on three fundamental features of the scientific social language: description (an account of a system, object or phenomenon), explanation (importing some form of a model or mechanism to account for a specific phenomenon) and generalization (a description or explanation that is independent of any specific context).

Explanation in science has been defined as importing some form of a model or mechanism to account for a specific phenomenon (Mortimer & Scott, 2003). Ogborn, Kress, Martins, and McGillicuddy (1996) point at some of the dilemmas of explanations in science classrooms. They focus on the importance of understanding the entities that models consist of before you come to the actual explanation, and that explanations provided in school science are often answers to questions posed by the teachers or the curriculum and not by the students themselves. This is quite different from the genuine enquiry you find in science. “If in science itself, phenomena can be envisaged as in need of explanation, in teaching science it is almost the other way around. The existence of an answer is the reason for posing the question.” (Ogborn, et al., 1996, p. 131) Further, this leads to that one of the crucial responsibilities of science teachers is to motivate students to ‘want what they need’. Subsequently, “… much explanation in science classrooms is not the explanation of phenomena, but is the explanation of resources the student needs in order to explain phenomena. […] For these reasons, much of the work of explaining in science classrooms looks like describing, labelling or defining. […] The entities which are to be used in explanations therefore have to be ‘talked into existence’ for students.” (Ogborn, et al., 1996). What is the role of explanations versus descriptions in our classrooms? Are the students given possibilities to engage in everyday language practices *and* scientific language practices?

DESIGN AND DATA SOURCES

The PISA+ study is an in-depth classroom video study. Six grade 9 classes (students aged 14–15 years) at six different schools were followed for 2–3 weeks in three subjects; science, mathematics and language arts. In sum 45 science lessons, 37 mathematics lessons and 44 language arts lessons were videotaped. Video-recordings from 10 cross disciplinary lessons plus video documentation of science excursions and experiments outside the classrooms were also made. The lessons were filmed using three surveillance cameras; one remote controlled following the teacher, one capturing the whole class and one focusing on a small group of students, usually two. The small student groups in science and mathematics lessons were interviewed immediately after the lesson. Teachers were interviewed twice during the 2–3 weeks. The use of surveillance cameras made the technology less intimidating. The use of the remote control camera further made it possible to back up the video documentation with participant observers to be present in the lessons; one following the group of students in order to prepare the interview and one observing the whole class. Both students and teachers had stimulated recall interviews, where video observations from the lessons were used. For more details about the methodological design and set up for the whole study, see Klette (2009).

Schools were chosen with the purpose of providing as wide a span as possible across cases regarding student background and school organization. PISA has shown that scores vary more within schools than between schools in Norway (Lie, Kjærnsli, Roe, & Turmo, 2001). This means that students from one school may represent a broad range of knowledge and literacy levels. The schools in this study represent urban and rural areas, differences in socio economic and ethnic backgrounds and, in addition, traditionally organized schools and schools with a modern organization.

The technology used in the project allowed us to conduct video initiated interviews with students immediately after the lesson. Students watched sequences from the lesson and were asked to comment on their interpretation of the events. In this way classroom observation data is compared to how the students' interpret events. Most of the students in a class were interviewed either in science, mathematics or both.

To make profiles of the instructional patterns across classrooms, each lesson has been coded on different levels with conceptual categories using the software programme Videograph®.[1] The analyses have been conducted in two stages. In stage one the lessons in all subjects were coded regarding instruction format in order to characterize typical lessons in mathematics, science and reading, and to expose similarities and differences between subjects and schools (Klette et al., 2005).

The second stage of coding was performed on the science lessons to give a more exact characterization regarding **teachers' instructional activities** (develop new content or skills, review existing knowledge, motivational activities, summary etc), **student activities** (seat work, laboratory/practical work, taking notes etc), and **language and dialogue characteristics** (scientific and everyday language, point of reference (empirical and theoretical), descriptions, explanations and generalizations, teacher expositions, teacher and students initiatives) (Arnesen & Ødegaard, 2006). The complete coding schemes are presented in Appendix I and II. In the analyses that follow we concentrate our discussion on teachers' instructional format, features of dialogues and language used in the observed science classrooms.

The video analyses of discourse and language features draw on the work of Mortimer and Scott (2003) and Lemke (1990). Taken together Mortimer, Scott and Lemke shed light on how conceptual language, coding categories and timescales are significant in analyzing meaning-making in science classrooms. However, further analyses on even smaller timescales need to be done in order to enrich the data according to the influence of student initiatives (Barnes, et al., 1969); and the significance of explanations and teacher questioning (Ogborn, et al., 1996; Wellington & Osborne, 2001).

PRESENTATION OF DATA ANALYSES

In order to gain a fuller understanding of offered learning possibilities within the video taped science classrooms, efforts were made to bring together different levels of analyses to illuminate organizational patterns, communicative patterns and thematic patterns in the observed classrooms. This study looks at three levels of analysis. The highest level being instructional format that distinguishes between teacher led instruction in whole class; group work; and individual work. The next level is aspects of the classroom dialogue; especially who initiates and influences the dialogue. The last and most fine grained level is features of language; whether scientific words are used, and characteristics of scientific statements. However, as Lemke (2000) asserts, each level in it self may have other sub-levels. For instance, instructional format has features of whole class instruction as an additional meso level, and classroom dialogue has content of student initiatives as another micro level. Even though, language is the lowest, and thus micro level in this study, it is possible to scrutinize and do even finer-grained analysis of the language aspect, making language the meso-level in that approach.

The following analyses draw on the significance of relating patterns from different levels in larger units of analyses. Lower levels can often explain patterns from higher levels, and this understanding is crucial if the goal is to alter undesirable patterns and improve teaching and learning in school science. However, by comparing videos from different classrooms and different schools we are also able to see how these moments or classroom actions are in some respect typical of their kind. The many classroom actions are seen as part of a larger-scaled and longer-termed activity system of teaching science (Lemke, 2000). By moving between different scales with different levels of functioning we hope to shed light on how they interact. We start out by discussing instructional formats in the observed science classrooms. We then turn to features of classrooms discourse such as *who* initiated the discussions and substantial elements in these dialogues. As a third approach of analysing we discuss features of language used in the observed science classrooms. We conclude the examination by discussing the many meanings of practices in science classrooms.

Instructional Format in Science Classrooms

Teachers' instructional format in science classrooms is analyzed using different sets of codes and categories, connected to teacher led instruction, group work and individual work. (See appendix I.) The analysis is performed on all three school subjects involved in the PISA+ study and thus, an interdisciplinary comparison is possible (see figure 1 below). Since we compare teaching sequences covering several weeks, this can be considered a macro level. The comparison indicates that in science education, teacher led instruction is the single most frequent activity. Language art education demonstrates a broader repertoire of practices; a recurrent mixture of teacher led instruction, individual seat work and group work (Klette, et al., 2008). Due to constraints in our research design (e.g. whole day excursions that could not be filmed) the amount of group work, which includes exercises and laboratory work, can be a bit adjusted, but still science has a special profile of teacher led instruction. At this stage one might conclude that science teaching is done in a quite traditional way with the teacher lecturing and the students mainly taking notes and listening.

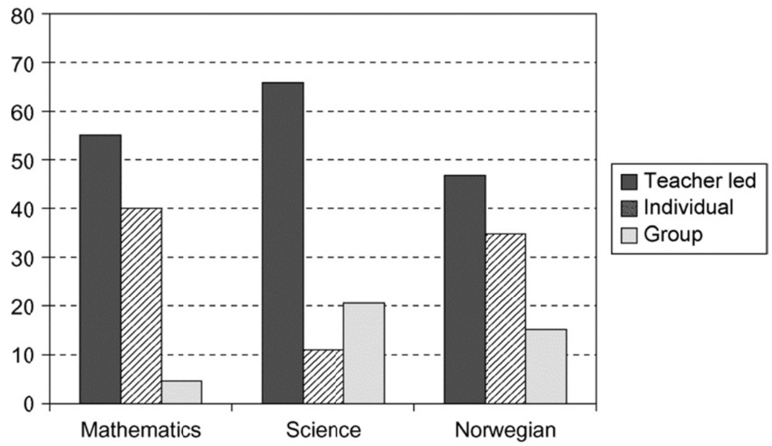

Figure 1. Instructional format in percent in the three school subjects (macro level).

However, if we distinguish the category of teacher led instruction into sub-categories, and thus look at the meso level with codes such as monologic instruction, dialogic instruction etc. (see figure 2 below), we see that for instance teacher monologues (defined as teacher lecturing for at least three minutes) are almost non-existing in the observed classrooms. On the contrary, what characterises the teaching in these classrooms is dialogic instruction where students play an active part in terms of posing questions and statements. (For definition of the coding categories see appendix I.) Whether this represents extended opportunities for meaning-making and talking science as outlined by Wellington and Osborne (2001), Lemke (1990) and Mortimer and Scott (2003), is however an open question. This will be further investigated in the next section where we use features of dialogues and language as categories of analyses. Another dominating feature of teacher led teaching in the observed science classrooms, is the role of task management. Task management in our coding manual was defined as teacher giving instructions about required student activities, assignments etc. In science this might mean giving instructions about practical work, seat work, or organising group work and excursions etc.

So far, we might conclude that teacher led *dialogic* instruction predominates the observed science classrooms, indicating ample opportunities for student initiatives and possible student involvement.

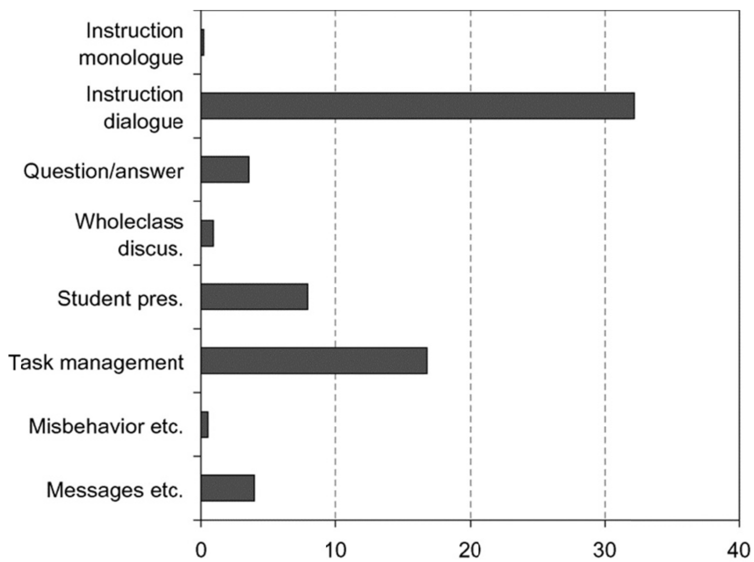

Figure 2. Features of whole class instruction in percent of filmed time in our science classrooms (meso level).

Classroom Discourse and Actors in Science Classrooms

At the second level of exploring educational processes in science classrooms, we focused on classroom discourse. While the first analyses showed an emphasis on teacher driven classroom dialogues, the second stage of analyses focused on dialogue features and initiation patterns. In our coding categories of classroom dialogue (for definition of the codes, see appendix II) we have coded for teacher and student initiative, defined as a sequence of questions, answers or comments initiated by either the teacher *or* the student. A third code is labelled teacher lecturing, indicating teacher talk without interruption. Unlike teacher monologue, this is not limited to three minutes. Although the teacher orchestrates most of the classroom dialogue, she or he is attentive to student initiatives, and often the flow of classroom talk is heavily influenced by student engagement.

From figure 3 we see that student initiatives are almost as frequent as teacher initiatives. Thus, our second approach of analysis, focusing on *who* initiates the conversations in class, enriches the general impression of the flow in our science classrooms. This shows that on a procedural level (e.g. who initiated the dialogue) the classroom discourse is student inclusive and provides ample room for student initiatives.

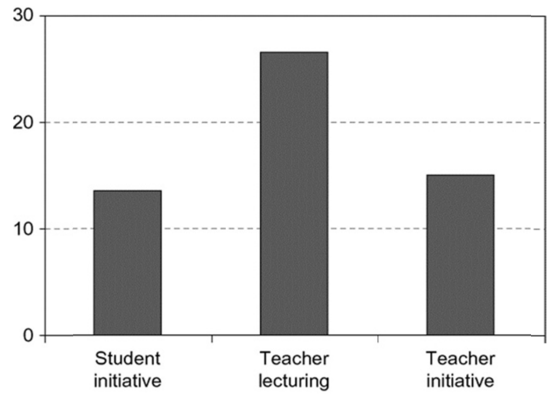

Figure 3. Classroom dialogue during teacher led instruction in percent of videotaped science lessons (meso level).

However, by narrowing down our material to substantial in-depth analyses (micro level) of the student initiations, we find that like Barnes et al. (1969), the student initiated sequences are mainly questions about ways of carrying out a task. Table 2 below illustrates an analysis of one such in-depth lesson. The lesson analysed was a quite structured science lesson about photosynthesis with both theory and practical work. As indicated from the table, of 26 student initiatives, only 7 were directly related to science issues. Although this is only one example of a lesson, the ratio of science related talk (less than 1/3 science related talk) is confirmed by cross-table analyses between student initiative and features of scientific talk. (See Ødegaard & Arnesen, 2010)

Tabel 1. Student initiative with examples from one lesson (micro level).

Student initiatives from one lesson Σ = 26	*Occurrences:*
About blackboard / taking notes: "Should we write it in our book?"	9
About practical / organization: "Who is in that group?"	7
About practical work: "What are we supposed to do?"	3
Comments to science issues: "Shouldn't it be hydrogen, not nitrogen?"	5
Own meaning making: "Is this about photosynthesis?"	2

More in-depth research on these situations will give us information on the significance of these patterns of initiative. For instance, how does the teacher respond to the different student initiatives? How much science is brought in to task management issues? Taken together, the overall picture places emphasis on task related enquiries regarding student initiated questions.

Features of Language Used in Science Classrooms

At the third analytical level for describing the complexity of science classrooms we have examined features of language. One of the categories we used for analyses is social language, which captures whether the social language used in the classroom discourse is of everyday or scientific nature. Scientific language is defined as the use of scientific concepts (Mortimer & Scott, 2003), and is coded by following the teachers' conversation with the students and includes both teacher and student talk. Our analyses show that scientific language is used in only a small part of a whole lesson. Less than 20% of coded time in our science lessons is labelled scientific language. See Ødegaard & Arnesen (2010) for more detail.

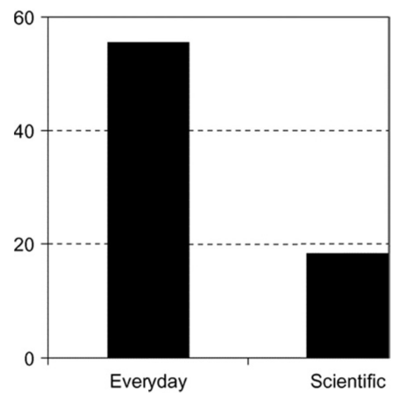

Figure 4. Social language in classroom dialogue following the teacher, in percent of videotaped science lessons (micro level).

However, we have experienced that categorising the language as "everyday" and "scientific" is problematic. We see that merely the use of scientific concepts is not a meaningful and precise definition for scientific language. In-depth analysis (micro level) of sequences labelled as everyday language in our coding might illustrate this important point. It is not enough to look at the amount of time the students are exposed to scientific concepts; the content of the talk has to be scrutinized. This is illustrated by the following example of a teacher-student dialog from a photosynthesis lesson from school 3 (a full transcript of the dialogue is available in appendix III):

T: Have you seen what comes up from the ground, the first that comes up from the ground?
S: One of those little green things.
T: Yes. Have you noticed how many leaves there is on it?
S: Two
T: Yes, good. Excellent.

Both the teacher and the student use everyday language in describing a scientific phenomena, which is labelled "little green thing" by the student. This label is not changed to a more scientific concept by the teacher throughout this sequence, and thus the label "little green thing" can continue to live on amongst the students. However, according to Lemke, this small dialogue is part of a scientific thematic pattern; "the little green thing" is given a descriptive characteristic: *green* and it is classified as having two leaves. And further into the dialogue, the teacher classifies the "the little green thing" as a dicot. In his semiotic analyses, Lemke (1990) refers to this as a nominal and a taxonomic relation. When thematic patterns are repeated they give an implicit message to the students of how science is organised. Thus, after many examples of describing and classifying organisms, in science lessons and in science text books, students will recognise this as one of the patterns of talking science. What is lacking is however a more explicit and teacher driven vocabulary that is able to link concepts like "the little green thing" to relevant scientific concepts such as sprout or seedling.

Another way of interpreting how much the students are exposed to science talk, is to code the classroom talk according to features of science brought up in the discourse. Like Mortimer and Scott (2003), we have seen that different features of scientific knowledge are focused upon in the classroom dialogue between teacher and student. In science the teacher may emphasize describing systems or phenomena, he can try to explain systems or phenomena, or he may generalize by giving a description or an explanation without specific context. In our material, only a small portion (less than 20%) of the dialogue between teacher and student contains science talk within such a framework (figure 5). In our analysis the dialogue is coded both when the dialogue occurs in whole class situations, and when the teacher moves around and has conversations with students, e.g. during practical work and seatwork.

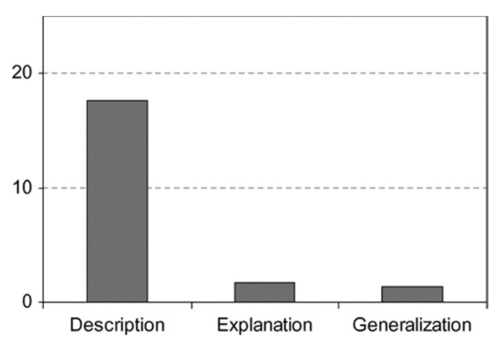

Figure 5. Use of scientific features following the teacher during the whole lesson in percent of videotaped science lessons (micro level).

As indicated from figure 5, the most frequent occurring feature is descriptions of systems or phenomena. During teacher-student conversations in class, there are minimal explanations or generalizations. Even during supervising one-to-one dialogues between teacher and student, focus is on descriptions only. The above presented excerpt from the teacher-student dialogue about the little green seedling is coded as a typical description. However, if we follow the dialogue further (for a full transcript of the dialogue, see appendix), we see that the teacher uses this description in order to build up a generalisation:

> *T: The plant kingdom is divided in two groups. One is monocots, these are the seedlings that come up from a seed with one leaf. Grass is an example of this.. […] And then there are dicots. They come up with two leaves first. [..like sunflowers..].*

So by expanding the timescale of the classroom dialogue analysis, the description becomes part of a generalisation. This is in agreement with the assumptions of Ogborn et al. (1996) described earlier. Still, there is reason to point out that in our data from science classrooms, there are so few explanations and generalisations that this can not explain the excess of descriptions. With such a strong emphasis on descriptions, we fear that the students might get an image of science as a variety of descriptive, objective facts about nature. Thus, science is portrayed as a "collection of knowledge", and the students will not have insight into understanding about the nature of science.

CONCLUSIVE DISCUSSION: THE MANY MEANINGS OF CLASSROOM PRACTICES?

Teaching and learning are complex, layered processes in which actions, themes and events are simultaneously produced and made meaningful at multiple scales and levels. These actions, events and processes are not neatly and uniquely situated, but are entangled in multiple and alternative scale constructions. Subsequently in the light of different levels of analyses, different interpretations can be drawn. Video technologies have made it possible to scrutinize and freeze in detail situations of teaching and learning processes and support multiple analytical endeavours regarding analysing classroom entities. As indicated in the introduction, scholars seldom make explicit their own favoured scales of analyses and subsequently tend to contribute to the unquestioned reproduction of established and authoritative scales and levels in studies of teaching and learning in classrooms (Klette, 2009). We accentuate therefore the importance of making explicit the preferred scales for investigations – whatever they are.

In our analyses we have used conceptual categories, actors, and levels as possible lenses for interpreting meaning in science classrooms. We have argued that when depending on preferred level for analyses, different and emergent conclusions can be drawn. Based on established conceptual categories at a macro level, regarding instructional patterns such as teacher led instruction, group work and individual work, our data paraphrase a very well documented pattern of science education; of basically teacher led teaching. However, looking at a different level; in-depth analyses of teacher led instruction as features of teaching activity, disclose attuned teaching approaches; sensitive and responsive to students' initiatives and utterances. Dialogic instruction is the single most frequent activity in our science lessons. In dialogic instruction the teachers still initiate, conduct and control the classroom discourse but with extended possibilities for student utterances and student initiatives.

By using actors (i.e. initiatives and participation structures) as the preferred scale of analyses these findings are further scrutinized. Based on the initiator of the utterances, students and teachers have joint opportunities for *initiating* classroom talk. Teachers still dominate classroom talk in terms of time spent and thematic patterns discussed but with a more mixed communicative pattern which includes more student initiatives than documented in earlier studies.

By again changing the level and doing in depth analyses of student initiated utterances in terms of language used, an enriched picture is revealed. It is not enough to only offer the students possibilities to talk science. Our students used mostly an everyday language with weak connections and bonds to features of science. The possible interconnections and relations between communicative patterns, scientific vocabulary and thematic patterns need however further investigations.

Taken together these aspects of classroom talk – instructional format, classroom discourse and features of language used in science classrooms – establish a mixture of well known and new ingredients. Depending on preferred level of analyses, stable or emerging patterns of teacher-student interaction can be exposed. Although instructional format tells us that there is an excess of teacher led instruction, this does not mean that the teacher talks and the students listen. The next level of analysis; classroom discourse, informs us that students have relatively strong influence on the classroom dialogue. How categories interact and how for example student initiatives as communicative patterns have impact on the scientific language patterns, need however further investigation.

NOTE

[1] Videograph ® is a computer software programme developed at IPN, Kiel, http://www.ipn.uni-kiel.de/aktuell/videograph/htmStart.htm (*Last visited 31.07.06*)

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APPENDIX I

Categories for video analysis of classroom activites with a focus on the teacher (Klette, K., Lie, S., Anmarkrud, Ø., Arnesen, N., Bergem, O.K., Ødegaard, M., Zachariassen, J.R., 2005)

Whole class instruction	
Monologue	*lecturing/story telling/teacher reading aloud etc.(min. duration 3 min.)*
Dialogue	*use/mobilise students' knowledge for instructional purpose in new subject matter*
Question/answer sequences	*systematic use of questions to check out students' knowledge and insight*
Whole class discussion	*dialogue pattern in which students speak directly to one another about the subject matter/ teacher acts as moderator*
Reading aloud	*students read aloud from textbooks or other textual material*
Student presentation	*students present assignments/ dramatizations i.e.*
Task management	*teacher gives verbal/non-verbal instructions regarding assignments and class projects (grouping, material resources i.e.)*
Comments on misbehaviour	*teacher admonishes students unwanted behavior*
Messages and comments	*general messages and comments of classroom business*
Teachers activities during individual seatwork	
Individual guidance	*teachers give individualised guidance and supervision*
Involving the whole class in individual students' questions	
Group guidance	*teachers give group guidance and supervision*
Out of the classroom	*teacher leaves the classroom area*
Non-interaction	*no direct interaction between teacher and students; reads, clears the classroom i.e.*
Teachers activities during group work	
Individual guidance	*teachers give individualised guidance and supervision*
Group guidance	*teachers give group guidance and supervision*
Involving the whole class in individual students' questions	
Not interaction	*no direct interaction between teacher and students reads, clears the classroom i.e.*
Out of the classroom	*teacher leaves the classroom area*

APPENDIX II

Categories for video analysis of science classroom activities
(Arnesen, N., & Ødegaard, M., 2006)

Student activities	
Copying notes	*The teacher periodically writes on the board material students are expected to copy into their notebooks*
Silent reading	*Students read silent in the textbook or other material*
Practical work/lab work	*Work involving use of apparatus or specimens, usually done in the laboratory or outdoor*
Seatwork	*Students work independently or in groups at their seats on tasks specified by the teacher or tasks from the work plan*
Listening/Engaging	*Students paying attention to what is going on in the classroom*
Use of ICT	*Students use ICT in their work*
Teaching activities	
Review	*Teacher summarizes in monologue or as students questions about previous lessons' themes*
Motivation	*Teacher use an artefact, anecdote or similar to motivate interest in a topic*
Teacher summary	*Teacher summarizes the theme of the lesson so far*
Going over the do now	*Teacher asks for results of student seatwork or other work done in the lesson*
Going over the homework	*Teacher asks for answers to students' homework*
Developing new content – cannonical knowledge	*New knowledge is developed through classroom dialogue, seatwork or in another way*
Developing new skills – procedural/ experimental knowledge	*Practical skills are developed through practical and experimental work*
Dialogue	
Student initiatives	*A student makes a comment or asks a question that brings up a new theme or issue*
Teacher exposition	*Teacher presents or explains something monologic (<3 minutes)*
Teacher initiatives	*Teacher asks questions in order to use or mobilize students' knowledge when developing new knowledge*
Social language	
Everyday	*Teacher and students use everyday concepts and language*

Scientific	*Teacher and students use scientific concepts and language*
Feature	
Description	*A scientific phenomenon, concept or event is described*
Explanation	*A scientific phenomenon, concept or event is explained*
Generalization	*Making a description or explanation that is independent of any specific context*
Referent	
Empirical	*The object or phenomenon that is described or explained is present and observable in the classroom*
Theoretical	*The object or phenomenon that is described or explained is not present or observable in the classroom*

APPENDIX III:

Transcription for S3_080905_0821neanat (1.09.13) S – Student, T – Teacher

S: Are we supposed to write anything under the line?
T: No, do not write under.
S: Hey, what's that picture there?
T: It's a seed. I've drawn a seed. Have you seen what comes up from the ground, the first that comes up from the ground?
S: Sprout.
T: …Vera?
S: One of those little green things.
T: Yes. Have you noticed how many leaves there are on it?
S: Two
T: Yes, good. Excellent.
(*draws a seedling with two leaves on the blackboard)*
T: The plant kingdom is divided in two groups. One is the monocots, and that are those leaves that come from the seed with one leaf. And that is for instance grass. All are grass species. Tulips. Lilies. If you look at the veins of the plants, those are the ones that have veins that only go straight up. *(draws veins in the air with her hand)* And down again. Not like those that ramify. *(gesticulates and illustrates with both hands)* While sunflower has lots… if we look at a leaf here *(picks a leaf)* they have veins that branch outwards, right? *(Shows the leaf)* And then there are the dicots. Then it comes up with two leaves first. *(points to the drawing on the blackboard)* Inside the little seed here *(draws a line from the seed)* there is stored nutrition. *(starts to write but wipes it out)* I said that I would not write anything there, so I have to hold it. *(writes "stored nutrition" further up on the blackboard without saying anything)* And it uses that stored nutrition to make that little plant there. *(points to the seedling drawing)* With some roots. *(draws roots) (pausing 13 seconds)*
What color do the leaves here have?
S: Green.
T: Yeah! *(colors the leaves with green chalk)*
T: And when a leaf has green color… Everything that is green in nature. What do they do? Or not everything that is green. There are green animals too, and they don't do that. Yes, May?
S: They produce oxygen.
T: Yes, and what do we call that process?
S: Photosynthesis?
T: Photosynthesis, yes. Great. Do you know… What do we know about algae then…? Brown algae in the sea. Are they plants that do photosynthesis?
S: Yes.
S: Yes.
T: But they are not green?
(several students talk at the same time)

S: No.
S: Yes, they become green if you put them in hot water.
T: Yes! Have you done it before, Nils?
S: No, you said so last week.
T: *(smiles)* I said so last time?! That's right. I did that once, you are the ones I did that leaf with. (points to the blackboard) Yes. Then I do not have to do it now. I get… get a bit confused, you know, because I have four groups where I do the same things.
But OK, it is green. The green is chlorophyll.
(writes "chlorophyll" on the seedling drawing)

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9. RESULTS AND PERSPECTIVES FROM THE ROSE PROJECT

Attitudinal aspects of young people and science in a comparative perspective

ABSTRACT

This article presents the comparative project ROSE (The Relevance of Science Education) on how 15-year old learners relate to science (and technology). The focus of ROSE is on the learners' science and technology (S&T) related prior experiences, their interests, their future plans, their attitudes to and perceptions of school science and science in society, their views on the environmental challenges and questions about priorities for their future job.

ROSE is a cooperative, low-cost, grassroot undertaking with researchers from about 40 countries from all continents. These researchers share some basic beliefs and perspectives on the role and purpose of science as a compulsory school subject for the whole age cohort, i.e. "science for all". This rationale of ROSE as well as some details of the development of the project is described, followed by some examples of results. These results reveal interesting similarities and differences between learners in different countries as well as between girls and boys.

An important aim of the ROSE study was to stimulate informed debates over important issues relating to school science. We end the article by describing the dissemination of results and by indicating possible implications of the ROSE findings.

INTRODUCTION: THE PURPOSE OF SCHOOL SCIENCE[1]

In most industrialized countries, compulsory school lasts some 9–10 years. Science is a central school subject, taught more or less throughout the compulsory school. This fact opens great possibilities for those concerned with science education, but it also entails dangers and pitfalls.

The great majority of young people will not become scientists. This simple fact is nevertheless often forgotten when subject specialists are concerned about their own subject, and scientists are no exception. Too often, many scientists consider that the prime purpose of school science is to recruit more scientists. School science is seen as the first step on a ladder to become

Doris Jorde and Justin Dillon (Eds.), Science Education Research and Practice in Europe: Retrospective and Prospective, 203–236.

scientists. When young people make other choices than towards S&T careers, this is often conceived as a "leaky pipe-line". (For a critique of this view, see also the report *Science Education in Europe: Critical Reflections* (Osborne and Dillon, 2009).

In a compulsory school, the main purpose of all subjects is to prepare the young learner for an active, informed and meaningful life in work and leisure in the decades that will follow. The school as a whole should broaden the minds, provide insights into our common values and cultural heritage and prepare the young to become active participants who can make a contribution as autonomous and critical citizens in the world of tomorrow. We, as science educators, should remind ourselves about such basic facts, and we should place our own subject within such a frame of reference. We should remember that the majority of learners are not going to become scientists or engineers. We may hope, however, that they leave school with knowledge and skills that will remain meaningful for them as citizens, and we may also hope that they will look back at their experience with school science with positive feelings, and that they will continue to have an interest in science-related issues and challenges.

This brief reminder about the obvious may serve as an introduction to a description of basic features of the project ROSE.

THE ROSE PROJECT

Rose in Brief

ROSE is an acronym for the Relevance of Science Education, and is an international, comparative project. The key feature of ROSE is to gather and analyze information from the learners about several factors that have a bearing on their attitudes to S&T and their motivation to learn S&T. Examples are: A variety of S&T-related out-of-school experiences, their interests in learning different S&T topics in different contexts, their views on their own school science, their views and attitudes to science and scientists in society, their future hopes, priorities and aspirations, their feeling of empowerment with regards to environmental challenges, etc.

Through international deliberations, workshops and piloting among many research partners, we developed an instrument that aims to map such attitudinal or affective perspectives on S&T in education and in society as seen by 15 year old learners. We tried to make an instrument that could be used in widely different cultures. In addition to the research as such, the aim of ROSE was also to stimulate cooperation and networking across cultural barriers and to promote an informed discussion on how to make science education more relevant and meaningful for learners in ways that respect gender differences and cultural diversity. We also wanted to shed light on how we can stimulate the students' interest in choosing S&T-related studies and careers – and to stimulate their life-long interest in and respect for S&T as part of our common culture.

Since the beginning of the project, in 2002, we have been in contact with researchers from about 70 countries. More than 40 of these have collected data, and many have used the instrument for their own, national or local purposes.

ROSE partners have met at conferences like ESERA and IOSTE, and several ROSE workshops have been hosted in Europe and in Malaysia, as a follow-up of IOSTE XII. In the comparisons that are presented in this article, we have included data that we consider to meet the quality requirements as described in the ROSE handbook (Sjøberg and Schreiner 2004) in terms of definition of population, sampling, data collection and coding etc. for such comparisons. The data from the following countries were found to meet these criteria: Austria, Bangladesh, Botswana, Czech Republic, Denmark, England, Estonia, Finland, Germany, Ghana, Greece, India (Gujarat), India (Mumbai), Iceland, Ireland, Japan, Latvia, Lesotho, Malaysia, N. Ireland, Norway, Philippines, Poland, Portugal, Russia, Scotland, Slovenia, Spain, Swaziland, Sweden, Trinidad, Turkey, Uganda, Zimbabwe. In some countries the ROSE target population is defined as the students in one *region* of the country (e.g. Karelia in Russia, Gujarat in India and the Central region in Ghana).

ROSE is a "low-budget" and "grassroots" project with some basic Norwegian support as well as national funding in the participating countries.[2]

The ROSE material may illuminate a range of important and topical discussions in the science education community, for example issues such as curricular content vs. students' interests, cultural diversity, students' disenchantment with their science classes, students' perceptions of science in society and gender differences. Discussions on such issues have been taking place in many papers and conference presentations based on the ROSE material (see e.g. Jenkins, 2005; Jidesjö & Oscarsson, 2004; Lavonen, Juuti, Uitto, Meisalo & Byman, 2005; Ogawa & Shimode, 2004; Trumper, 2004). Many Ph.D. students are basing their thesis on ROSE data, and the first Ph.D.-thesis was presented in Norway in March 2006 (Schreiner, 2006), the second in Ghana (Anderson, 2007). Several Master degree dissertations have been based on ROSE, e.g. Jensen, 2008 and Ullah, 2008.

ROSE: Aims and Common Commitments

The introduction to this article stresses that science education in a compulsory school has a mandate to prepare for citizenship for all students. Such concerns provide the ideals and commitments of the project. In more concrete terms, a quote from the research contract for the grant from the Research Council of Norway may serve as an introduction to the ROSE project:

We believe that the lack of perceived relevance of the S&T curriculum is one of the greatest barriers for good learning as well as for interest in the subject. The ambition of the ROSE project is to provide insight into factors that relate to the relevance of the contents as well as the contexts of S&T curricula. We hope that the outcomes of the project are perspectives and empirical findings that provide a base for informed discussions on how to improve curricula and enhance the interest in S&T in a way that

- respects cultural diversity and gender equity
- promotes personal and social relevance
- empowers the learner for democratic participation and citizenship

The ROSE research partners share a set of common commitments. These can be seen as an elaboration of the contract:

1. Basic literacy in S&T is crucial for the individual's autonomy and quality of life, for national development as well as for meaningful democratic participation citizenship in all societies.
2. The teaching and learning of S&T takes place in particular social contexts. This context (cultural, political, religious, linguistic context, dominating world-view, etc.) will rightfully influence what the society values as important knowledge and skills. This wider context has to be taken into account when curricula are made.
3. Children come to school with different life experiences, they have different interests and plans for their life and they have different values and priorities. These different backgrounds are important determinants for their learning. Besides, they have to be respected in their own right. Only by doing so, can S&T education become meaningful and relevant to them as individuals.
4. Children also have more or less well-founded images about the nature and purpose of S&T; and they have different perceptions of how people in these areas are as persons. Such perceptions about the 'body language' of S&T are likely to colour their attitudes to the subjects and their willingness to enter S&T areas of study and work.

ROSE Development, Method and Limitations

Details of the project development, the resulting ROSE instrument definition of population and sampling, data collection and coding etc. are given in detail in Schreiner and Sjøberg (2004), also available from the ROSE web site (http://roseproject.no).

A **ROSE advisory group**, consisting of key science educators,[3] covering all continents, was established when the project funding was secured. In cooperation with this project group, we used a year and half to draft, pilot and revise the **ROSE instrument** (a questionnaire), and to develop the details of data collection. The original instrument is in English (and Norwegian) and was later translated to the language in each participating country. The ROSE instrument is therefore available in several languages, many are to be found on the ROSE site. The questionnaire has a core of some 200+ items. In some countries, they also collected additional background data, like type of school, locality of the school (i.e. urban/rural or district) as well as data of socio-economic status of parents. Such data are used in some national reports, but are not used in the international comparisons.

The many **ROSE international partners** are also listed on the ROSE site. This group of partners was established partly before the project started (and received funding), but it grew considerably during the project development, when colleagues in other countries got to know about the project. The initial project invitation was sent to science education researchers through mail lists for IOSTE, NARST, ESERA and similar. Many of the interested partners had also taken part in a previous study, called SAS (Science And Scientists) also organized from Oslo University and funded by the Research Council of Norway. Many items from SAS found their way to ROSE, and SAS may be regarded as a large pilot study for ROSE, also for the data collection, coding, logistics etc. Details and results for SAS are reported in Sjøberg (2002).

Many ROSE items were taken from the Eurobarometer studies on perceptions of science and technology. The ROSE organizer was later invited to be on the scientific committee for the Eurobarometer studies on *Europeans, science and technology* (see e.g. EU 2005). In this way, more ROSE questions were introduced in the Eurobarometer data collection in 2005.[4] Data from ROSE and Eurobarometer therefore open for interesting comparisons between the young learners and the adult population. (Examples are presented later in this article.)

The **target population** for ROSE are the young learners around the age of 15, i.e. towards the end of what in most countries is the final year of the compulsory school. The ROSE handbook (main points are reproduced in Schreiner and Sjøberg (2004)) provides detailed instructions on the definition of population, sampling procedures, coding etc. In principle, we aimed at the whole age cohort, but in some countries, like most African, school attendance is far from 100% at this age. Therefore, our population is, more precisely, the school attenders in the class level where the 15–year olds are most likely to be in majority. Whole classes were sampled, one class per school, and with a probability for the school proportional to the number of pupils at that class level. For most countries, the number of respondents are around 1000, in some countries, considerably higher. For each country, a report was made to describe the details of population, sampling, number of respondents, practical challenges and other details. The country reports are posted at the ROSE web site.

The ROSE data were not collected simultaneously in each country. Timing was decided in each country, dictated by practical concerns. The data in the file used for common analysis was collected over a time span from late 2002 to early 2006. Although there are no particular reasons to expect radical changes in attitudes over these years, this fact calls for some care in data interpretation. After the main data collection was completed, several other countries have joined the study and collected data according to the same procedures. Because of the time span, we have not included these data in the file that we use for our comparisons presented here. Some of these "new countries" have, however, made national reports, and these are made available on the ROSE web site.

The above details underscore that the data should be interpreted with some care. Our data do, of course, not meet the rigour that is demanded by the "official" large scale comparative studies like TIMSS and (in particular) PISA. The aim of ROSE is, however, not to rank countries against certain measures of achievement. There are no "correct" answers to ROSE items, and no responses are "better" than other.

As can be seen form our rationale and basic commitments, we think of the ROSE data as an input for critical and informed discussion of questions of value and priorities. High precision in any measurement is therefore not a key point.

The ROSE project, as such, cannot be said to have one particular *theoretical framework* with clearly defined theoretical constructs that underlie the development of scales of items. We had, of course, a series of hypotheses and questions that we wanted to probe, and these guided the development of the project and the instrument. The countries that take part are widely different in terms of culture, level of economic development etc. and one cannot use one (say) sociological or psychological theory that applies in all these countries. In her Ph.D., based mainly on the Norwegian data, Schreiner (2006) uses recent sociological theory on youth culture in late modern societies as a frame for understanding the Norwegian data. In other countries, other theories might be used to explore and understand findings. The data can be used with explorative statistical analysis to probe a series of different hypotheses.

The ROSE Instrument

The ROSE instrument has in total 250 items under the 7 following headings (details, theoretical background, previous research etc. are given in Sjøberg and Schreiner, 2004).

- My out-of-school experiences (61 items)
- What I want to learn about (108 items)
- My future job (26 items)
- Me and the environment (18 items)
- My science classes (16 items)
- My opinions about science and technology (16 items)
- Myself as a scientist (Open written response)

All ROSE questions have very simple wording, with closed responses to be given on a 4-point Likert scale. The estimated time was one school lesson, but there was no constraint on the available time. The responders could use the time that they needed, and the teacher could also help clarify if there was something that was not fully understood. The important point was to get a genuine and honest answer. On the front page of the ROSE instrument, the purpose and instructions read like this.

> There are no correct or incorrect answers, only answers that are right for you. Please think carefully and give answers that reflect your own thinking. This questionnaire is being given to students in many different countries. That is why some questions may seem strange to you. If there is a question you do not understand, just leave it blank. If you are in doubt, you may ask the teacher, since this is not a test! The purpose of this questionnaire is to find out what students in different parts of the world think about science at school as well as in their everyday life. This information may help us to make schools better.

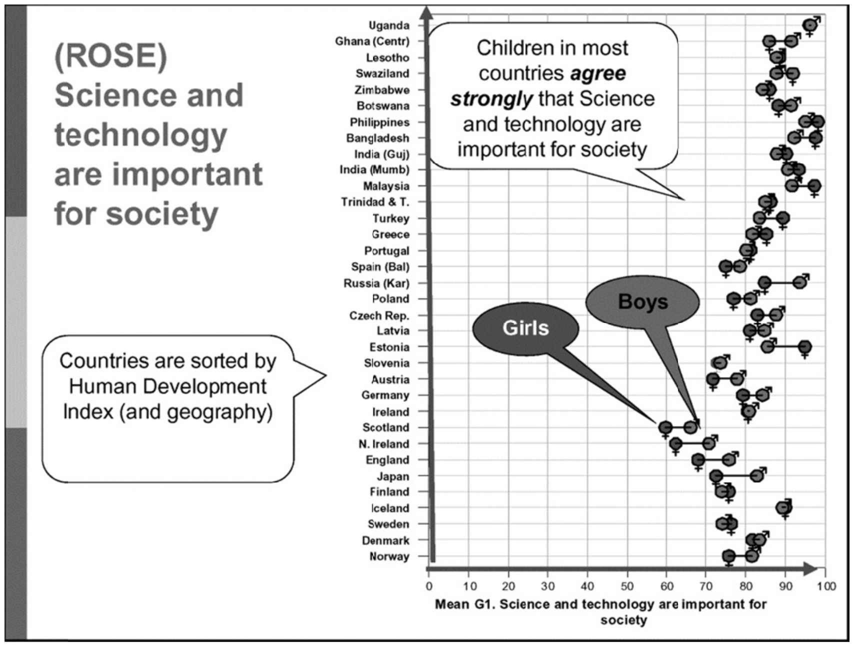
All ROSE items use a **Likert scale** with response 4 categories, in principle from "small" to "large" (*never* to *often*, *disagree* to *agree* etc) A thorough discussion of our use of Likert scale, the chosen number of 4 response categories, and the use of statistical methods for Likert-type data are thoroughly discussed in Schreiner (2006).

ROSE: KEY FINDINGS

In the following, we will report some results from analysis of the ROSE material. All diagrams show mean scores (in percentage) for 14–16 years old girls and boys from a number of countries in the ROSE sample. The countries are sorted partly geographically, with neighbouring countries together; and partly by level of development, using the Human Development Index[5] as a proxy.

In the diagrams in the following, we have simplified the results by collapsing the first two categories (1 and 2) and labeled those *Disagree* and the two upper categories (3 and 4) and labeled those *Agree*. By this, we present results in terms of percentage of respondents who agree. This simplification is done for ease of interpretation by an audience, but we use the whole 4-point scale for correlations and other forms of statistical analysis.

The presentation below gives the details of the principles for the following presentation of data.

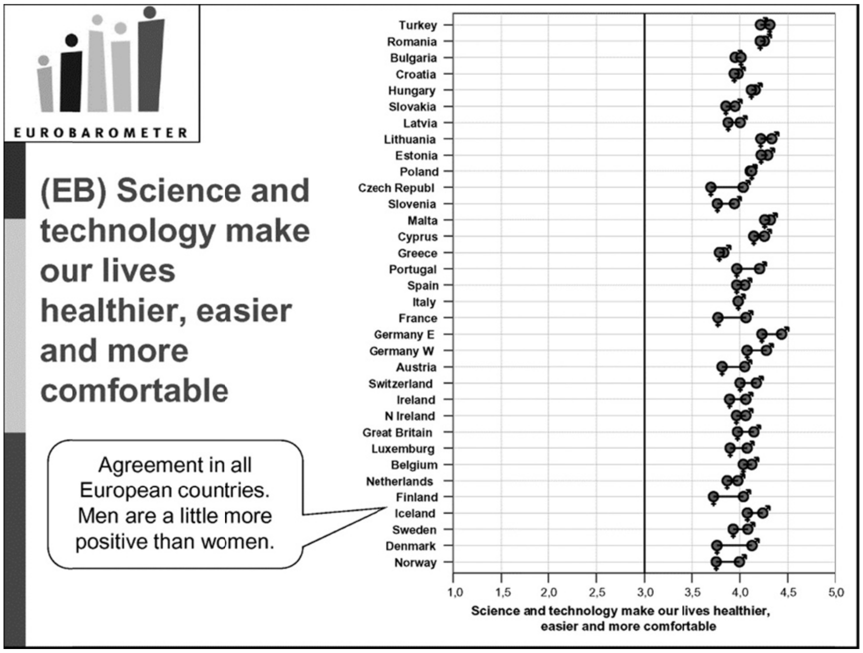


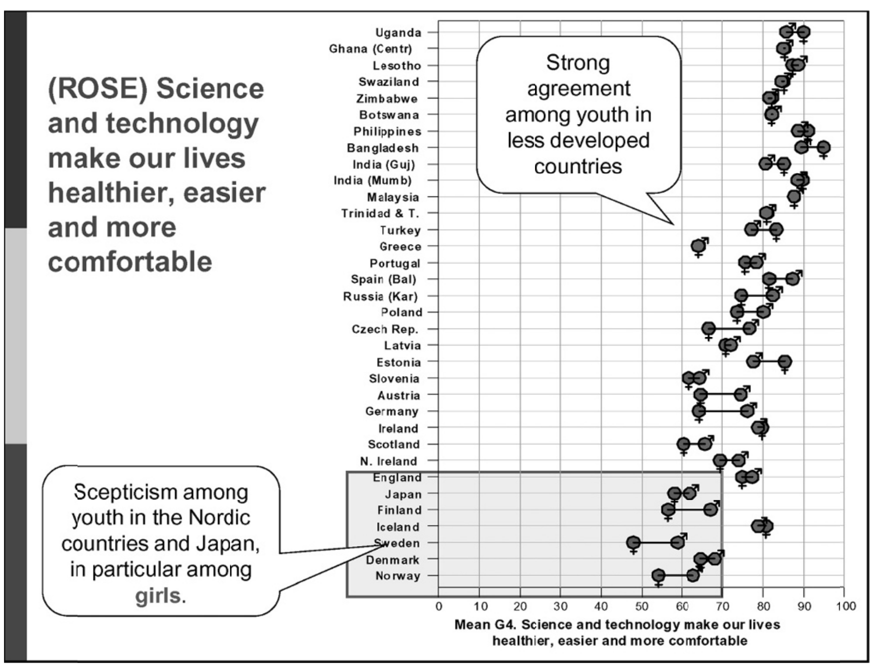
Positive Attitudes to Science – but also (Growing?) Doubt and Skepticism

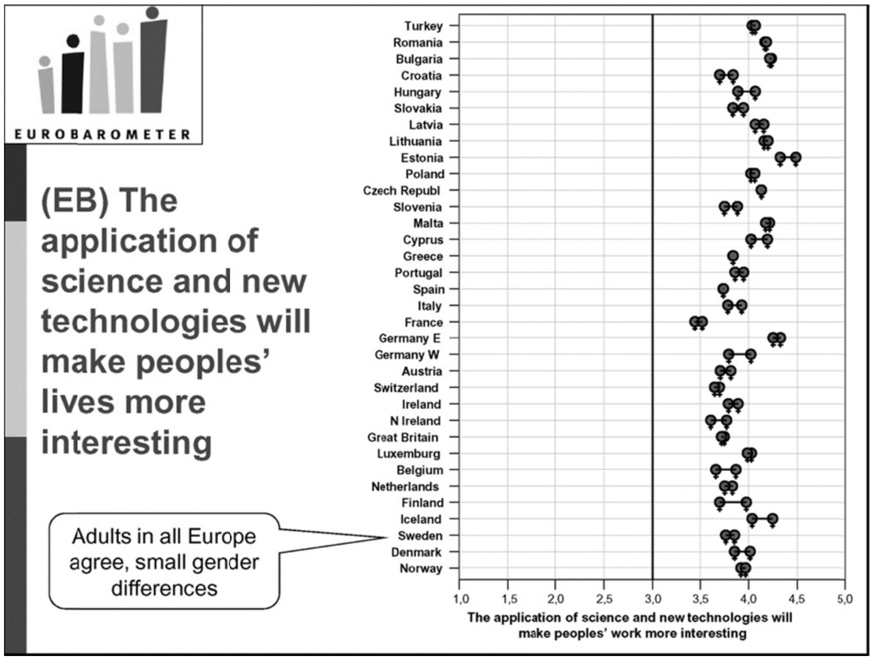
As mentioned, some of the questions in ROSE are identical to those asked in the Eurobarometer[6] studies, where the target population is the adult population in 32 European countries (EU 2005). The results open for interesting comparisons between the young generation and adults.
The overall picture is that of optimism in most countries. Young people, in great majority, tend to agree with statements like these:

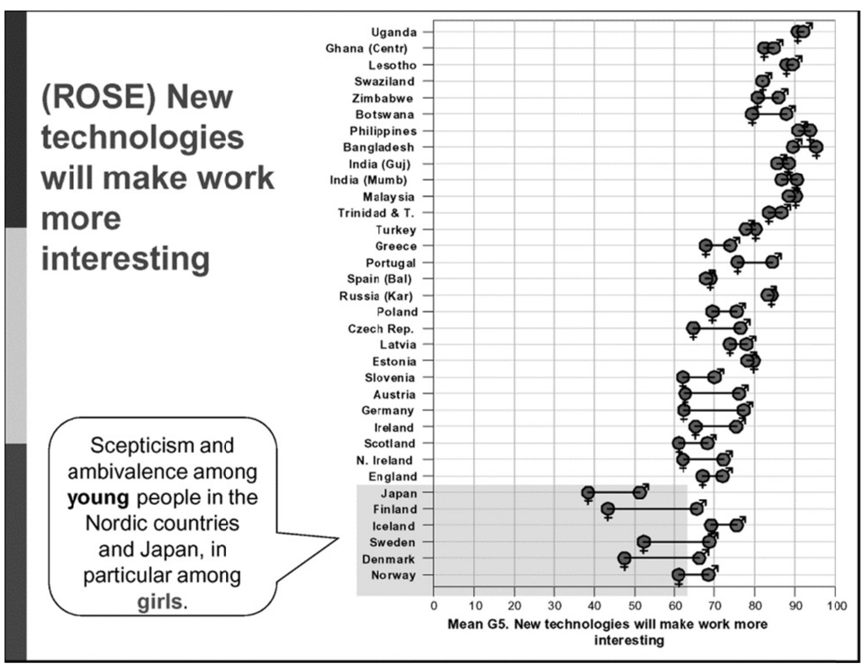
- Science and technology will find cures to diseases such as HIV/AIDS, cancer, etc,
- Science and technology are important for society,
- Thanks to science and technology, there will be greater opportunities for future generations,
- New technologies will make work more interesting,
- The benefits of science are greater than the harmful effects it could have, and
- Science and technology make our lives healthier, easier and more comfortable.

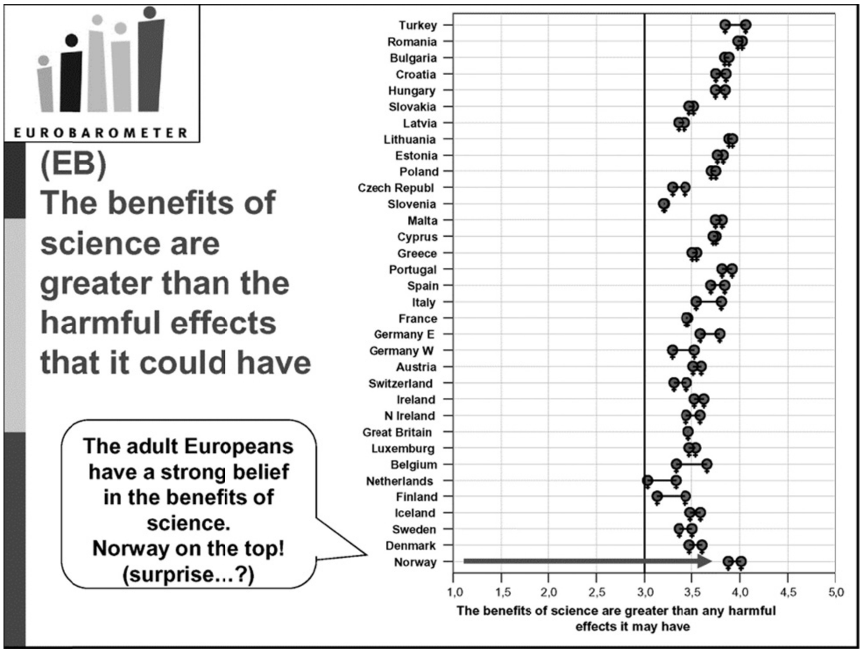
There are signs, however, that young people in the in the richest countries (Northern Europe, Japan) are more ambivalent and sceptical than the adult population. A remarkable general pattern is also that, on nearly every item, there is a growing gender difference, with girls, in particular in the richest countries, being more negative (or sceptical, ambivalent) than boys.

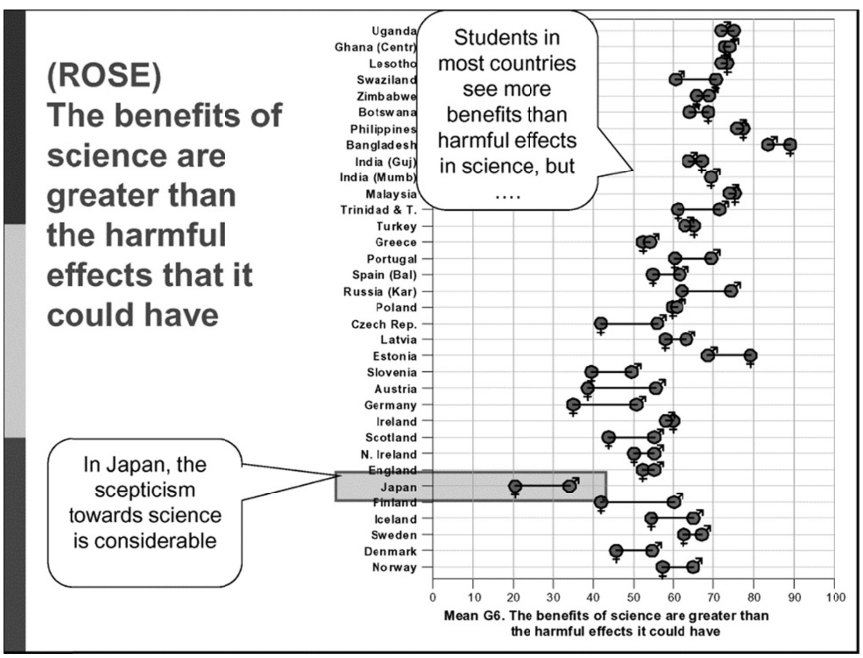

EUROBAROMETER
(EB) Science and technology make our lives healthier, easier and more comfortable
Agreement in all European countries. Men are a little more positive than women.
Turkey
Romania
Bulgaria
Croatia
Hungary
Slovakia
Latvia
Lithuania
Estonia
Poland
Czech Republ
Slovenia
Malta
Cyprus
Greece
Portugal
Spain
Italy
France
Germany E
Germany W
Austria
Switzerland
Ireland
N Ireland
Great Britain
Luxemburg
Belgium
Netherlands
Finland
Iceland
Sweden
Denmark
Norway
1,0 1,5 2,0 2,5 3,0 3,5 4,0 4,5 5,0
Science and technology make our lives healthier, easier and more comfortable


(ROSE) Science and technology make our lives healthier, easier and more comfortable
Strong agreement among youth in less developed countries
Scepticism among youth in the Nordic countries and Japan, in particular among girls.
Uganda
Ghana (Centr)
Lesotho
Swaziland
Zimbabwe
Botswana
Philippines
Bangladesh
India (Guj)
India (Mumb)
Malaysia
Trinidad & T.
Turkey
Greece
Portugal
Spain (Bal)
Russia (Kar)
Poland
Czech Rep.
Latvia
Estonia
Slovenia
Austria
Germany
Ireland
Scotland
N. Ireland
England
Japan
Finland
Iceland
Sweden
Denmark
Norway
0 10 20 30 40 50 60 70 80 90 100
Mean G4. Science and technology make our lives healthier, easier and more comfortable


EUROBAROMETER
(EB) The application of science and new technologies will make peoples' lives more interesting
Adults in all Europe agree, small gender differences
Turkey
Romania
Bulgaria
Croatia
Hungary
Slovakia
Latvia
Lithuania
Estonia
Poland
Czech Republ
Slovenia
Malta
Cyprus
Greece
Portugal
Spain
Italy
France
Germany E
Germany W
Austria
Switzerland
Ireland
N Ireland
Great Britain
Luxemburg
Belgium
Netherlands
Finland
Iceland
Sweden
Denmark
Norway
1,0 1,5 2,0 2,5 3,0 3,5 4,0 4,5 5,0
The application of science and new technologies will make peoples' work more interesting


(ROSE) New technologies will make work more interesting
Scepticism and ambivalence among young people in the Nordic countries and Japan, in particular among girls.
Uganda
Ghana (Centr)
Lesotho
Swaziland
Zimbabwe
Botswana
Philippines
Bangladesh
India (Guj)
India (Mumb)
Malaysia
Trinidad & T.
Turkey
Greece
Portugal
Spain (Bal)
Russia (Kar)
Poland
Czech Rep.
Latvia
Estonia
Slovenia
Austria
Germany
Ireland
Scotland
N. Ireland
England
Japan
Finland
Iceland
Sweden
Denmark
Norway
0 10 20 30 40 50 60 70 80 90 100
Mean G5. New technologies will make work more interesting


EUROBAROMETER
(EB)
The benefits of science are greater than the harmful effects that it could have
The adult Europeans have a strong belief in the benefits of science.
Norway on the top!
(surprise...?)
Turkey
Romania
Bulgaria
Croatia
Hungary
Slovakia
Latvia
Lithuania
Estonia
Poland
Czech Republ
Slovenia
Malta
Cyprus
Greece
Portugal
Spain
Italy
France
Germany E
Germany W
Austria
Switzerland
Ireland
N Ireland
Great Britain
Luxemburg
Belgium
Netherlands
Finland
Iceland
Sweden
Denmark
Norway
1,0 1,5 2,0 2,5 3,0 3,5 4,0 4,5 5,0
The benefits of science are greater than any harmful effects it may have


(ROSE)
The benefits of science are greater than the harmful effects that it could have
Students in most countries see more benefits than harmful effects in science, but ….
In Japan, the scepticism towards science is considerable
Uganda
Ghana (Centr)
Lesotho
Swaziland
Zimbabwe
Botswana
Philippines
Bangladesh
India (Guj)
India (Mumb)
Malaysia
Trinidad & T.
Turkey
Greece
Portugal
Spain (Bal)
Russia (Kar)
Poland
Czech Rep.
Latvia
Estonia
Slovenia
Austria
Germany
Ireland
Scotland
N. Ireland
England
Japan
Finland
Iceland
Sweden
Denmark
Norway
0 10 20 30 40 50 60 70 80 90 100
Mean G6. The benefits of science are greater than the harmful effects it could have

These results emerge not just from single items shown here, but are consistent through a series of questions, and should be taken seriously by educators and policymakers.

The following examples give data to support the points above. Note that the Eurobarometer countries only include European countries, and that these are sorted in the graphs by the same principle as the ROSE countries (i.e. mainly by HDI). Since the Eurobarometer study uses a 5-point Likert scale, these data are not converted to percent, but give the mean on this 5-point scale.

Science in Schools: Not a Success Story?

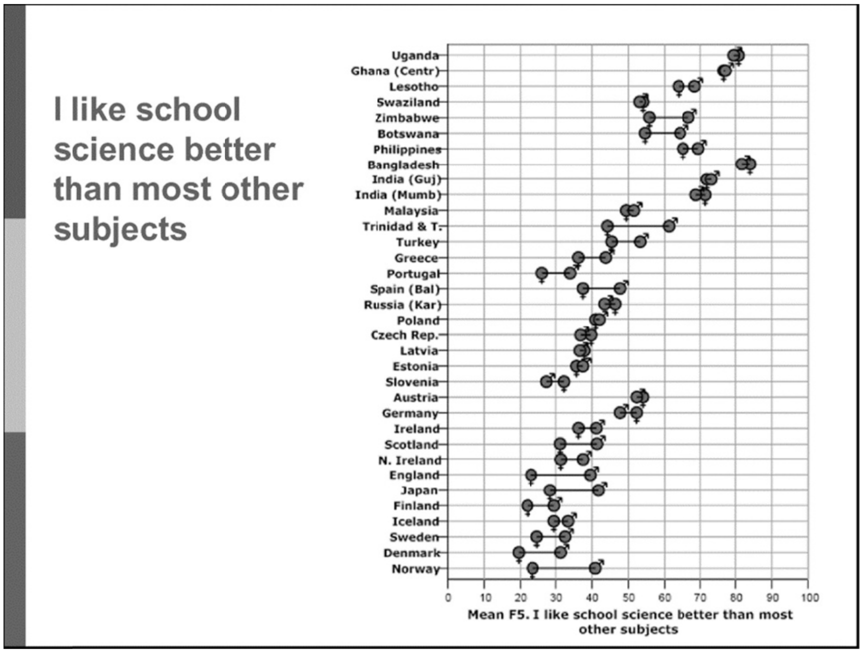
The ROSE project asks 16 questions about how the learners consider their experiences with school science. The heading is "My science classes. To what extent do you agree with the following statements about the science that you may have had at school?"

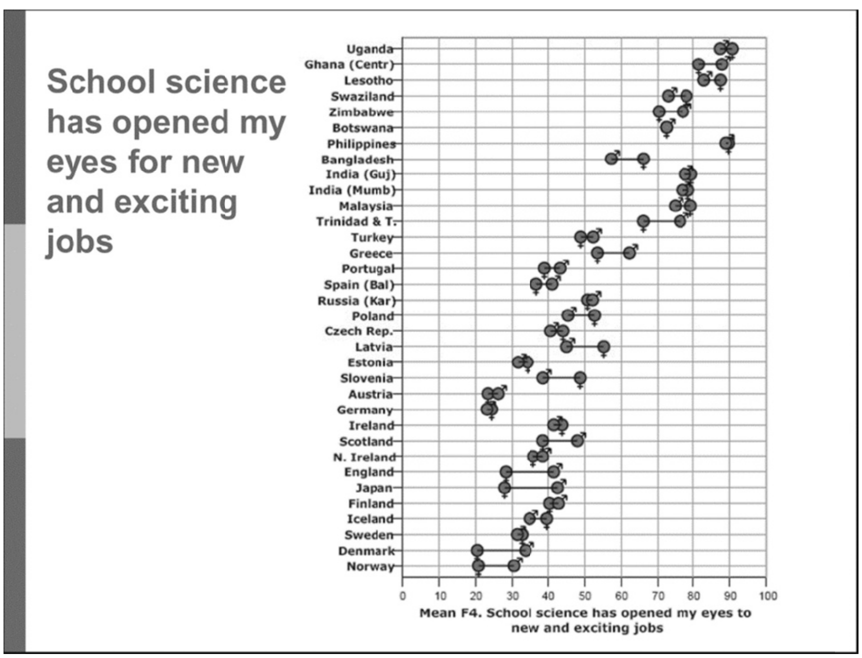
These students have had science for most of their years at school. Hence, the answers provide a kind of summative evaluation of those experiences. The results vary strongly between countries, but for European countries (and Japan), the answers indicate that school science fails in many ways. Some data and the exact wording of the questions are given in the following graphs, and the overall picture is the following:

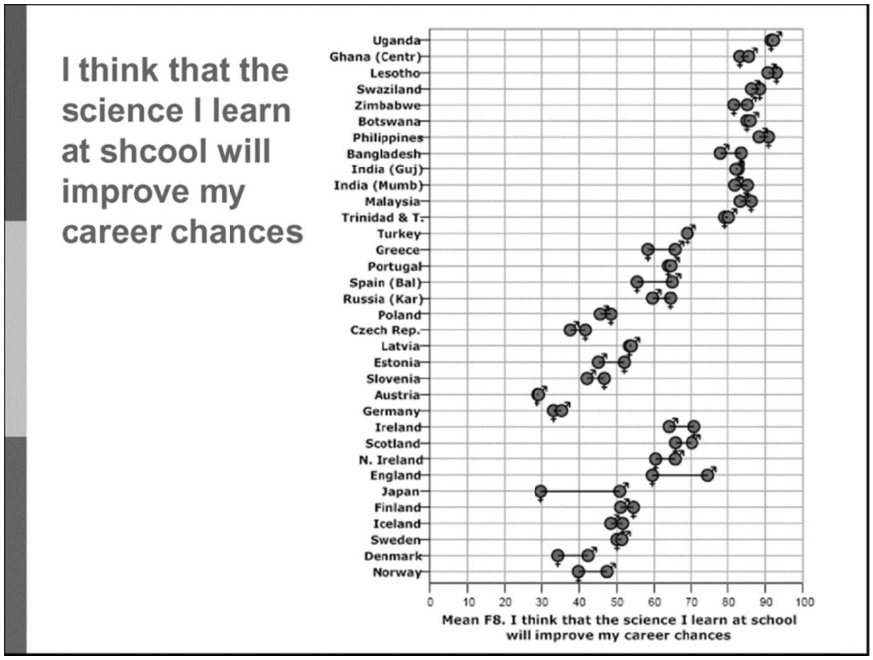
"School Science …

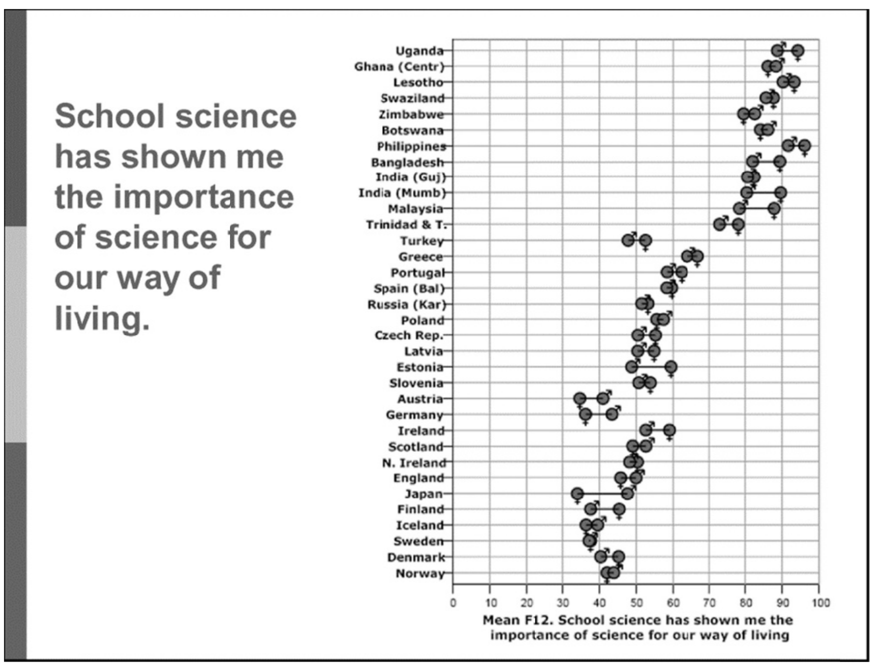
- *is less interesting than other subjects."*
  There is a strong gender difference here, with girls less positive than boys, especially in the wealthier countries.
- *has not opened my eyes for new and exciting jobs."*
  The gender pattern is the same here, and the positive response is lowest in the richest countries.
- *has not increased my career chances."*
  There are interesting differences between countries here, with the young people in the 4 English-speaking countries being more positive than in other parts of Europe.
- *has not increased my appreciation for nature"*
- *has not taught me how to take care of my health"*
- *has not increased my curiosity"*
- *has not shown me the importance of S&T for our way of living."*
  In most European countries, less than 50% of the respondents agree with this statement. Gender differences are small.

Examples follow, as annotated graphical representations.


I like school science better than most other subjects
Uganda
Ghana (Centr)
Lesotho
Swaziland
Zimbabwe
Botswana
Philippines
Bangladesh
India (Guj)
India (Mumb)
Malaysia
Trinidad & T.
Turkey
Greece
Portugal
Spain (Bal)
Russia (Kar)
Poland
Czech Rep.
Latvia
Estonia
Slovenia
Austria
Germany
Ireland
Scotland
N. Ireland
England
Japan
Finland
Iceland
Sweden
Denmark
Norway
0 10 20 30 40 50 60 70 80 90 100
Mean F5. I like school science better than most other subjects


School science has opened my eyes for new and exciting jobs
Uganda
Ghana (Centr)
Lesotho
Swaziland
Zimbabwe
Botswana
Philippines
Bangladesh
India (Guj)
India (Mumb)
Malaysia
Trinidad & T.
Turkey
Greece
Portugal
Spain (Bal)
Russia (Kar)
Poland
Czech Rep.
Latvia
Estonia
Slovenia
Austria
Germany
Ireland
Scotland
N. Ireland
England
Japan
Finland
Iceland
Sweden
Denmark
Norway
0 10 20 30 40 50 60 70 80 90 100
Mean F4. School science has opened my eyes to new and exciting jobs


I think that the science I learn at shcool will improve my career chances
Uganda
Ghana (Centr)
Lesotho
Swaziland
Zimbabwe
Botswana
Philippines
Bangladesh
India (Guj)
India (Mumb)
Malaysia
Trinidad & T.
Turkey
Greece
Portugal
Spain (Bal)
Russia (Kar)
Poland
Czech Rep.
Latvia
Estonia
Slovenia
Austria
Germany
Ireland
Scotland
N. Ireland
England
Japan
Finland
Iceland
Sweden
Denmark
Norway
0 10 20 30 40 50 60 70 80 90 100
Mean F8. I think that the science I learn at school will improve my career chances


School science has shown me the importance of science for our way of living.
Uganda
Ghana (Centr)
Lesotho
Swaziland
Zimbabwe
Botswana
Philippines
Bangladesh
India (Guj)
India (Mumb)
Malaysia
Trinidad & T.
Turkey
Greece
Portugal
Spain (Bal)
Russia (Kar)
Poland
Czech Rep.
Latvia
Estonia
Slovenia
Austria
Germany
Ireland
Scotland
N. Ireland
England
Japan
Finland
Iceland
Sweden
Denmark
Norway
0 10 20 30 40 50 60 70 80 90 100
Mean F12. School science has shown me the importance of science for our way of living

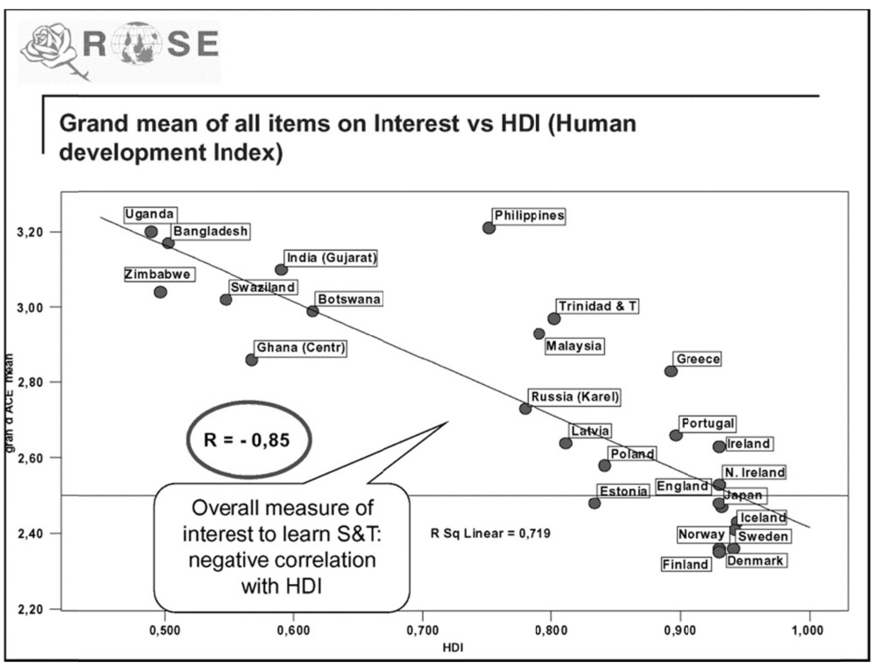
The More Developed, the Less Overall Interest in Science?

The ROSE instrument contains 108 items asking for "What I want to learn about: How interested are you for learning about the following?"

The items cover a wide variety of possible topics for science learning. The underlying structure in this pool of items is based on a kind of two-dimensional grid. The idea behind the selection of these topics is that different science **contents** (like electricity, heat, mechanics, botany, chemistry etc.) are placed in different **contexts** (social, technical, ethical, practical, theoretical etc.).

The underlying rationale is, of course, to explore to what degree the context determines the expressed interest in a particular content area. (For details of the instrument and the underlying assumptions, see Schreiner and Sjøberg, 2004.) Some of the striking results are summarized in the following sections.

An overall pattern is that young people in the less developed countries express an interest to learn about nearly all the topics that are listed. One can notice a strong negative correlation between the average interest score (horizontal axis) and the level of development. If HDI (Human development Index) is used as the indicator for development, the correlation is **-0.85** between overall interest and HDI.



Care should be taken when interpreting this overall result. One should *not* assert that young people are less interested in science the more developed the country is. A better explanation for these data is rather to suggest that for young people in (mainly) developing country, going to school at the age of 15 is a "luxury" or a "privilege". Hence, they are, in principle, happy to learn about nearly everything the school may offer. Young people in rich countries (in particular countries with low rates of unemployment) can "afford" to see school more as a duty and an obligation more than as a privilege. Many students also think that school should be fun and entertaining. Therefore, they are more likely to express what they like and what they dislike. One might say that they are more "selective" in their choices.

Interests – Similarities and Differences Between Countries

It is interesting to explore differences and similarities in how students in different countries respond to the questions about their interests in learning different science topics. For this purpose, hierarchal cluster analysis is a useful explorative statistical tool. Results from the hierarchical cluster analysis can be presented in *dendrograms*. The dendrogram in Figure 1 below shows how similar or close the countries and country clusters are to each other: The branches illustrate how clusters are formed at different stages in the analysis and the distances between the clusters.

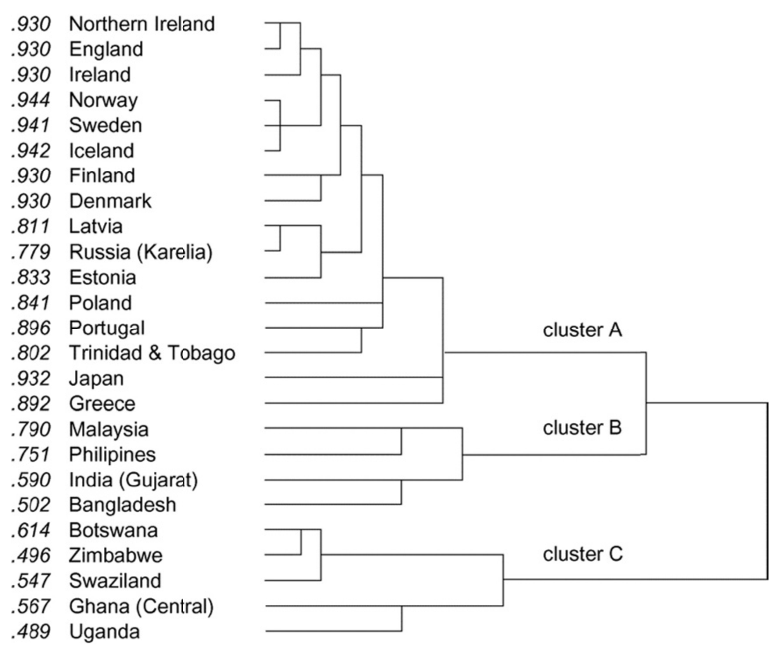


Figure 1. Hierarchical cluster analysis of residual ACE mean scores for all countries. Proximity measure: squared Euclidean distance. Clustering method: between-groups linkage. To the left, we have inserted a column showing the national HDI values (UNDP, 2004). (Source: Schreiner, 2006).

The distance along the horizontal axis from the point at which the clusters come into existence to the point at which they aggregate into a larger cluster represents the distinctness of the clusters. The distinctness tells us how different one cluster is from its closest neighbour. The more compact a cluster is, i.e. the further to the left the branches merge, the more similar to each other the countries are.

In this analysis, the HDI-value (based on data from 2004) is used as an indicator for the level of development in a country. To the left in Figure 1, we have inserted a column showing the national HDI values.

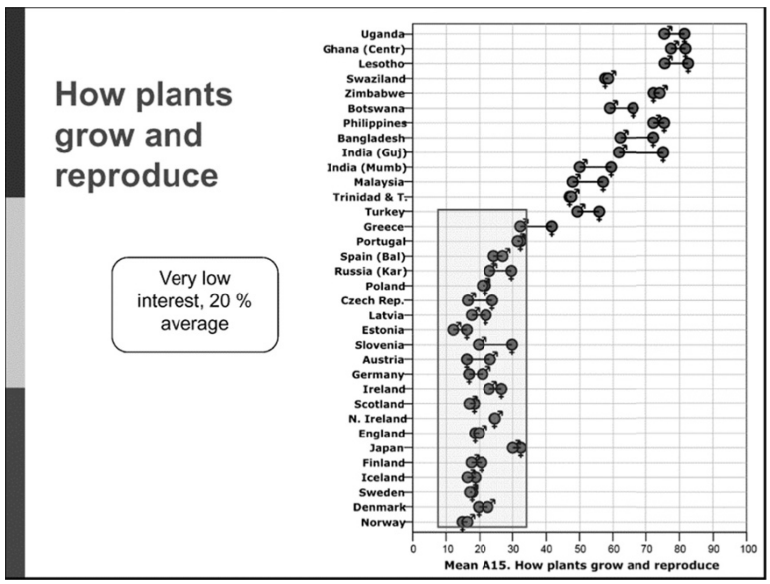
By reading the dendrogram from the right towards the left, we see that the meta-cluster contains three main clusters: (A) High HDI countries including all the European countries plus Japan and Trinidad and Tobago, (B) Medium HDI Oriental countries and (C) Low HDI African countries. As the length of the branch for all these three clusters are relatively long, they can be perceived as three distinctive clusters of countries. Cluster B is more similar to cluster A than cluster C.

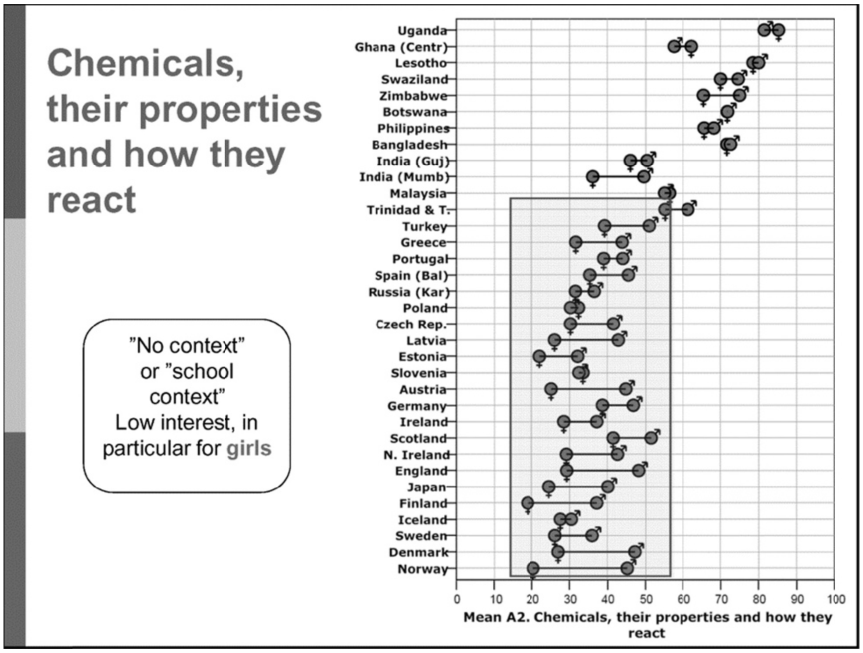
One noticeable result from the analysis above is that similarities between countries in this part of the questionnaire seem to be determined by two properties: geographical closeness and level of development. The general pattern is that first, the countries merge with geographically neighbouring countries, and next, the group of neighbouring countries merge with groups of countries having a comparable level of development.[7] But the unifying effect of geographical closeness only works within a certain limit of diversity in development. For example, Japan is geographically closer to the Philippines and Malaysia than to Europe, but the Japanese students seem to have more interests in common with European students. This may possibly be explained by the relatively high level of development and industrialization in Japan. The response profiles of students in the Oriental countries (like Malaysia, Philippines, India and Bangladesh) appear as relatively similar to each other. We should note that the Russian students' orientation towards science and science education appear as comparable to the profiles of the students in the Baltic countries (Latvia and Estonia). Keep in mind that the Russian students in ROSE come from Karelia, a region quite close to the Baltic countries and Finland.

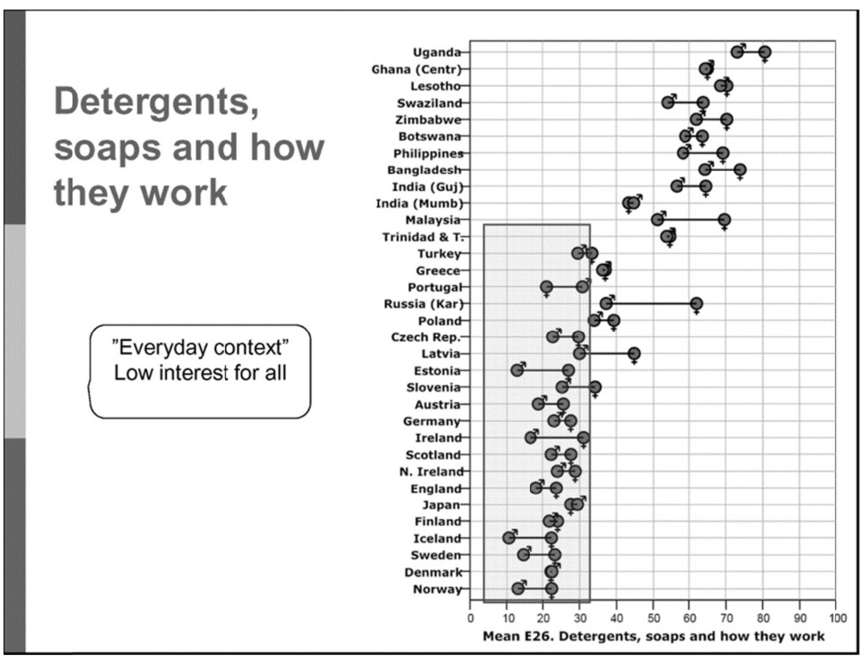
The More Developed, the Less Interest for "School Science" – also Practical, "Relevant" and Everyday Science and Technology

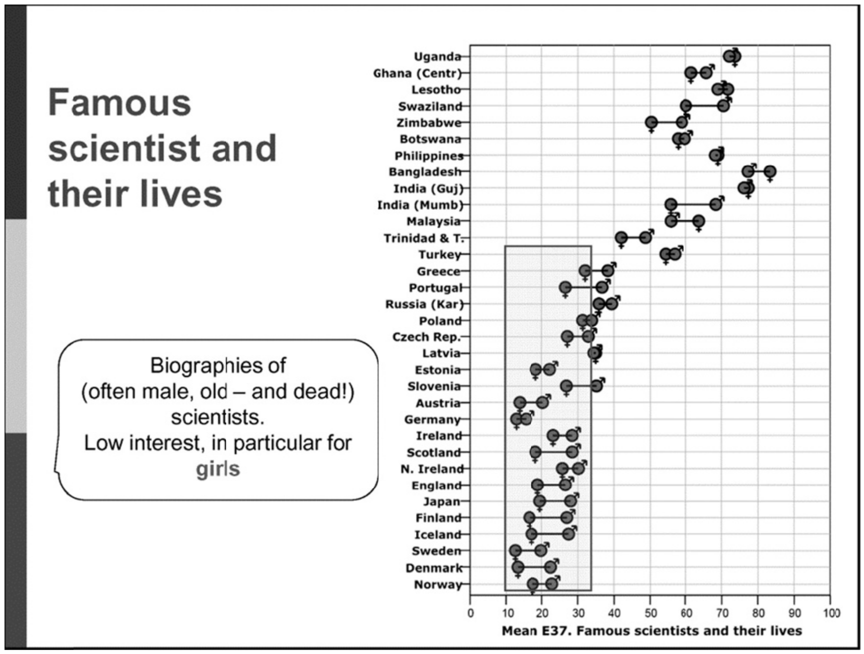
A clear pattern is that topics that are close to what is often found in science curricula and textbooks have low scores on the rating of interest among young learners from Europe and other well developed countries.

Examples follow.




Chemicals, their properties and how they react
"No context" or "school context" Low interest, in particular for girls
Uganda
Ghana (Centr)
Lesotho
Swaziland
Zimbabwe
Botswana
Philippines
Bangladesh
India (Guj)
India (Mumb)
Malaysia
Trinidad & T.
Turkey
Greece
Portugal
Spain (Bal)
Russia (Kar)
Poland
Czech Rep.
Latvia
Estonia
Slovenia
Austria
Germany
Ireland
Scotland
N. Ireland
England
Japan
Finland
Iceland
Sweden
Denmark
Norway
0 10 20 30 40 50 60 70 80 90 100
Mean A2. Chemicals, their properties and how they react


Detergents, soaps and how they work
"Everyday context" Low interest for all
Uganda
Ghana (Centr)
Lesotho
Swaziland
Zimbabwe
Botswana
Philippines
Bangladesh
India (Guj)
India (Mumb)
Malaysia
Trinidad & T.
Turkey
Greece
Portugal
Russia (Kar)
Poland
Czech Rep.
Latvia
Estonia
Slovenia
Austria
Germany
Ireland
Scotland
N. Ireland
England
Japan
Finland
Iceland
Sweden
Denmark
Norway
0 10 20 30 40 50 60 70 80 90 100
Mean E26. Detergents, soaps and how they work

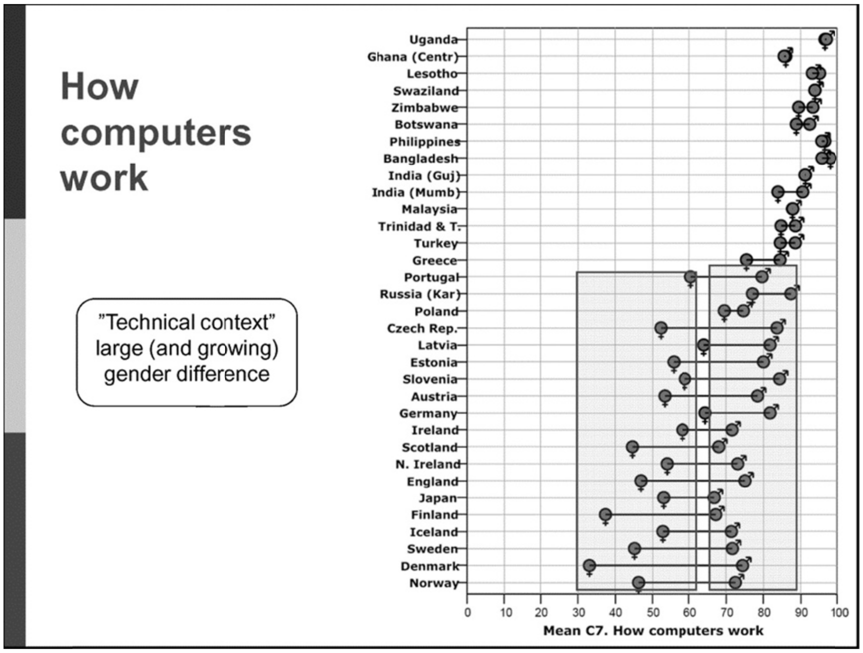


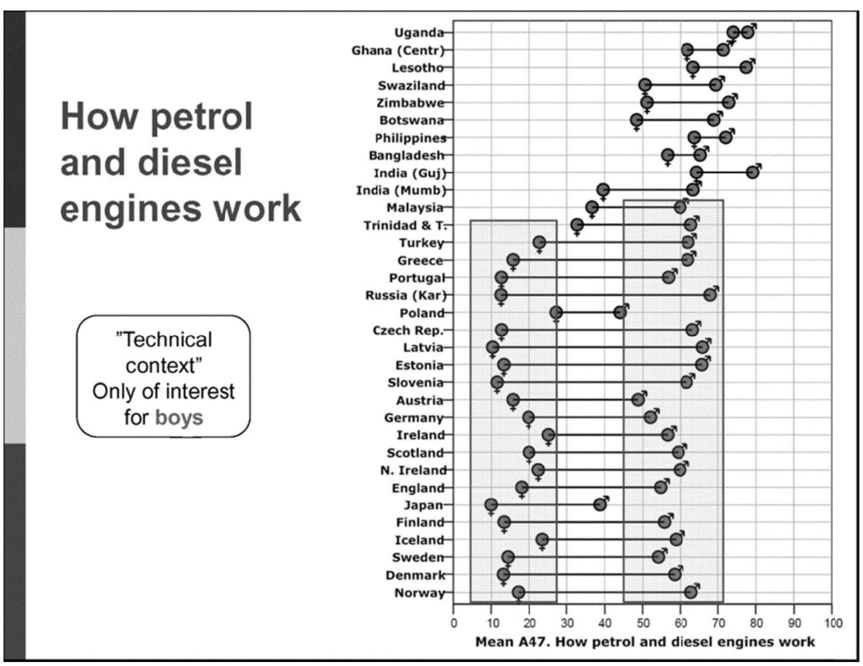
Girls' and Boys' Interest are Context-Dependent – and Growing with Level of Development

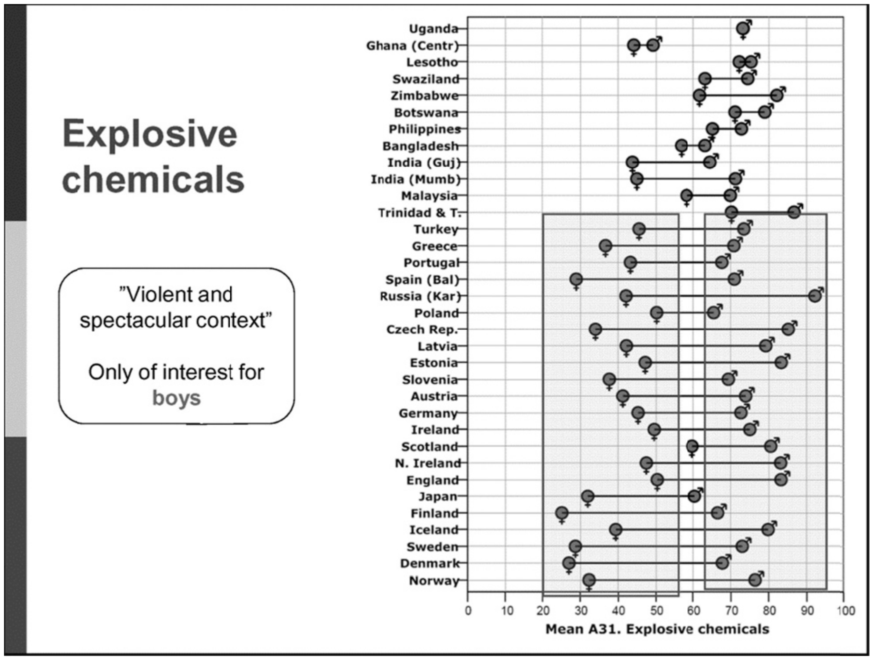
The annotated graphs on the following pages illustrate that the ***Context*** is a key to understand the expressed interest.

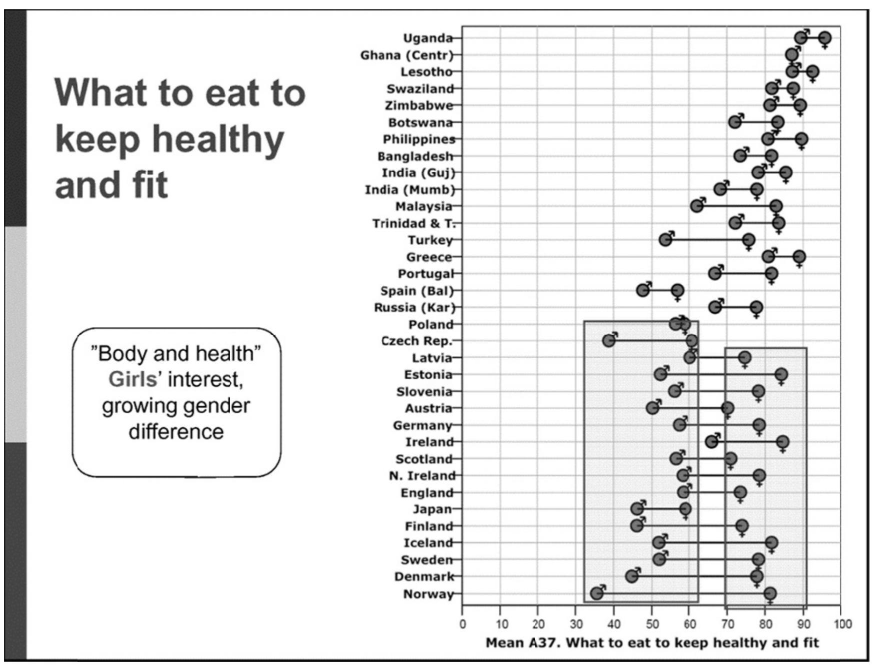
In sum:
Boys' interests (and **NOT** the girls'):
The technical, mechanical, electrical, spectacular, violent, explosive…
Girls' interests (and NOT the boys')
Health and medicine, beauty and the human body, ethics, aesthetics, wonder, speculation (and the paranormal.)

Examples follow.

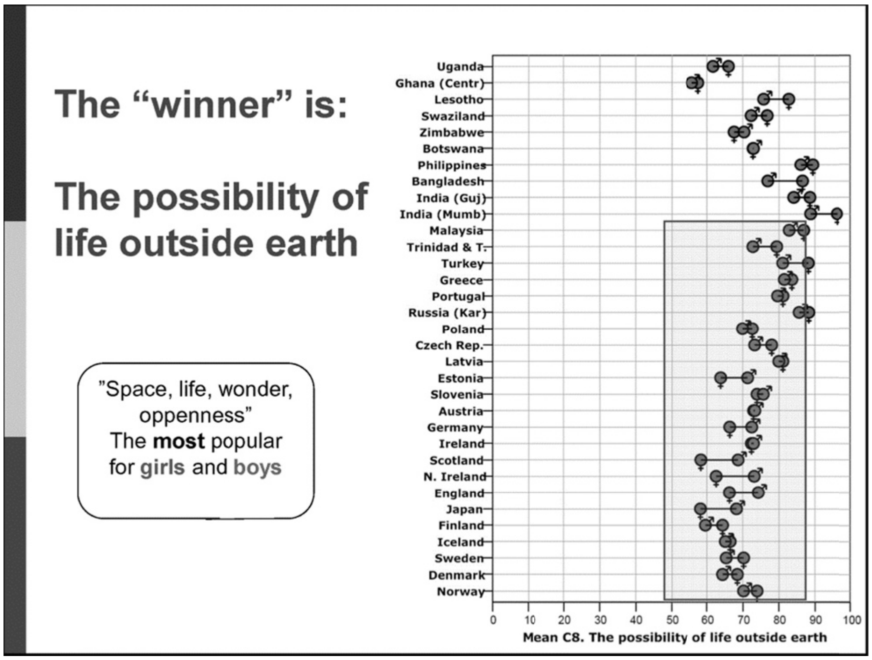





Explosive chemicals
"Violent and spectacular context"
Only of interest for boys
Uganda
Ghana (Centr)
Lesotho
Swaziland
Zimbabwe
Botswana
Philippines
Bangladesh
India (Guj)
India (Mumb)
Malaysia
Trinidad & T.
Turkey
Greece
Portugal
Spain (Bal)
Russia (Kar)
Poland
Czech Rep.
Latvia
Estonia
Slovenia
Austria
Germany
Ireland
Scotland
N. Ireland
England
Japan
Finland
Iceland
Sweden
Denmark
Norway
0 10 20 30 40 50 60 70 80 90 100
Mean A31. Explosive chemicals


What to eat to keep healthy and fit
"Body and health"
Girls' interest, growing gender difference
Uganda
Ghana (Centr)
Lesotho
Swaziland
Zimbabwe
Botswana
Philippines
Bangladesh
India (Guj)
India (Mumb)
Malaysia
Trinidad & T.
Turkey
Greece
Portugal
Spain (Bal)
Russia (Kar)
Poland
Czech Rep.
Latvia
Estonia
Slovenia
Austria
Germany
Ireland
Scotland
N. Ireland
England
Japan
Finland
Iceland
Sweden
Denmark
Norway
0 10 20 30 40 50 60 70 80 90 100
Mean A37. What to eat to keep healthy and fit

In spite of the strong gendering of interest, there are some items that seem to be interesting for both girls and boys. One example is given below.

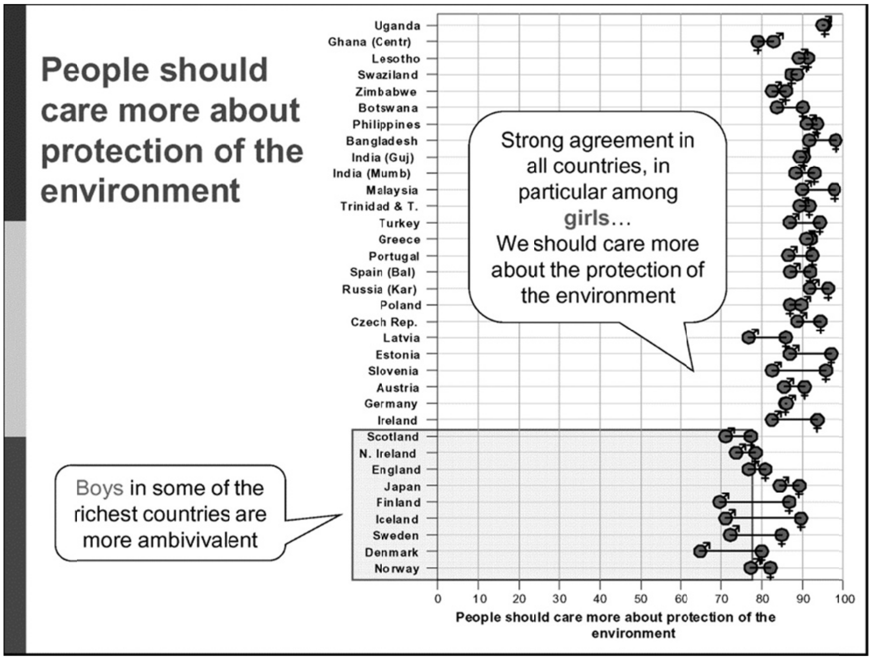


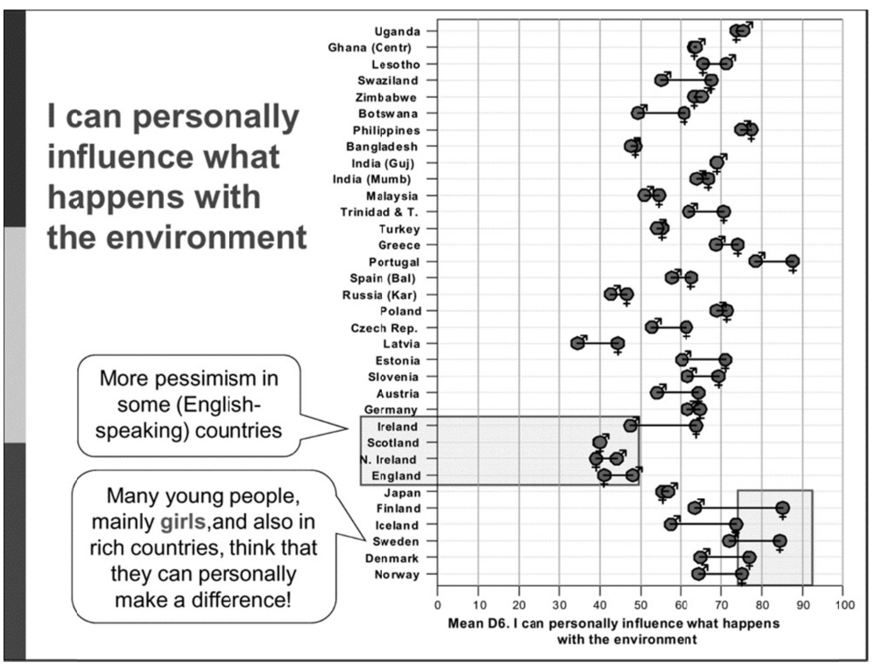
Concern for the Environment – Mainly a Concern for Girls?

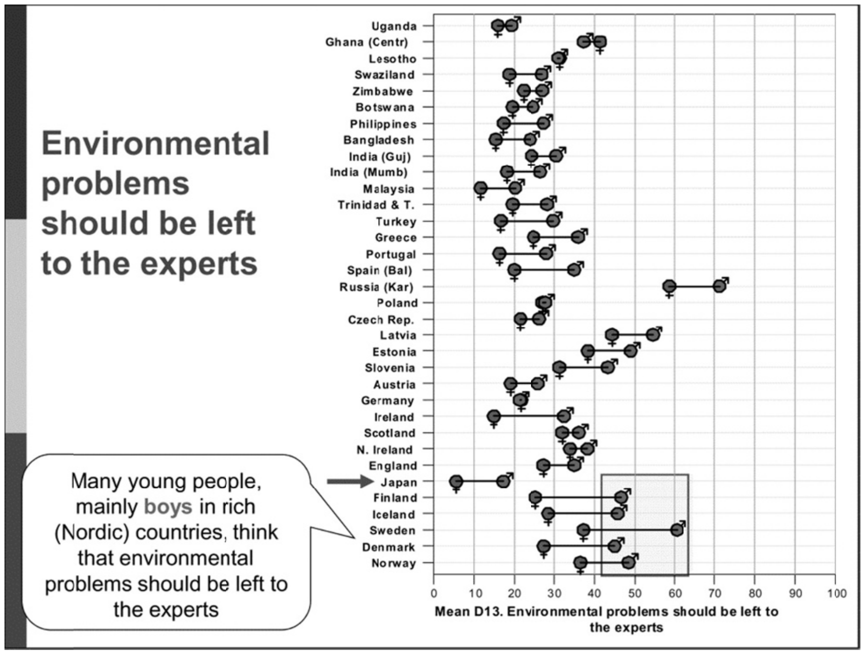
The ROSE instruments contain 18 items that probe how young people relate to environmental challenges. The overall impression is the following: Environmental issues are important for all, but mainly for **girls**.

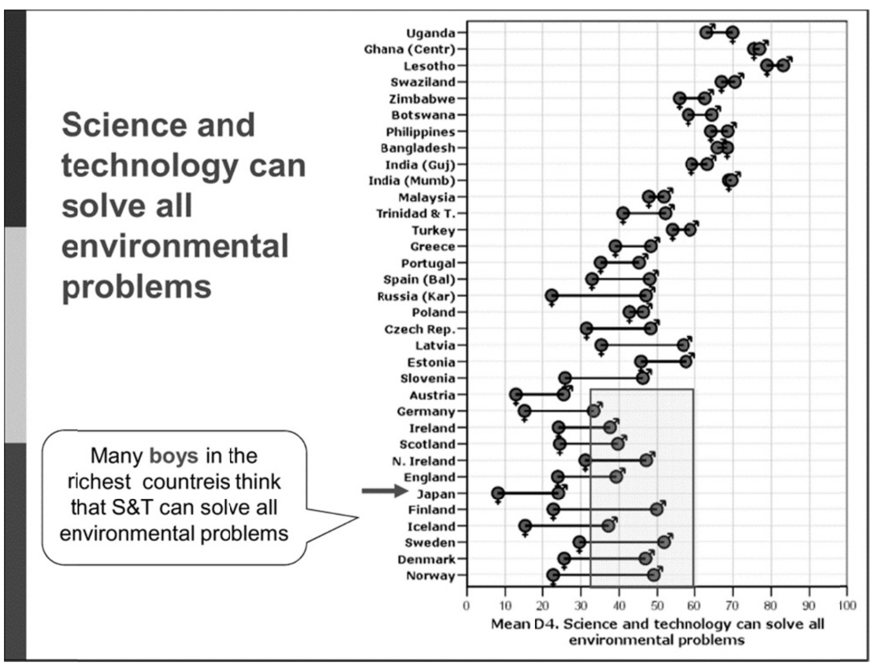
- **Girls**, more than boys, agree with statements like:
  People should care more about protection of the environment, I can personally influence what happens with the environment
- **Boys,** more than girls think problems are exaggerated and trust experts to sort out the problems
- **Boys**, more than girls think that science and technology can solve **all** environmental problems, (a considerable number of boys also agree with statements like, Science and technology can solve nearly **all problems)**
- **Girls** believe that each individual makes a difference
- **Girls** are willing to ‘pay the price’
- **Boys** are more reluctant

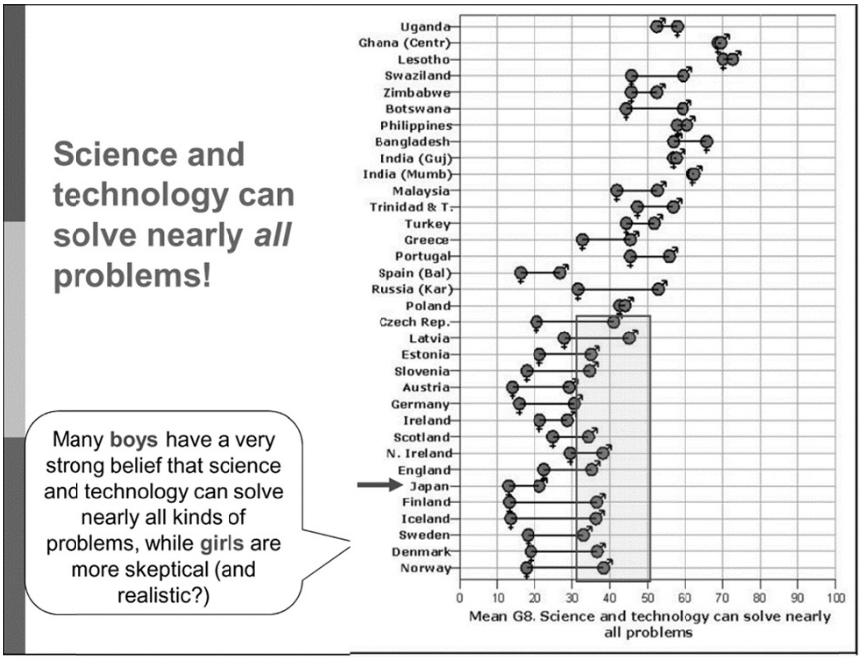
Examples follow.






Environmental problems should be left to the experts
Many young people, mainly boys in rich (Nordic) countries, think that environmental problems should be left to the experts
Uganda
Ghana (Centr)
Lesotho
Swaziland
Zimbabwe
Botswana
Philippines
Bangladesh
India (Guj)
India (Mumb)
Malaysia
Trinidad & T.
Turkey
Greece
Portugal
Spain (Bal)
Russia (Kar)
Poland
Czech Rep.
Latvia
Estonia
Slovenia
Austria
Germany
Ireland
Scotland
N. Ireland
England
Japan
Finland
Iceland
Sweden
Denmark
Norway
0 10 20 30 40 50 60 70 80 90 100
Mean D13. Environmental problems should be left to the experts


Science and technology can solve all environmental problems
Many boys in the richest countreis think that S&T can solve all environmental problems
Uganda
Ghana (Centr)
Lesotho
Swaziland
Zimbabwe
Botswana
Philippines
Bangladesh
India (Guj)
India (Mumb)
Malaysia
Trinidad & T.
Turkey
Greece
Portugal
Spain (Bal)
Russia (Kar)
Poland
Czech Rep.
Latvia
Estonia
Slovenia
Austria
Germany
Ireland
Scotland
N. Ireland
England
Japan
Finland
Iceland
Sweden
Denmark
Norway
0 10 20 30 40 50 60 70 80 90 100
Mean D4. Science and technology can solve all environmental problems



What is Important for Future Work?

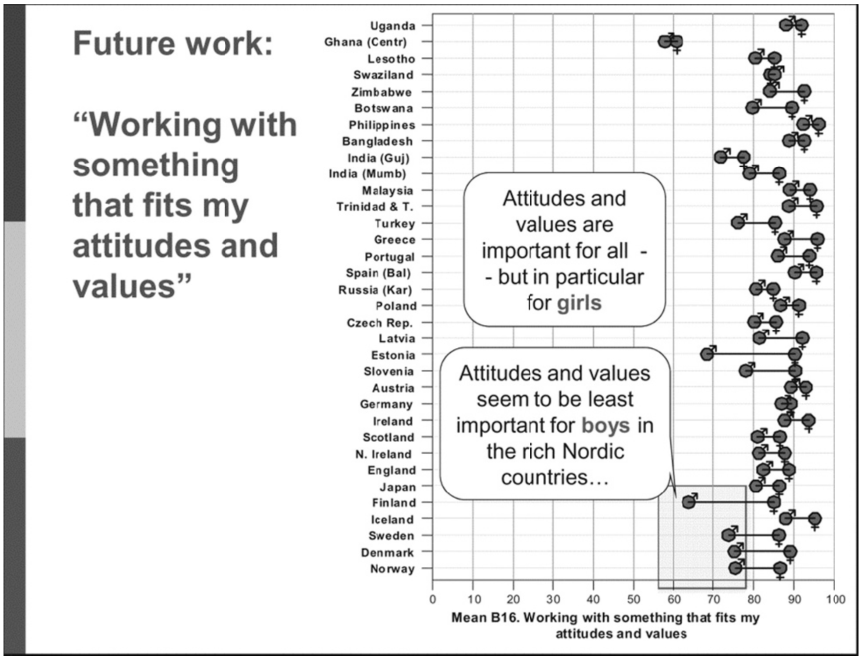
The ROSE instrument contains 26 questions that probe the plans and priorities for future work.

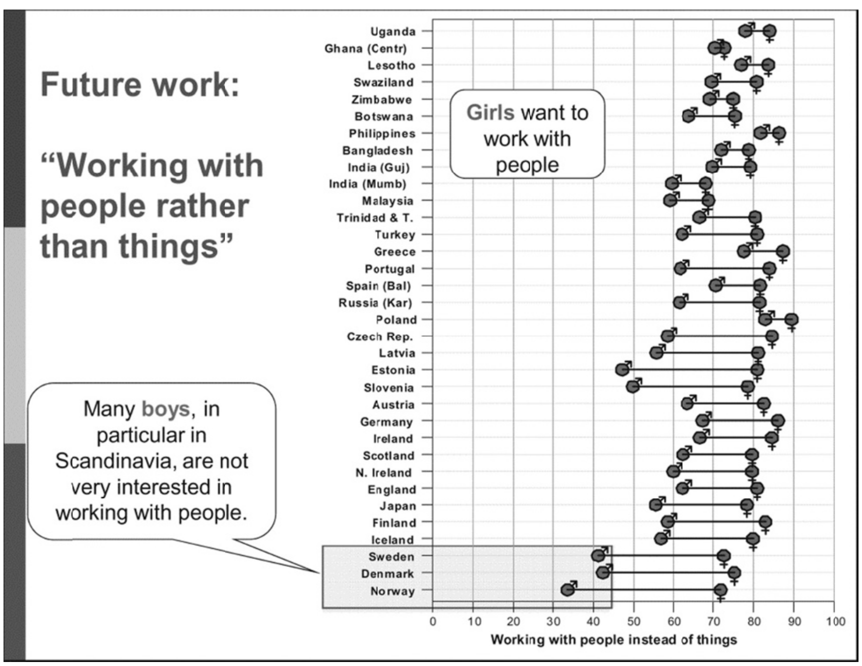
The wording is: **My future job:** How important are the following issues for your potential future occupation or job? This is followed by a list of 26 different options.

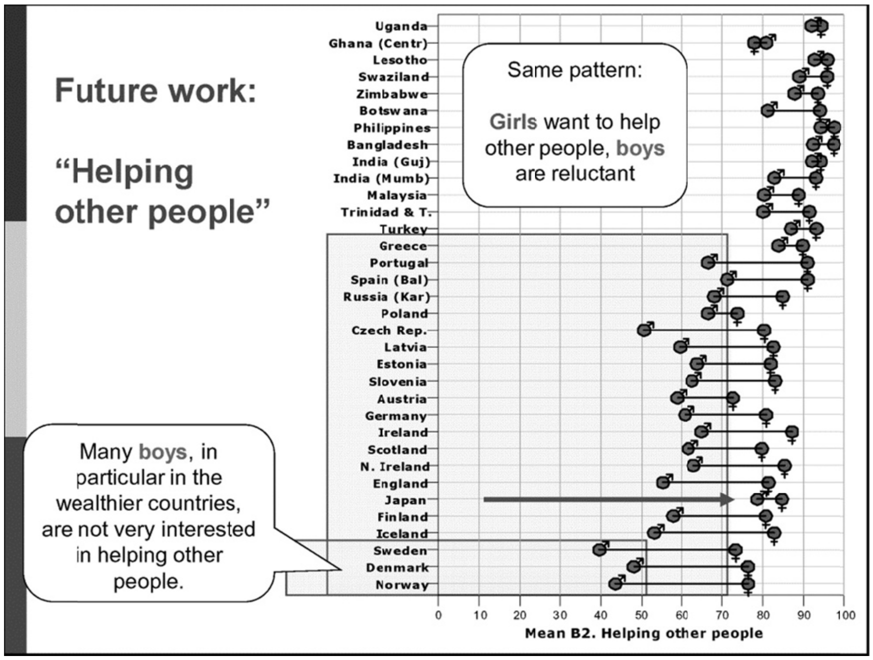
The results confirm our initial assumption about the prime importance of **values, attitudes and meaning**! However, on all items probing this, we find that **girls**, in all cultures, seem to value these aspects even more than boys do. In addition, we observe the following pattern:

- **Girls**’ priority: Working with, and helping people
- **Boys**’ priority: Working with their hands, with things, machines and tools
- Boys, more than the girls favour:
  Earning lots of money, becoming the boss at the job, becoming famous…. and *having an easy job*…)

Examples follow:







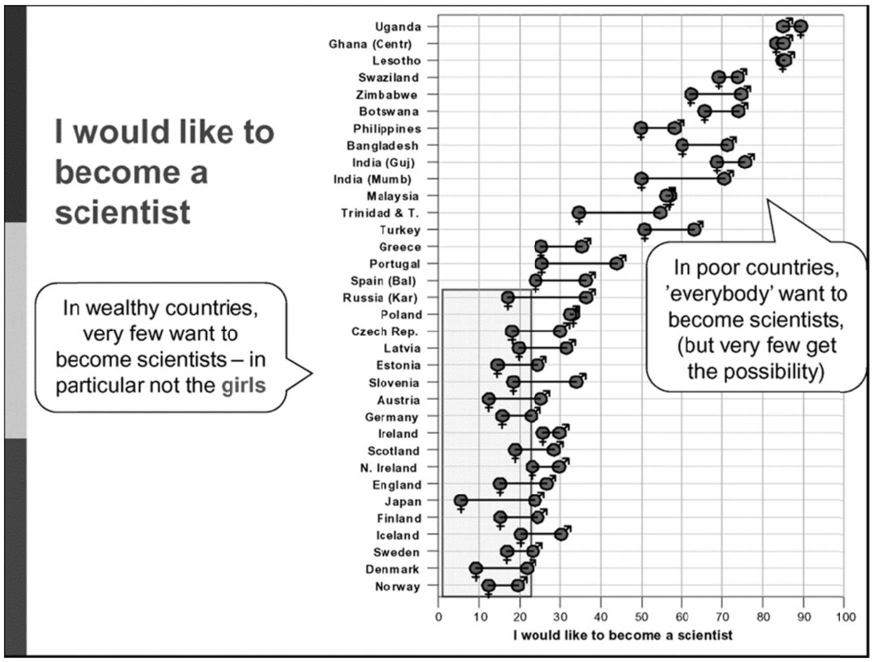
Recruitment to Science and Technology?

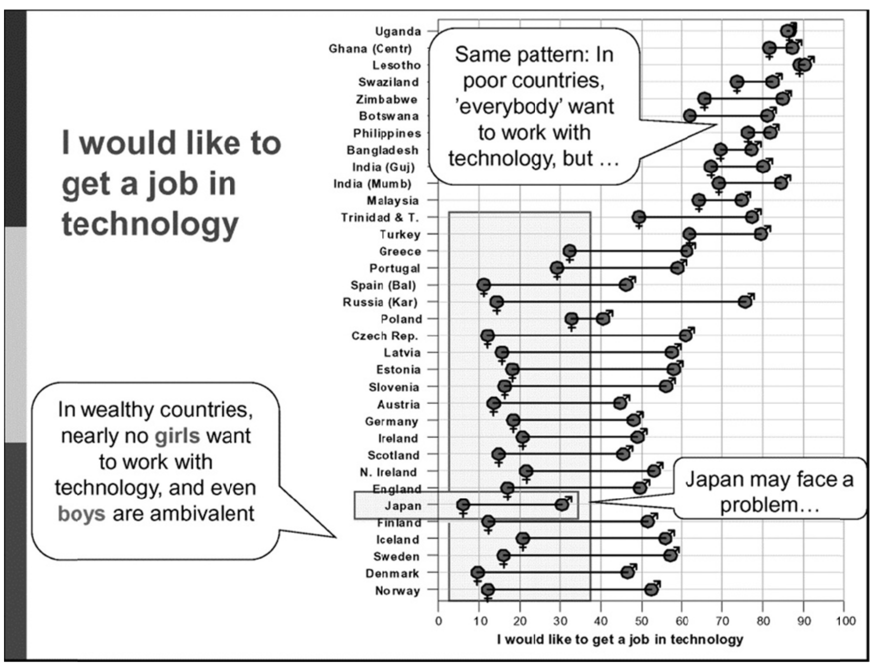
Since recruitment to S&T is a prime concern for the EU (as well as for most OECD countries), we have some questions that directly address this issue. The results are not very encouraging.

Very few young people agree with the statement *“I would like to become a scientist”*. In particular, there are extremely few **girls** who want to become scientists, and even for the boys the percentage is very low. We also observe that the more developed the country is, the lower the desire to become a scientist.

Similar responses are given to the question. *“I would like to get a job in technology*”. In Europe, around 50% of the boys give a positive response, but very few girls indicate that they want such a job. This gender difference is, indeed, dramatic, and there seems to be something about the perception of “technology” that puts off girls in all well developed countries.

Examples follow.





DISSEMINATION AND POSSIBLE IMPLICATIONS

An important aim of ROSE has been dissemination of results to stimulate informed discussions about important issues regarding S&T in education and society. To a large extent, this aim has been fulfilled far above our expectations. In many countries, national debates, reports and action plans make reference to ROSE results. At the international level, ROSE results and has been presented and discussed at several large EU conferences (on Science in society, on Science communication, Gender and science etc.) as well as for more professional S&T organizations like ESERA (European Science Education Research Association), NARST (National Association for Research in Science Teaching), IOSTE (International Organization for science and technology Education) and PCST (Public Communication of Science and Technology).

Organizations for science centres (like Ecsite, the European network of science centres and museums) also use results, and ROSE data are also used in several international reports, such as the EU (2004) report *Europe needs more scientists*, the OECD (2008) report *Encouraging Student Interest in Science and Technology Studies* and The Nuffield Report *Science education in Europe: Critical reflections* (Osborne and Dillon 2007) .

ROSE results have also been used by the *Wellcome Trust* in their preparation for their Wellcome Monitor[8] and by the *European Roundtable of Industrialists*[9] in their multi stake initiative “Inspiring the next generation” to stimulate recruitment to industry and technology.

While dissemination and the discussion about priorities is an important aim in itself, it is more problematic to state clear-cut implications of the ROSE results. This is, of course, not unique to this project. It is always problematic to move from the descriptive to the normative, to draw educational implications from empirical findings. Recommendations for possible actions necessarily involve (open or implicit) choice of values. One might, however, based on the value commitments of the project, say something about possible consequences.

From our perspective, criteria for success in SMT teaching at the compulsory level will be closely linked to lasting, possibly life-long attitudinal aspects , and , for instance, not just higher scores in tests like PISA. These attitudinal aims are for instance higher interest in SMT, positive (as well as critical!) attitudes to SMT, willingness to engage in SMT related issues, understanding the significance of SMT for our well-being, for democracy and culture. For some, but not for all, this may lead to a motivation to choose SMT as subjects in schools, even to go into SMT studies and occupations.

With such “criteria for success”, we may suggest some implications of the research findings.

Students’ experiences as well as their interest should be attended to in the construction of curricula, in the production of textbooks and other teaching material as well as in the classroom activities. In doing this, one should keep the documented gender differences in interests and values in mind. However, “listening to the students” does, of course, not imply that they should be taught "what they want to have". Teaching has to be motivating (in particular in the more wealthy countries), meaningful and engaging. It has, in some way, to link up to the values and interests that the learner brings to the classroom. If not, no other "learning" than rote memory based on duty is likely to occur. If the learners' encounter with school science is negative, they are likely to develop negative attitudes, and will turn their backs to SMT when they make their decisions in the future lives, be it as students or as citizens.

There is today an international recognition that SMT (and other subjects) should be "contextualized", should have meaning in the *context of the learners*. (Some countries use the term "localizing the curriculum".) Current theoretical concepts like "constructivism", "situated learning" and "socio-cultural theory" point in the same direction. The implication of these current perspectives is also that students' own attitudes, values and interests should be given high priority in the selection and presentation of the science curriculum content. Teaching material and teaching practices that do not engage students in meaningful learning are not likely to give lasting positive results. An implication of this is also that since the contexts of the learners vary widely from one country to another, science curricula (at this age, and as an obligatory subject) cannot and should not strive to be the same in different countries and cultures. Academic science may be seen as universal, but obligatory school science should, in our opinion, be context-based, and in some sense "local". This view also implies that we have a critical view on the implications of testing like TIMSS and PISA. In such tests, the items are *by definition* identical for learners in all countries. Moreover, in order to be "fair", no country should be favoured by the context of the items. In the PISA test construction there are procedures to exclude items which seem to be favour particular countries. In practice this means that the assumed "real life context" in PISA in practice is no context. The vision of having context-based, "authentic" and "real life challenges" items in an written, common, international "fair test" is impossible. This critique, shared by many science educators, is elaborated in Sjøberg, 2007.

As mentioned earlier, current science curricula, also in the early ages, are to a large extent based on the assumption that school science is the first step in the process to educate the future scientist. Curricula follow the logic and the structure of well established academic science. Although "logical" from a scientific point of view, this is not likely to be engaging for the great majority of children. This critique is well developed in the recent Nuffield report (Osborne and Dillon, 2007) and is not further explored here.

The ROSE data on pupils' interest profiles, show that a lot of "text-book science" is at the bottom of the students' interest. Rather surprisingly, also everyday science and technology seems to not be very attractive. While many science educators stress the need to connect school science to everyday situations, our results indicate that this might not be very appealing to many learners. This is particularly the case in more wealthy European countries. This poses some intriguing questions to what young learners see as "relevant" science.

On the other hand, we see an interest and a curiosity with phenomena that are unknown or exotic. Some of these questions are close to the research front, where clear answers do not yet exist (like “life in the universe”), other questions may open for philosophical speculation, where there is not necessarily one correct answer. It seems obvious that school science has an image of just providing a series of correct answers, with no room for debate and doubt. Although school science has an obligation to provide a basic understanding of established science knowledge, one should also be more open for exploring and discussing “frontier science” or things we still do not understand. Such discussions, in our opinion, may also open up for the creativity and openness that should be seen as parts of the image of science.

In particular, there seems to be a need to “humanize” school science, to show that science is part of human history and culture, and that it is a corner-stone in our present, modern world-view. The learners should also see that S&T form the basis of our current way of life as well as a basic element of many jobs and occupations, also for those who do not choose to work in what is perceived to be the S&T sector.

The purpose of ROSE is to provide empirical data of the views, interests and attitudes of young people for an informed discussion on such issues. As one can see, there are remarkable differences between countries, but the most striking are the differences between girls and boys.

The low proportion of girls who choose studies and occupations in SMT is an important concern in most countries. The ROSE data may provide insights into how to increase girls’ interest and motivation for SMT studies and careers. Girls are, more than boys, orientated towards values. They are, on the average, and across nations, more idealistic, more people-oriented as well as more oriented to care for the environment. If SMT school curricula, teaching (and testing!) open up for such aspects of the subjects, one may hope for a better gender balance in the future. It is important to stress that such a turn in priorities does not imply a “watered- down” version of real science. On the contrary, one may well argue that the needs of our future society will be better served if potential scientists, engineers as well as science teachers see the relevance of SMT to meet the pressing demands of our societies.

But most important is, of course, that students who will not pursue SMT as studies and careers, leave school with an understanding that science is crucial for addressing the many challenges that we are facing, at a local as well as on a global level. In this way, they may be better prepared to act as informed citizens.

NOTES

1 This article draws on material from the following publications: Schreiner, 2006; Schreiner & Sjøberg, 2004, 2005; 2007 and Sjøberg & Schreiner 2012.

2 ROSE received basic funding from The Research Council of Norway, The Ministry of Education in Norway, The University of Oslo and the newly established Norwegian Centre for Science Education. Industrialized countries have covered their own expenses, while some funding for data collection was provided for developing countries and countries with less available resources. Joint international workshops have been covered by the Norwegian funding. Participation in the project has, in many countries, led to the release of local funding for the national ROSE project.

3 The group had, in addition to the Norwegian team, the following members: Dir. Vivien M. Talisayon (The Philippines), Dr. Jane Mulemwa (Uganda), Dr. Debbie Corrigan (Australia), Dir. Jayshree Mehta (India), Professor Edgar Jenkins (England), Dir. Vasilis Koulaidis (Greece), Dr. Ved Goel (The Commonwealth, now India), professor Glen Aikenhead (Canada) and professor Masakata Ogawa (Japan).

4 A new "special Eurobarometer study on Science and technology" collected data in 32 countries in the beginning of 2010. Also here, the overlap with ROSE was considerable.

5 The United Nations Development Programme (UNDP) publishes an annual Human Development Report (HDR) with indexes for human development for each country (Human Development Index, HDI). HDI-values range from 0 to 1, where a higher value means higher level of development. HDI takes into account three indicators of development; health measured through life expectancy; education seen through educational attainment in terms of adult literacy and ratio of enrolment in primary, secondary and tertiary schooling; and economy, in terms of adjusted real income (for technical details, see UNDP, 2005).

6 For details on Eurobarometer. http://ec.europa.eu/public_opinion/index_en.htm

7 In spite of non-random sampling procedures, countries that are commonly considered as similar to each other (for example African, Baltic or Asian countries) do in most instances show similar or related response patterns. This can be seen as some validation of the data.

8 The Wellcome Trust Monitor is a survey of UK adults' and young people's views of medical research and seeks to develop a more systematic approach to describing and understanding trends in public interest in, knowledge of and attitudes towards medical research and its associated advances and applications. http://www.wellcome.ac.uk/About-us/Publications/Reports/Public-engagement/WTX058859.htm

9 The European Roundtable of Industrialists (ERT) is an informal forum for around 45 chief executives and chairmen of major multinational companies of Europe, covering a wide range of industrial and technological sectors. http://www.ert.be/

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10. THE CULTURAL CONTEXT OF SCIENCE EDUCATION

INTRODUCTION

In this chapter we argue that national cultural historic developments influence science education and gendered teaching and scientific career paths from primary school to higher education. The argument is based on a number of field studies spanning over recent studies in physics practiced at university institutes in Denmark, Italy, Poland, Finland and Estonia to a study of physics education in primary schools in Denmark and a comparison between physics students' possibilities for embarking on a physicist education in Demark and Italy. The influence of national culture on the relation between gender and physics education is complex and profound. Results are not testable in any simple way; yet, we contend that the cultural diversity found affects male and female emotions and motivation to study science as well as their possibilities to become outstanding scientists. The empirical data are discussed within the framework of cultural-historical activity theory. In the Russian psychologist Lev Vygotsky's theory of a zone of proximal development he discussed how human capacity for development can be aided by other human beings. He does not explicitly discuss how the developmental zone is related to cultural influence. We shall argue that the zone of proximal development in science education from a cultural perspective becomes a *relational* zone of proximal development.

We shall first briefly introduce the problems of gender and science education. Then we present the zone of proximal development as it is often explained and develop the notion of a culturally *relational* zone of proximal development. Culture is used as a heuristic device for understanding gender diversity in science education and we discuss the relational zones of proximal development in the culture of the classroom in relation to learning and not-learning in activity. Next we move on to discuss the culture of the classroom as embedded potentiality for development in national cultures and finally we discuss how relational zones of proximal development for girls in physics differ in Denmark and Italy.

THE GENDER PROBLEM IN SCIENCE EDUCATION

Physics has often been depicted as 'outside of culture' and an objective scientific endeavor whose practitioners regard their scientific career paths as determined by

Doris Jorde and Justin Dillon (Eds.), Science Education Research and Practice in Europe: Retrospective and Prospective, 237–252.

hard work and natural skills and where ‘temperament, gender, nationalism or other sources of disorder’ are of secondary importance (Traweek 1988,162). It has however, especially since the 1980’s become more and more apparent that physics as a discipline is in crisis in the Western world, when it comes to attracting new practitioners to the field. In the second half of the 20th century two major connected movements have changed the face of higher education in the Western world, which can be said to have deepened the crisis. In the wake of the women’s liberation movement more and more women have embarked on a higher education. This movement has led to the appearance of a ‘mass university’, but physics and other disciplines within science education such as engineering has not benefited from the move towards education for the masses experienced in all areas of higher education such as universities and other institutions which award academic degrees. This fact has been explained as ‘science anxiety’ (Mallow & McDermott 1988, Mallow 1986) and is related to students lack of technological and scientific literacy (Garmire & Pearson 2006). The very idea of science education seems to repel many young students. This repulsion is apparent already in secondary school and it is most salient among girls (Sjøberg & Schreiner 2005). It has been speculated that the apparent dislike for studying physics and other ‘hard sciences’ (as it is termed in many western countries) rests on profound differences between boys and girls (Stadler, Duit & Benke 2000), which could also be explained as a “natural” female tendency toward science anxiety (Mallow 2006,5). These differences in secondary school could explain why we find a gender diversity in the motivation for studying physics at the higher levels of education. The problem, however is more complex. Even though science education and the possibilities to chose a career as scientists seem to be equally open to male and female scientists in the industrialised world we find a huge diversity in how many female physicists are employed in countries like USA, Japan, Denmark, and in Italy, Portugal, Turkey and in former Eastern European countries in general. This diversity seem to point to the need for deeper explanations than a simple ascertainment of gender diversity or differences in gendered identities, which places physics as a masculine activity (e.g. Merchant 1990, Keller 1984). We shall address this complexity by introducing Vygotsky’s concept of a zone of proximal development. This concept will help us understand how cultural learning processes (Hasse 2008) in a profound way shape cultural motivations for men as well as women as they develop in historically formed societies, which affect individual life-histories as well as the learning of scientific disciplines.

THE ZONE OF PROXIMAL DEVELOPMENT

A deeper understanding of cultural diversity in the development of an interest in science education and scientific and technological literacy can be obtained with help of the concept of the zone of proximal development. With this concept Vygotsky introduced learning as a key prerequisite for development in cultural historic processes.

One of the examples given by Vygotsky to exemplify the concept of the zone of proximal development describes two students in a school, who have the same actual level of development. This puts them on par when asked to solve a test – but with the aid of the teacher it turns out that they have different zones of proximal development. One student moves much further ahead than the other when helped by the teacher (Vygotsky, 1978, 74). This process is defined as:

> *The distance between the actual developmental level as determined through independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers. (ibid., 86).*

By analyzing the educational process in this manner Vygotsky shows that when properly organized (exceeding the actual developmental level - and not exceeding it beyond the zone of proximal development) – learning results in development. Thus learning is a necessary and universal aspect of the developing culturally organized, specifically human psychological functions, (ibid., 90).

It is difficult to render justice to Vygotsky's original idea even when studying primary sources, because the concept was developed and redeveloped over time. This concept is not only one of the most well known contributions of Vygotsky, but also one of the most misunderstood and contested (Chaiklin 2003). According to Chaiklin many of the contemporary applications of Vygotsky's concept of the zone of proximal development goes way beyond the theoretical issues Vygotsky was trying to address. When researchers like Yrjö Engeström (1987) connect zones of proximal development with activity systems, communities of practices and when connected with culture (Hasse 2001) we take the concept out of its original discussion related to the development of children and use it for our own purposes.

In extracting and expanding the theory we are not trying to replicate the theory of zone of proximal development precisely as it was discussed by Vygotsky himself. We follow the argument of Sylvia Scribner (1985) who expounds the theories of Vygotsky to include a general perspective on adults' learning and development. Scribner's interpretation of Vygotsky's theoretical framework includes:

1. The general history of humankind
2. The history of individual societies
3. The individual life-history in society
4. History of a particular psychological system

As higher mental processes do not originate in biological evolution and cannot be explained with reference to natural laws, but with reference to 'laws of history', socially organised activities change in history but the changes have directionality. This movement is expressed as mental development (the zone of proximal development). Questions of how motivation and emotions are created cannot be separated from the history of how human mental life becomes what it is.

Vygotsky himself named the symbolic-communicative spheres of activity in which humans collectively produce regularity for 'cultural' and new forms of behaviour 'specifically cultural forms'. And Scribner concludes that it follows that a methodology appropriate to study these cultural means and forms in the everyday practice must be employed.

The theory underlines the social character of development as learning, which:

> [a]wakens a variety of internal developmental processes that are only able to operate when the child is interacting with people in his environment and in cooperation with his peers (Vygotsky, 1978, 90).

The most important aspect of the theory for our purpose in our argument is the definition of the relation between learning and development. Learning is not reduced to a simple process of 'faxing' cultural messages into children's minds. What is learned is a potential for development – the direction of development and new learning. Developmental process in other words lags behind learning processes – and they are directed. We shall, with reference to Scribner, add that the process does not end in adolescence, but can also be used to describe the continuous lifelong learning processes of adults. Though children to a larger extent than grownups might be assimilators and adults the inventors of cultural artefacts (Scribner 1985, 130), children can also be inventors and adults also have zone of proximal developments affecting the development of creative processes (Moran & John-Steiner 2003).

In the line of argument presented here adults have to continuously learn what cultural-historical activity is about. Culture is what gives the direction of development and can be defined on many levels (classroom, institute and nation). Culture is:

> *[o]ften transparent to those who use it. Once learned, it becomes what one sees with, but seldom what one sees (Hutchins 1980, 12).*

Development is defined by us as the changes in our ever-moving perspectives of the world, on which we build new learning. It is neither used to refer to child development in the general understanding of the word, nor in the rather evolutionary sense used by most scholars in the 1920's.

Vygotsky himself refers to a number of anthropological studies on what was then considered 'primitive' people in his wider discussion of learning theories, but this dimension is not quite unfolded, just as his concept of culture remains unspecified (Veer 1996).

We have sought a method to study processes – not the products – of contemporary adults and in everyday life and to look for arguments for the *motivation behind the words (and actions)*. This is not child development of rudimentary to higher psychological forms, but the motivational changes which take place as national cultural-historical developments affect male and female life-histories.

THE RELATIONAL ZONE OF PROXIMAL DEVELOPMENT

We have all gone through cultural historical developments which might be unknown to (adult) newcomers. This process becomes clear for a researcher meeting with a group of people, who have already developed in each other's company over time – but it is not only researchers who occasionally are newcomers. This is also the situation for example for new students embarking in higher education.

In 1996 one of the authors of the present chapter enrolled as a physics student in a department of physics in a higher education institution in order to study the inclusion and exclusion processes of male and female physicists students at close-hand (Hasse 2008). Through participant observation, with an underlining of 'participant' she, as the other newcomers had to learn a new understanding of the meaning of well-known words and physical artefacts. Some students also learned to develop a new identity as 'physicists-to-be'. They were encouraged as their learning turned into development in the meeting with the established staff of teachers at the institute. Other students quickly learned that they did not belong in the discipline of physics. As has been argued this process of inclusion and exclusion had much less to do with good grades in physics as with the teachers´ recognition of potentials in some of the students, which clearly had a motivating effect (Hasse 2002, 2001). Theoretically we can argue that particular cultural patterns are reinforced or weakened as we continue to learn; not only official curricula but also the informal 'code-curricular' taught to all newcomers through complex processes in everyday life. This is generally not taught in words, but through reactions (e.g. to actions, spoken words, how we dress and what we read) (Hasse 2008). Communications are not just verbal in science education. "Body, gesture, and context have become recognized as important resources in human communication" (Roth, 2004, p. 1040). However, whether communication is conducted verbally or through gestures or material artefacts, we do not have the same prerequisites for learning. No two newcomers are alike in their zones of proximal developments but as a relational zone of proximal development some will soon learn that they sooner than their peer obtain a deeper understanding of the local institutional 'code-curricula' which is to be learned along with the deeper understanding of scientific concepts. The code-curricula is not taught or learned in the same way for everybody. Thus, there might *not* be a correspondence between an actual phenomena of cultural development in the child/student and in the development of cultural history in a national scale.

The relational zone of proximal development of a child's ability to develop into a scientist is, in our line of argument, determined by the history of the development of the scientific discipline, the way it is interpreted and contextualised by individual teachers who have developed their understanding of the discipline in the cultural histories of societies. With 'individual' we do not mean essential entities with closed boundaries, but rather persons with experiences which are supporting certain cultural patterns roughly (but not necessarily solely) equivalent with language areas. The child going to a school in the language area in question might already have developed a zone of proximal development, which can develop into an understanding of scientific concepts. Whether this takes place or not, depends on the teacher's actual ability to discern potentials in the student and this in turn depends on the teachers former experiences. These can be formed in a cultural historical development which *prevents* the teacher from recognizing perfectly able students as having potentials for learning natural sciences (Sinding 2007b). The distance between a student's actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance must therefore be seen in relation to the actual developmental zone of the adult (or peers) helping the student. The zone of proximal development is relational, when the teacher's actual development is included in the potential developmental zone of the students (Hasse 2001).

CULTURE AND MOTIVATION

Culture is not so much about a shared uniform homogeneity in a group of people as a force which includes and excludes the culturally suitable. These 'chosen ones' shares an understanding, which reaches beyond any lexical meaning of words and deeds. They share thoughts, emotion and motivation.

Thoughts do not immediately coincide with verbal expression. Thoughts do not consist of individual words like speech (Vygotsky 1987, 281). What does this imply? It implies there is a line, albeit not direct, from what we call culture to the cultural understandings of individuals living the culture.

Even our thoughts, motivation and emotions are cultural-historical products in the sense described by Jerome Bruner in the foreword to the collected works of Vygotsky (1987), where he connects the zone of proximal development with Vygotsky's extensive discussion of what he calls the 'moving inward of speech" (Bruner 1987, 4) and he refers to the passage in Thinking and Speech where Vygotsky claims:

> *Understanding the words of others also requires understanding their thoughts. And even this is incomplete without understanding their motives or why they expressed their thoughts. In precisely this sense we complete the psychological analysis of any expression only when we reveal the most secret internal plane of verbal thinking – its motivation. (Vygotsky, 1987, 283).*

To be products of cultural-historical processes we have to understand the thoughts of others, because we understand their culturally created motivation. There were many examples of particular students sharing thoughts with their teachers at the Niels Bohr Institute, which went way beyond the learning of the formal curricula. Some students quickly learned to discuss the potential developments for physics connected to the rules learned in the classroom. These students and teachers could be seen discussing in the hallway after class. They shared an interest in questions like 'is there life in outer space?' 'Can physics allow for the construction of time machines?' etc. and in their discussions students developed a wider understanding of physics. They became motivated, not only to become physicists, but to become physicists with a sense of direction. Emotions were also tied to these directions. When one of the teachers, who often spoke to students about finding life in space, informed the students about a cancelled mission to Mars (where it was expected to find traces of water – a prerequisite for life) some of the students expressed almost as deep a disappointment as he did, while others did not seem to care. The students, who were disappointed, had connected their own emotions and interests to the expected outcome of the search for life on Mars, which helped to engage the students in the physics teaching of the teacher. They used physics to discuss why the mission failed. The students who did not invest the same kind of the emotions in the information of the cancelled mission to Mars did not engage themselves to the same extent in the physics discussions in the classroom (Hasse 2002, 290 *ff)*. Where Vygotsky's example dealt with two students on exactly the same level, in these examples the situation is more complex, because we do not know if the students actually were at the same level to begin with. When learning from teachers reactions it was clear that students who connected physics with the science fiction-like idea of going to Mars were often praised for their skills as 'physicists-to-be'. Physics students who asked about the general purpose of exercises or who simply solved the tasks put before them were not praised. The students, in other words, also learned who among them were developing into real physicists and who did not belong.

The teachers in general seemed unwilling to answer what was considered 'stupid' questions and these were often asked by women (Hasse 1998). Students who asked questions relating to 'the limit of God in physics' and how to develop the rules of physics into games and plays, where appreciated. If development is triggered by adult guidance, only some students would get this guidance.

GENDERED ZONES OF DEVELOPMENT

Exactly the same pattern has been discovered in secondary schools, where girls would ask questions, which were regarded as uninteresting by the teacher. A typical example is taken from a 9th grade class in physics working with patterns of inference:

Sanne looks at the diagram, and then Mia does the same. Thomas [the teacher] approaches the girls and asks: "Can you see a pattern"?
Sanne: "What kind of pattern?"
Thomas: "You should be able to see a pattern".
Sanne: "What are we going to use it for?"
Thomas: "You have to count the spots."
Sanne raises her eyebrows and looks puzzled. Thomas walks away.
(Sinding 2007b, 27)

In this case Sanne´s zone of proximal development remains proximal. She does not receive any usable help from the teacher and remains puzzled. She might be disappointed like the students longing for results of 'life in space', but for entirely different reasons. She is not disappointed along with the teacher's motivation and emotions, but because of the teacher. She is 'de-motivated'. This is not a question of science anxiety, but of feeling rejected. This is in strong contrast with several examples from the same school (and the Niels Bohr Institute) where teachers kept encouraging young males and clearly followed their line of thought, motivation and emotions better than the females.

At the Niels Bohr Institute a teacher approaches two students; a young man, Alexander, and a young woman, Anni, solving a task given earlier by the teacher. Alexander is playing around with the task given and tries to create a completely different task than he has been given – but this time the teachers approach is approving. He gives the young man good advice on how to precede. Anni, who has expressed worry about their possibility to solve the task originally proposed by the teacher, is overlooked and expresses disappointment (Hasse 2001).

Everyday life in education is filled with examples like these. Teachers have preferences and prefer some students and their questions to others. But when the teachers, in research analysis, appear to react in much the same way, cultural patterns begin to appear. There are similarities in the pattern in so far girls/young women get disappointed with teachers, whereas boys/young men get encouraged and recognized as scientists-to-be. Such patterns have be found in Denmark in relation to teachers' lack of interests in helping girls and young women with tasks to be solved even when they verbally express a wish to do so (Hasse, Trentemøller, Sinding 2008). Although most of the teachers discussed in the research would deny that they deliberately promoted gender differences, the net result of their actions and reactions are a reinforcement of exclusion patterns of women from physics. In everyday life in school situations we hear the remark again and again that physics is an activity for boys. Taken together these reactions to girls in the classroom should reinforce exclusion mechanisms for girls interested in physics (Sinding 2007a; 2007b); a pattern we find repeated in higher education. The lack of women in physics in Denmark is not a matter of science anxiety, gender-bias or outright discrimination – it is rather an expression of relational zones of proximal developments.

When the teacher himself is interested in science fiction or God in physics, questions relating to the 'reality' of Star Trek or life in space are not seen as stupid. When the student does not understand the use of looking for spots in a diagram and these spots are obvious to the teacher, questions appear as stupid. Sanne and Alexander are allowed to develop in very different ways and they can both be argued to form new potential developmental zones. What does Alexander learn? That he shares the teachers' motivation for praising him, because now he understands that play is the road to become a creative physicist (Hasse 2001). Alexander develops his general understanding of the context of the activity, but Anni remains puzzled and might begin to wonder if she belongs in physics at all. If she, like Sanne, has already in school experienced being brushed off as a pattern that is reinforced, she might decide to leave physics all together.[1] The zone of proximal development is relational as it depends on what activity the teacher you encounter regards as the leading activity of the institute (exam or play) (Hasse 2001, 209–210).

THE CONTEXT WHICH EXCLUDES

Activity theory can be a helpful tool in enhancing our understanding of what makes the actions of the teacher and Alexander meaningful. In the activity of education we find numerous relational zones of proximal developments, which include and exclude (and thus enforce particular cultural patterns). The germ-cell holding this process together can be seen as an activity. Activity can be seen as a specification of what is meant by context (Engeström, 1993, p. 67). The zone of proximal development is relational as it depends on what activity the teacher you encounter regards as the leading activity of the institute. But when activities across a country reinforce the same cultural patterns, we can begin to speak of national cultural historical activities. If these activities form a consistent pattern of diversity across national borders, we can argue that national cultural historical processes may form profound differences in people's emotions and motivations. Even in a global world with continuous traffic across borders (to an extent which might make us question the concept of national cultures at all) we can find such differences in patterns of inclusion and exclusion. This is not a question of culture being defined as different languages or of claims that every micro-location is typical of the national (McSweeney 2002, Hofstede 2002). Culture is in our use of the concept a pattern of inclusion and exclusion from activities, which are linking thoughts, motivation and emotion.

In activity theory activity is first and foremost defined as being collectively driven by an object-related motive, as summarized by Yrjö Engeström, Reijo Miettinen, and Raija-Leena Punamäki from the works of Lev Vygotsky, Alexander Luria and Aleksei Leont'ev (Engeström, Miettinen & Punamäki, 1999).

Following Vygotsky the cultural connections define the meaning of the words spoken. We would add that cultural connections also define the meaning of actions. If you do not understand connections tied to the activity (the cultural context) you do not understand the meaning of the words. Zones of proximal development might also be about learning these connections tied to the meaning of words and actions in particular social activities - a point *not* originally specifically developed by Vygotsky.

The culture of the classroom formed in everyday activity in schools creates a particular potential for development which to some extent might be informed by national cultures in so far national cultures induce culturally specific connections e.g. about science in relation to the wider society.

If we look at the proportion of male and female students in higher education in different parts of the world, it become apparent, that science anxiety is far more a culture than a gender issue. Italy, Portugal Spain and many Eastern European countries have many female physicists, whereas Denmark is among the ten countries with the smallest proportion of female physicists (together with Japan, Canada other Northern European countries and USA) and women seem to do much better in the "hard science" of physics in Eastern and Southern Europe (Barinaga 1994). In countries influenced by Islam like Turkey and Kuwait we find many female physicists (Ebeid 1998). In a country like Thailand girls are doing much better at physics and chemistry than boys (Fensham, Klainin &West 1989). In the most industrialised countries, such as USA, Denmark and Japan and the 'difference in interests between girls and boys vary from topic to topic, but are generally largest in the Nordic countries and Japan' (Sjøberg 2002). In higher education we find more female physics students in countries like Turkey and Italy than in Denmark (Hasse 2008a) and when it comes to permanent staff we have in a comparison between Denmark, Italy, Finland, Poland and Estonia found the highest proportion of female physicists is Italy (Hasse & Trentemøller 2008). In a wider perspective of women in science we find an even greater diversity between top and bottom scores (Barinaga, 1994, Thörngren et al., 2002).[2] As the stereotypes of practitioner in science are often males, also in countries like Turkey and India (Narayan, Park & Peker 2009), these differences cannot be explained with differences of connections between science and gendered stereotypes alone. That we find such marked gender differences between who is engaging in science severely counter scientific epistemologies, which rest on the central assumption that the success of science is insured by its internal features and that cultural influence on science is a superficial factor to be weeded out.

CULTURE AND SCIENCE EDUCATION

We can now ask: do cultural historical activities create different contexts for learning – even in a discipline as 'neutral' as physics? What kind of differences in thoughts, motivations and emotions appear and how is that tied to specific cultural connections? In Italy we find more female physics students than in Denmark. In Denmark the proportion of female physicist students is 18–20%, in Italy 40–45% (Hasse 2008a). We also find different connections (cultural models) which, through detours, appear to link science with gender in different ways. The Danish Ministry of Education refer to "hard" science and "soft" science in many homepages. "Hard" science is physics and math – biology is considered "softer" and studying languages and classical languages is considered very very "soft" (http://www.uvm.dk retrieved 30.06.2005). In 2000/01 23080 students were matriculated as physics studies at Italian universities. Of these 43.9% were women and of these more than a third enrolled with a humanistic often classical background, whereas there were less than a tenth of the men. Out of 25 Italian tenured physicists interviewed having a classical background, 14% were male physicists and 64% were female physicists (Hasse 2008a).[3]

In a Danish context humanities and natural sciences have most often been seen as mutually exclusive i.e. there are not many connections made between between 'hard' physics and 'soft' languages. This was made clear by the physics students Hasse followed at the Niels Bohr Institute: about the worse fate for a physicist was to be degraded to a person connected with the soft subjects from the humanities.[4] This was clearly de-motivating to be regarded as a 'soft' humanist in physics – and it called forth strong emotions to be regarded as such (Hasse 2002). However, many of the very successful Italian professors in physics Hasse later interviewed turned out to have entered their study with a high school background as classical

students versed in philosophy and cultural history, studying Aristotle in Greek, reading Cicero in Latin and the like.[5]
Italian male professor:

> *I myself have a background equivalent to a mathematical-physicist high school student in Denmark. But here in Italy it is rather an advantage to have a classical linguistic background, when you start physics studies at university level. The "classical" students are simply better at analyzing. What we learned in science high school was to think much more "mechanically" – to think in the correct answers. I have always believed students with a classical background are the most advantageous.*

An Italian teacher of philosophy expresses the same opinion in a slightly different manner. The "classical" students become especially apt physics students because they, through their knowledge of philosophical and classical subjects, learn to think in the abstract lines of thought of importance to both the natural sciences and the humanities. She underlines that until 15 years ago is was not uncommon that most of the matriculated at the physics institutes in Italy originated from the classical language area in high school – and thus did not have a scientific background.

> *The high school in classical languages simply was the best at training students in reasoning, because such a systematic and profound study of classical subjects had a formative influence on the students' intelligence – especially their ability to think in abstractions and make inferences.*

She furthermore underlines that a non-specialised education system like the Italian does not make to hard a division line between humanistic and natural sciences. And we do not find the same kind of gender divisions that we find in countries like Denmark, where girls and boys have had to choose between a humanistic or scientific line – and where we find that the girls in much greater numbers have chosen the humanistic line just as the boys in much greater numbers chose the scientific line.

This also conflates somewhat with a more relaxed attitude towards science in Italy.[6]

Learning this kind of connections through everyday life, organize our thought and motivation behind our words in cultural specific patterns in self-evident ways, which we take so much for granted, that they become our naturalized way of thinking about for example physics studies. We may become aware of the cultural aspects we meet persons from other cultural background who have other (likewise naturalized) ways of organizing their understanding of for example good physics education.

In one cultural context the female student is met with a relational zone which allows her to develop as a female physicist student being interested in classical studies – in another not.

CONCLUSION

We take seriously the idea that culture connects thought, motivation and emotions formed in everyday activities, as it has been argued in cultural historical activity theory (building on Vygotsky's claim that cultural-historical processes form the higher psychic processes) As also argued in the cultural-models theory. We also contend that when the relational zones of proximal development are formed in broad national cultural historical processes we are rarely aware of how profound thought, motivations and emotions are culturally connected. We speak and act as though our motivations spring from a free will and our emotions from inner psychological states. This line of thought conflates with a general understanding in science education, which assumes anyone who studies hard enough can learn to become a scientist.

In a discussion of the relational zone of proximal development we have made a new argument for the relation between science, culture and gender – which in fact makes the question of why girls perform badly and do not seem interested in physics in Denmark a kind of epiphenomena to other cultural-historical processes. Gender is not in itself an obstacle to become a scientist and there is no 'natural' tendency for women to develop science anxiety. What appears a 'natural fact' becomes questionable when confronted with what is natural for girls in other national cultures developed through other activities (not necessarily better, but different and equally 'naturalized').

When we find that in Denmark the coming elite of physics is considered playful rather than diligent and that physics is connected with 'being a hard subject' which is connected with masculinity, and that in general boy are connected with being playful while girls are seen as more diligent we find it natural that women in physics run into problems, develop negative feelings and science anxiety and have a difficult time identifying themselves with the physicist elite. We also have evidence that women to a larger degree than males lose confidence when they begin science studies in higher education. A survey showed that 100% of the female students embarking on a university study of physics express confidence in their own ability (excellent/pretty good) in physics, whereas after three months of university studies there was a drop in confidence among 53% of the females. For the males the numbers looked quite different. Only 92% of the males physics express confidence in own ability (excellent/pretty good) in physics when they begin their university studies but after three months of study only 16% of the males had become less confident (Hasse 1998). Young female physicist students thus seem to lose confidence to a larger extent than male students when they met the university requirements. When we learn that in Denmark, women seek language studies rather than science studies (Henningsen 1998), this dichotomy in a Danish context almost appears as a natural distinction: male = science = hard versus women = languages = soft. It becomes natural that women, who might also be interested in languages or other 'soft' subjects, lose confidence and are de-motivated in the world of natural science.

It is only when we contrast with Italy that these naturalised connections between 'soft' and 'hard' is questioned. In Italy classical studies are seen as a perfect legitimate road to study physics rather than an opposite to it. Physics is not connected to masculinity and 'hardness' and there is no playful elite consisting only of young males. Physics can be connected with languages and philosophy. In Denmark the relational zone of proximal development enforces connections between a playful elite in physics and a hard masculine science. These connections lead to less motivation especially for girls (but also some boys) and instead enforce a 'bad circle' of connections between physics and science anxiety = negative feelings = less motivation = more science anxiety. In Italy the relational zone of proximal development enforce connections between physics and classical and philosophical studies – and in general connections between physics and everyday life (Hasse 2008a). Fewer connections than in Denmark are made between being a hard, playful, elite which is also connected to being male. On the contrary connections are made between being expert on classical languages, being an elitisk scholar, which gives more directional force and more motivation to study physics for the many girls who are interested in classical languages.

Do we go too far here? Are we in our analysis connecting elements, which have in fact nothing to do with one another? Our research is not quantitative and it is difficult to research how people organize thoughts, motivation and emotion in everyday life activities. It is made even more difficult because connections are characterized by being fleeting rather than stable. We do not have much empirical evidence to build our analysis on. Yet, several of our studies have supplemented each other. According to Vygotsky, perhaps one of the most important aspects of education is historical expressions – which are changeable. In fact, his educational theory is a theory of cultural transformation as well as a theory of development. Education implies for Vygotsky:

> *[N]ot only the improvement of the individual's potential, but the historical expression and growth of the human culture from which Man springs (Bruner 1987,1–2).*

Connections may change over time, but can have real effects on the development of emotion, motivation as well as thoughts. Cultural models and the Vygotskyan framework may be an important contribution to our deeper understandings of why it is so hard to motive girls and women to become physicists in some national cultures and easier in other national cultures.

NOTES

1. These patterns of reinforcement can be named 'cultural models' (Strauss & Quinn 1997, Hasse & Trentemøller 2008).
2. A number of other reports also illustrate this diversity (see for instance the homepage of the International Union of Pure and Applied Physics: http://www.iupap.org and the Working Group on Women in Physics: http://www.if.ufrgs.br/~barbosa/women.html). A consistent pattern seems to be that eastern and southern European countries have a higher score in percentage of women working as professionals in physics.

[3] This tendency that especially Italian women study physics with a background in classical language studies were confirmed in a later study and thus a profound cultural connection between classical languages and physics is formed in a natural cultural setting (Hasse & Trentemøller 2008, 53 *ff*).

[4] New reforms have since blurred this distinction, but the political pressure is more directed at underlining that physics has a humanistic value, than the opposite found in Italy, that languages and philosophy has something to offer physics.

[5] It was these surprising findings that led Cathrine Hasse to start searching for information on criteria for the intake of students and the group interviews with students with and without "classical" backgrounds (see e.g. 2008a).

[6] Some might get the idea that the Danes learn "better" physics because it's considered a "hard" subject in Denmark, but in the PISA survey, Italy and Denmark are almost equal (Mejding 2004).

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11. ARGUMENTATION IN SCIENCE EDUCATION RESEARCH: PERSPECTIVES FROM EUROPE

INTRODUCTION

Argumentation studies in science education are relatively young. It can be said that classroom-based research in scientific argumentation began in the 1990s. The first batch of studies focused on exploring whether science classroom environments favoured argumentation, an exploration with negative outcomes (e.g., Driver, Newton & Osborne, 2000), as well as on investigating students' argumentation (e.g., Duschl, Ellenbogen, & Erduran, 1999; Jiménez-Aleixandre, Bugallo & Duschl, 2000; Kolstø, 2006; Kortland, 1996). As the field continued to develop, the focus shifted towards an interest in the quality of arguments, or how to analyze the development of students' argumentation competences (e.g., Erduran, 2008; Erduran, Simon & Osborne, 2004). In the last few years there is an emerging interest about how to support students' engagement in argumentation, through the design of learning environments (e.g., Jiménez-Aleixandre, 2008; Mork, 2005) and professional development of science teachers (e.g, Erduran, Ardac & Yakmaci-Guzel, 2006; Erduran, 2006; Simon, Erduran & Osborne, 2006).

In this chapter, we present an overview of how argumentation studies in science education have developed over the past two decades, with a particular focus on the work of European scholars. An extended discussion of the argumentation literature throughout the world is available in the edited volume by Erduran and Jimenez-Aleixandre (2008). We situate the policy context in Europe that has created the precedence for the inclusion of argumentation in the science curriculum. Here we elaborate on the notion of 'competences' that has been developed as part of the European Union (EU, 2006) and the Program for Indicators of Student Assessment (PISA) framework (OECD, 2006). We then turn our attention to the role of language sciences in the development of perspectives about argumentation and linguistics, particularly in France. Next we highlight the models of 'argument' that European researchers have used in their work as well as the framework of 'socio-scientific issues' that have underlined an extensive body of literature related to argumentation. We trace some of the developments in the strategies that support students' argumentation including the use of Information and Communication Technologies (ICT), as well as the approaches to the professional development of science teachers. The chapter ends with an outline of some future perspectives for a European agenda for research, curriculum design and teacher education in argumentation.

Doris Jorde and Justin Dillon (Eds.), Science Education Research and Practice in Europe: Retrospective and Prospective, 253–289.

ARGUMENTATION IN THE FRAME OF DEVELOPMENT OF COMPETENCES

Argumentation studies about science education contexts in Europe share most theoretical frames and methodological approaches with argumentation research worldwide, including a definition of argumentation as the evaluation of knowledge claims in the light of available evidence. Researchers from different continents interact in joint symposia in conferences, co-author papers and contribute to books. As an instance, from the 22 authors in a book we recently co-edited (Erduran & Jiménez-Aleixandre, 2008), half are based in European countries, half in the United States. However, there are four particular features of the European studies worth examining. First, European scholars have been situated within the policy context of 'competences' advanced by the European Union policies. Furthermore, the rationales of some European researchers draw on the field of language sciences to a greater extent than in other regions in the world. Third, a considerable proportion of work conducted in Europe belong to a strand focusing on socio-scientific issues (SSI), which may shed light on similar areas of research in other parts of the world. Finally, there may be particular ways in which European science education researchers' work has had an impact on policy and practice of argumentation. In this section we examine these features and how they shape the research in argumentation across European institutions.

A distinctive feature of argumentation studies in Europe, and in general of the attention given to argumentation throughout Europe in the last decade, is its connection to the development of competences (Jiménez-Aleixandre et al., 2009). In particular, argumentation is framed in the development of scientific competence. Jiménez-Aleixandre et al. support this claim on the characterization of scientific competence, both in the European Union recommendation of eight key competences (EU, 2006), and in the Program for Indicators of Student Assessment (PISA) framework (OECD, 2006). This connection to competences may distinguish argumentation studies carried out in Europe from those undertaken in the United States, for example, where argumentation is framed in scientific practices (e.g. Berland & Reiser, 2009). However, both approaches are convergent, as European argumentation studies set as an explicit goal for students the engagement in scientific practices (e.g., Puig & Jiménez-Aleixandre, 2011).

The PISA framework addressed the notion of scientific competence since 1999, several years before than the EU recommendation. PISA emphasizes three dimensions of the scientific competence (OECD, 2006, p. 29) characterized as the abilities to:

– Identify scientific issues and questions that could lend themselves to answers based on scientific evidence;
– Explain or predict phenomena by applying appropriate knowledge of science;
– Use scientific evidence to draw and communicate conclusions, and to identify the assumptions, evidence and reasoning behind conclusions.

From these points, it is the third one that can be identified as targeting the same practices as argumentation, namely the use of evidence to evaluate scientific claims, be it to draw conclusions from evidence or to identify the evidence behind conclusions. Although, certainly, the three dimensions are connected and support one another.

We can examine now how scientific competence is defined in the European reference framework. "Competence in science refers to the ability and willingness to use the body of knowledge and methodology employed to explain the natural world, in order to identify questions and *to draw evidence-based conclusions*." (EU, 2006, page L 394/15, our emphasis). This definition collapses the three dimensions of the PISA notion of scientific competence, including the use of evidence and, implicitly, argumentation.

In the half-decade since this reference framework was issued, its recommendations have been translated into the steering documents of many European countries. We will discuss argumentation in policy documents at the end of this section. However, it is worth noting that, in a recent report about 15 European countries participating in the EU-funded S-TEAM project, Jiménez-Aleixandre, Puig and Gallástegui (2010) found that, in nine of them, argumentation was used with the meaning of evaluation of claims, hypothesis and conclusions. That meaning is cohesive with the characterization of scientific competence in the EU framework. Framing argumentation in scientific competences as well as in general competences means that the emphasis is on the ability to apply knowledge and skills in diverse contexts and settings. In other words, learning to participate in argumentation, learning to use evidence to support claims, to back up explanations, in summary, is to participate in scientific practices.

ARGUMENTATION AND THE LANGUAGE SCIENCES

There are at least four theoretical bodies framing argumentation studies: developmental psychology, including the distributed cognition perspective; philosophy, as for instance the theory of communicative action; language sciences; and science studies, that is history, philosophy and sociology of science. As we have discussed elsewhere (Jiménez-Aleixandre & Erduran, 2008), rather than being a one-way relationship, argumentation studies and science education have the potential to inform these perspectives, leading to fruitful interactions. However, one thing is the existence of these potential interactions and another the relationships among different fields, which are currently nonexistent in most cases. As Buty and Plantin (2008a) point out, in their introduction to a volume reporting work on argumentation from seven French science education research groups, the established community in argumentation studies does not take into account the substantial work on argumentation in science education in the last two decades. Evidence for this lack of attention can be found in reference books, in the scarce presence of science education related papers in journals as *Argumentation* and in the proceedings of the ISSA (International Society for the Study of Argumentation) conferences, or in the conspicuous absence of a strand about argumentation in science education contexts in the list of the 18 themes for the ISSA 2010 conference.

An example of cooperation among different fields, constituting an exception to this compartmentalisation, is found in the French research groups, where science educators work alongside with philosophers, psychologists or researchers from language sciences. We will focus our discussion on this case. In the book edited by Buty and Plantin (2008b), four chapters are co-authored by scholars from outside science education, and one of the book editors, Christian Plantin, belongs to the field of language sciences and even to the argumentation studies community. This collaboration is related to a robust tradition of argumentation studies by French language scientists, providing theoretical frames from which science educators draw in their work. Two influential authors are Oswald Ducrot (1972–1998), focusing on the role of language in argumentation, and on semantics and polyphonic utterances, and the Swiss Piagetian scholar Jean-Blaise Grize (1996), whose work is more concerned with natural logic, and the cognitive processes in argumentation. Grize proposed some notions for argumentation analysis that include schematization and a dialogic production assuming an audience, both of which have been extensively used by French science educators in argumentation studies. Unfortunately, none of Grize's books and only one of Ducrot's (Ducrot & Todorov, 1987) are translated into English, and only a few of the French researchers on argumentation in science education, besides Plantin, publish in English, such as Simonneaux, (2008) and Albe (2008), whose work is discussed in the section about SSI.

The interactions between linguistics and science education are not unproblematic. Buty and Plantin (2008a) caution against the temptation to consider all linguistic interactions as argumentative, proposing a restricted characterisation of argumentation as the process of contrasting two views or two incompatible meanings and of negotiating a solution. It follows that not all tasks or activities involving discursive interactions can be regarded as argumentative, but only those involving, for instance, formulating claims, supporting them (we would add supporting them with evidence), or evaluating arguments. On the other hand, argumentation in science education is not just a linguistic activity, but requires drawing from the relevant knowledge, selecting appropriate documentation and information sources, analyzing it by means of particular skills.

An interesting point raised by Plantin (2005) is the relationship between argumentation and rhetoric, criticizing a biased view of rhetoric, which identifies it with manipulative moves. But, as he points out, persuasion (and therefore, rhetoric) is a part of the argumentation process. The relevance of persuasion as one of the goals of argumentative practice is also highlighted by Berland and Reiser (2009), who found that students did not subscribe to it. Plantin (2004) has argued for giving consideration to the place of emotions in argumentation, acknowledging that they may be positive or negative, a point that has relevance for the analysis of argumentation in SSI. In summary, argumentation studies in science education contexts by French researchers offer an example of productive interactions with language sciences. We are not implying that these interactions do not occur outside of France or indeed Europe, as they are exemplified for instance in the work of Kelly and colleagues (Kelly & Bazerman, 2003), but that the development of this work in France has occurred independently and this cooperation is a useful example of how to extend work in science education contexts to other fields.

MODELS OF ARGUMENT

The work of science educators in Europe has drawn on a range of perspectives on argument and argumentation (e.g. van Eemeren et al., 1996; Perelman & Olbrechts-Tyteca, 1958; Toulmin, 1958; Walton, 1996), as well as linguistic perspectives on discourse and communication (e.g., Bronckart, 1996; Grize, 1996), particularly from French researchers, as discussed above. The research emphasis in science education has typically concentrated on a definition of argument based on the work by Stephen Toulmin (e.g. Erduran & Villamanan, 2009; Erduran, 2007; Erduran, Simon, & Osborne, 2004; Jiménez-Aleixandre, Bugallo, & Duschl, 2000; Jiménez-Aleixandre & Pereiro, 2002; von Aufschnaiter, Osborne, Erduran & Simon, 2008) whilst the use of Douglas Walton's model has been relatively minimal in science education across the world at large (e.g. Duschl, 2008) and in Europe in particular (e.g. Jiménez-Aleixandre, Agraso & Eirexas, 2004; Ozdem, Ertepinar, Cakiroglu, & Erduran, in press). Although these two models (Figure 1 and Table 1) have often been presented as a contrast to each other, it is worthwhile to highlight that they actually address different aspects of argument and argumentation (Erduran, 2008). Toulmin's framework concentrates on the components of an argument whereas Walton's schemes detail different types of arguments.

Toulmin's model of argument has been used as a methodological tool in the characterisation of teaching and learning processes in the science classroom (e.g. Erduran et al., 2004; Jiménez-Aleixandre et al., 2000) as well as a pedagogical and learning tool (Osborne, Erduran & Simon, 2004). For example, in the IDEAS Project, writing frames for supporting learners have been generated with statements such as "My idea is…", "My reasons for my idea are…", "I believe in my reasoning because…" which were derived from the features of Toulmin's model in terms of claims, data, warrants and so on (Osborne, Erduran & Simon, 2004). In the Mind the Gap Project, Toulmin's frame has been used to support teachers in introducing argumentation in the classroom (Jiménez-Aleixandre et al., 2009). Also in this project, to be detailed later in this chapter, we have developed our understanding of how science teachers engage in the use of such writing frames (Erduran & Yan, 2009; Erduran & Yan, 2010).

Claims: **Assertions about what exists or values that people hold.**
Data: **Statements that are used as evidence to support the claim.**
Warrants: **Statements that explain the relationship of the data to the claim.**
Qualifiers: **Special conditions under which the claim holds true.**
Backings: **Underlying assumptions that are often not made explicit.**
Rebuttals: **Statements that contradict either the data, warrant, backing or qualifier of an argument.**

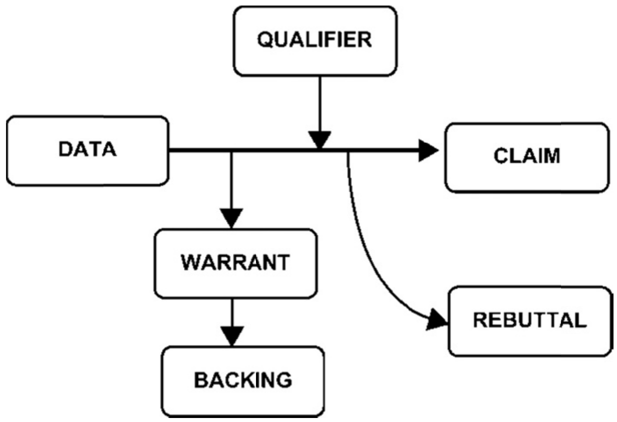

Figure 1. Toulmin's argument model (from Toulmin, 1958).

Table 1. Selected schemes from Walton's Presumptive Reasoning (Duschl, 2008)

Argument Form:	*Definition*
Sign	Reference to spoken or written claims are used to infer the existence of a property or occurrence of an event.
Commitment	A claims that B is, or should be committed to some particular position on an issue, and then claims that B should also be committed to an action.
Position to Know	A has reason to presume B has knowledge of or access to information that A does not have, thus when B gives an opinion, A treats it as true/false.
Expert Opinion	Reference to an expert source external to the given information.
Evidence to Hypothesis	Reference to premises followed by a conclusion.
Correlation to Cause	Infers a causal connection between two events from a premise describing a positive correlation between them.
Cause to Effect	Reference to premises that are causally linked to a non-controversial effect.
Consequences	Practical reasoning in which a policy or course of action is supported/rejected because the consequences will be good/bad.
Analogy	Used to argue from one case that is said to be similar to another.

Some examples of uptake of Walton's model in science education research have been used among doctoral candidates and researchers across Europe. For instance, in Spain, Cristina Pereiro and Marta F, Agraso at the University of Santiago de Compostela, and Aikaterina Konstantinidou at University of Barcelona; Stein Dankert Kolstø in Norway and Yasemin Ozdem at Middle East Technical University in Turkey have incorporated the Walton framework as part of their methodological approaches in their research. Some of the preliminary research from Ozdem's dissertation is a particular illustration of how Walton's framework can be used to differentiate affordances for types of tasks and arguments generated as a result of engagement in these tasks. Results of her study (ie. Ozdem et al., in press) illustrated that some kinds of argumentation schemes were more frequently used in all tasks, whereas others were specific for tasks. For example, *argument from sign, argument from example, argument from evidence to hypothesis, argument from correlation to cause, argument from cause to effect,* and *argument from consequences* were generated in all tasks. Therefore, these argumentation schemes can be interpreted as task-independent. It is quite possible that these argumentation schemes would appear in scientific contexts where participants have some background knowledge on the issue. On the other hand, there were other argumentation schemes that appeared specifically on one or more tasks, but could not be located in others. For example, *argument from verbal classification* and *argument from expert opinion* could only be located in certain tasks and not others.

In Cristina Pereiro's doctoral dissertation about students' argumentation in the context of environmental management, Walton's categories about argument from expert opinion have been used to examine the issues of scientific authority and expertise in students' discourse (Jiménez-Aleixandre & Pereiro-Muñoz, 2002). For instance, students' positions about their own status as experts evolved during the 17 sessions of the teaching sequence, from expressing doubts about their capacity to critizice the engineers' technical proposal, to confidence in their own competence. Students also made appeals to consistency with evidence, one of Walton's categories of arguments from expert opinion.

In her research, Agraso (e.g., Jiménez-Aleixandre, Agraso & Eirexas, 2004), draws on Walton's distinction among explicit and implicit commitments of participants in a dialogue. Walton distinguishes two sides in the commitment-set of each participant: *light side*, propositions known or in view to all the participants, and *dark side*, propositions not known or visible. Jiménez-Aleixandre et al. use this distinction in their analysis of students' argument about an oil spill. This study also explored students' evaluation of the expertise of the scientists whose positions were discussed.

Kolstø (e.g., Kolstø & Ratcliffe, 2008) has also made use of these two Walton schemes, arguments from expert opinion and the potential bias or dark side in experts' claims. Bronckart's (1996) frame about argumentation markers or modalizations has been used by Simonneaux (2008) as a tool to teach argumentation to a group of 12th grade participants. These argumentation markers represent different degrees and types of agreement with the content of a given piece of discourse and, according to Bronckart can be: logical (certainty or probability), deontic (social values), appreciative (subjective) and pragmatic (personal responsibility). Simonneaux found that the frame helped students of the intervention group to develop more sophisticated written arguments than the control group. Simonneaux (2001) has also made use of Grize's (1996) frame for comparing the effects of role-play and debate teaching strategies on the quality of argumentation.

A relatively recent interest in the work of some doctoral researchers has been the extension of the argument models in science education to be more inclusive of activity systems in which argumentation takes place. For example, the ongoing dissertation work of Xiaomei Yan and Demetris Lazarou (Lazarou, in press) both working with Erduran at University of Bristol, has been using Engeström's notion of 'activity theory' (Engeström, 2005). Yan has been focusing on chemistry undergraduate students' learning of argumentation in the broader context of their lectures, laboratory instruction as well as independent research in a community of researchers. Lazarou himself was a primary school teacher in Cyprus and has been working with primary school teachers to study the ways in which a group of primary school teachers engage with argumentation across various contexts including workshops and classroom teaching with an emphasis on framing the activities in a longitudinal fashion using the key concepts of activity theory, such as division of labour, objects and subjects.

A further aspect of the notion of 'argument' in the work of science educators in Europe has been the emphasis on socio-scientific issues. As one of the early contributors to argumentation research in Europe, Rosalind Driver had paved the way for the socio-scientific framing of argumentation by highlighting the significance of children's images of science and adequate representation of the socially constructed nature of science (Driver, Newton, & Osborne, 2000). A line of research focusing on argumentation in the context of socio-scientific issues has emerged across Europe in the work of researchers in Norway (e.g. Kolsto, 2001; Mork, 2005), France (e.g. Simmonneaux, 2001; Albe, 2005), England (e.g. Grace & Ratcliffe, 2002), Greece (e.g. Patronis, Potari, & Spiliotopoulou, 1999), Israel (e.g. Zohar & Nemet, 2002) and Spain (e.g. Jiménez-Aleixandre & Pereiro-Muñoz, 2002). Among other things, the work on argumentation in the context of socio-scientific issues has highlighted the need to characterize science from an interdisciplinary perspective (Simonneaux, 2008).

ARGUMENTATION IN THE CONTEXT OF SOCIO-SCIENTIFIC ISSUES

Argumentation studies focusing on socio-scientific issues (SSI) are carried out in many regions of the world, as reviewed for instance by Simonneaux (2008) and Sadler (2009). In Europe, this strand of studies has been particularly fruitful, constituting a substantial proportion of the work on argumentation. Socio-scientific issues are characterized as social dilemmas or controversies rooted in scientific domains (Simonneaux, 2008), or as issues and problems with two elements: a) conceptual and/or procedural connections to science and b) social significance (Sadler, 2009). According to Kolstø and Ratcliffe (2008), science is involved in a social debate over these issues, typically concerning personal or political decision-making related to health or environmental controversies. The notion of SSI is grounded on previous approaches such as as Science – Technology – Society or

Science-based social issues. In the French-speaking community, SSI overlaps with a field called "questions socialement vives" (QSV), translated by Simonneaux (2008) into "socially acute questions". QSV have a broader scope than SSI, comprising both issues from science education and from history and social sciences education, such as issues about immigration, European identity or unemployment. All these issues are widely discussed in society and in the classrooms, as illustrated in the volume edited by Legardez and Simonneaux (2006) about QSV-based teaching, a work emphasizing the interactions among science education and other fields in the French community as discussed earlier. They can be viewed in the perspective of citizenship education and, in the case of science education, as a contribution towards the goal of science for citizenship.

It needs to be noted that the social relevance of SSI cannot obscure the science dimension embodied in them. Typically, reaching decisions on SSI issues requires students to master scientific models, concepts and skills, as well as knowledge about science. The science dimension of SSI is examined by Kolstø (2001a) who proposes an analysis framework composed of eight content-transcendent topics. Kolstø defines content-transcendent knowledge as knowledge *about* science rather than knowledge *in* science. The content-transcendent topics are grouped under four headings: a) science as a social process; b) limitations of science; c) values in science; and d) critical attitude. He sees this notion as related to the widely used term "nature of science", but broader. The goal of this framework is to address three problems faced by science educators when teaching controversial SSI in secondary school, first, which specific content-transcendent topics should be taught, second, the relevance of the knowledge for the students' lives, and third, the need to adjust the amount of content-transcendent knowledge to be within the intellectual reach of most students. Kolstø argues that each of these eight topics can serve as a tool for students when examining the science dimensions of SSI. The framework holds potential for SSI-based teaching and some of its topics including the demands for underpinning evidence, the criteria about what counts as evidence and a critical attitude related to the scrutiny of scientific evidence, are highly relevant for learning argumentation.

While all socio-scientific issues are scientific, it needs also to be acknowledged that the controversies, either in the classroom or in society, have sometimes a strong ethical component, while in other cases students need to appeal primarily to scientific explanations (Jiménez-Aleixandre, 2010). In other words, values and ethics might at times pose dilemmas in scientific argumentation. To take some instances grounded in genetics, decisions about cloning (Jiménez-Aleixandre & Federico-Agraso, 2009) or genetic screening (Zohar & Nemet, 2002) require students to know about genes and inheritance, but a great weight in their options would relate to values. On the other hand, to argue about the relative weight of genes and environment on human performances as athletics, or on intellectual achievements (Puig & Jiménez-Aleixandre, 2011), demands from students to apply causal explanations about gene expression, although social representations may influence their claims. Another example of a strong science component is the work about marine resources management by Bravo-Torija & Jiménez-Aleixandre (2012). Students need to understand and apply the complex model of energy flow in ecosystems, in order to reach a decision about whether to eat carnivorous or herbivorous fish, two options with different impact on sustainability.

Kortland (1996; 2001) published one of the first European studies exploring argumentation about SSI, in the frame of developmental studies undertaken at the University of Utrecht. He examined the effect of consecutive versions of a teaching sequence in secondary school (students aged 13–14) about decision-making on waste management. The tasks required students to criticise different arguments about the choice of a milk container and then to derive the requirements of a well-argued position. This task proved to be extremely difficult, and the effect of the intervention on the quality of the student's argumentation was limited. This limited effect was attributed by Kortland (1996) to the lack of attention paid to supporting students' reflection on their own arguments.

Another early work about SSI and decision-making was Ratcliffe's (1997), with secondary school students, all male (14–15 year old) in the UK. Students were asked to decide what materials –aluminium, PVC, softwood, hardwood– would they use for window frames. They discussed the advantages and disadvantages of each option, but in some cases they were persuaded by one of the members of the group. Ratcliffe discussed the effect of using values shared among the students (sometimes egocentric), rather than scientific evidence, to back their options. She pointed out the interrelationship between affective and cognitive criteria in reaching a decision. This research program was continued in the work of Grace (2009) about the quality of 15–16-year-old students' reasoning on the conservation of biodiversity. The study examined the effect of using a structured framework for decision-making debates on the improvement of the quality of students' arguments. Grace found an increase in the arguments' quality, and suggested the relevance of students' reflection on their own ideas.

Patronis, Potari and Spiliotopoulou (1999) examined the arguments of 14-year-old students, while choosing among several courses of action about the plans for a road, a teaching sequence based on an actual controversy in their local setting in Greece. The students progressed from individual work, to group reports and finally had to agree on a class decision. The authors attributed the coherence of the students' arguments to the relevance of the problem, close to their daily lives, and to the personal commitment of students in the search for solutions.

In France, focusing on work published in English, Laurence Simonneaux has conducted a research program on SSI, about issues as biotechnology (Simonneaux, 2001). She compared the impact of two teaching strategies, role-play and debate, on students' argumentation. The study showed that arguments were more complex in the debate, while in the role-play students used more rhetorical schemes. Other dimensions of her studies are reviewed in Simonneaux (2008). Virginie Albe began her work in Simonneaux's research group. She has focused on teaching controversies (Albe, 2009), analyzing argumentation about the potential health risks of cell-phones with 11th grade students, (Albe, 2008a) and about climate change (Albe, 2008b). In the study about cell-phones she identified processes of group argumentation, as well as the influence of students' epistemological representations and of social interactions in the argumentation patterns.

The work of Stein Dankert Kolstø, in the University of Bergen, Norway, combines theoretical reflections and empirical studies, in a perspective of science education for citizenship (Kolstø, 2001a). An instance of his theoretical work is the framework, discussed at the beginning of this section (Kolstø, 2001a), about the complex interplay between science and social context. His empirical research focuses on students' ways of examining and evaluating the science dimension of controversies and in how they use science in their own argumentation. An instance of the examination about students' judgements of information in a socio-scientific issue is his study about 16 year old students' views on the risk of power transmission lines (Kolstø, 2001b). For instance, he found how some of them accepted information from scientists without evaluating its reliability. Patterns in students' arguments and their use of science in them are explored in a paper about the same SSI of risk of power transmission lines (Kolstø, 2006). Overall, Kolstø's work has as a goal to support students in reflective decision-making and in performing evidence-based argumentation.

At the University of Oslo, also in Norway, Sonja Mork's doctoral dissertation focused on the teacher's (and researcher's) role in the management of argumentative role-play debates (Mork, 2005a), as well as on the contribution of ICT to the introduction of argumentation and SSI in science classrooms (Jorde & Mork, 2007). (This second issue discussed below in the section about ICT and argumentation.) The problem of wolves was used to involve students in dealing with contradictory evidence and in providing justifications for their claims. Mork identified several types of teacher's interventions, for instance: to model how to behave in a debate, to challenge the accuracy of the information provided by the students, to extend the range of topics introduced by the students, to get the debate back on track, to rephrase students' statements, and to promote participation. It needs to be noted that learning about ecology was one of the goals of the teaching sequence, alongside with practising argumentation.

A recent doctoral dissertation that, as Mork's, combines the SSI context with a focus on the contribution of ICT towards supporting argumentation is Maria Evagorou's work (Evagorou, 2009). Her study explores the argumentation processes of 12–13 year old students in the UK. They were asked to engage in arguments about a UK government's mass culling programme for the grey squirrel, which involved poisoning or shooting part of them. Red squirrels are native to the UK, while the grey squirrel was introduced in the 19th century. The population of the red has been declining while the grey is now found in more regions of the country. Scaffolding was provided for students' construction of argument by means of the Argue-WISE online learning environment (Evagorou and Osborne, 2007). The nature of students' decisions and how they changed during instruction is addressed in Evagorou, Jiménez-Aleixandre and Osborne (2012).

The work about SSI in project RODA in Spain is discussed in the next section in the context of the argumentation research programme lead by Jiménez-Aleixandre at the University of Santiago de Compostela. Introducing SSI in science classrooms is challenging, as these are complex issues and working with them puts high demands on teachers. Researching them is equally demanding. However, as Kolstø (2001a) points out, these are the kind of issues students are likely to be confronted with in their lives.

SUPPORTING STUDENTS' ARGUMENTATION IN SCIENCE

Numerous science educators across Europe have been involved in the development of resources to support the teaching and learning of argumentation, as evidenced in the previous account about argumentation in SSI contexts. In this section, we will discuss our own work conducted in England (Erduran) and in Spain (Jiménez-Aleixandre).

In England, Osborne, Erduran and Simon have developed a video-based training resource (in the IDEAS Project) that promotes a set of frameworks intended to support the learning of argument (Osborne, Erduran, & Simon, 2004a,b). The Nuffield Foundation supported the development of the IDEAS Project, included a teacher training resource DVD as well as lesson materials for teachers. The argumentation frameworks are generic in nature and can be adapted to different subjects and topics. Erduran has applied the "Constructing an argument" framework in chemistry in the context of laws (Erduran, 2007). In this framework, the students can be presented with an observation about the Periodic Law and they are given a number of statements that would either support or refute this observation. They can then be asked to select the piece of evidence from the statements that best supports the observation. For example, the group of calcogens are neither metals nor non-metals. The group of calcogens (oxygen, sulphur, Selenium, Tellurium, Polonium, Ununhexium) share a spectrum of properties of metals, semi-metals and metals. The physical properties of Selenium (grey metallic) do not match its non-metal chemical properties. Tellurium is silvery grey and semi-metallic. The extent to which students can use the rest of the Periodic Table and knowledge of the Periodic Law to support which calcogens are more likely to be metallic and which non-metallic can create a forum for the selection, evaluation and justification of evidence. The IDEAS Project resources have been adapted and used with pre-service science teachers in Turkey (Erduran, Ardac, & Yakmaci-Guzel, 2006).

A network of projects was also carried out in England with the financial support of the Gatsby Foundation. The project aimed to produce resources for student-teachers and pupils so as to facilitate the teaching and learning of ideas and evidence in science at Key Stage 3 (Braund, Erduran, Simon, Taber, & Tweats, 2004). This 'Ideas and Evidence' project was carried out at several British universities: Cambridge, Keele, Institute of Education, King's College London and York. For example, the King's College materials consisted of five sets: one focusing on assessment for learning, one focusing on supporting writing and three focusing on teaching ideas and evidence in particular science contexts such as explaining combustion and the rotation of the Earth (Erduran, 2006). In producing the resources, a particular emphasis was placed on the role of evidence in scientific ideas – that is, how we know what we know in science and how we justify scientific knowledge. There were two meetings when the mentors and the tutors had the opportunity to discuss and refine the materials. The purpose of the first meeting was to introduce the mentors to some resources and generate a plan of action for the project. The mentors then went back to their schools and worked with trainee teachers who implemented the lessons. Nine mentors and eleven trainee teachers were recruited for the King's project. Five university-based tutors produced the materials and conducted the workshops. At the second meeting, the mentors and trainees shared their experiences and provided feedback on the effectiveness of the materials. The university-based tutors subsequently revised some of the materials in light of the suggestions from the mentors towards publication.

The activities produced as part of the King's project included many science topics including chemistry. The 10 sets of materials are consistent with the curricular goals set by the Key Stage Three Strategy. The materials are organised as activities that included some guidelines for teachers and materials for pupils. The activities are titled as follows: (1) Acids & Alkalis; (2) Changes in Matter; (3) Sliding on Surfaces; (4) Cells; (5) Constructing a Written Argument; (6) Chemical Reactions and Measurement; (7) Compounds & Mixtures; (8) Environment & Health; (9) Examining a Scientific Argument; and (10) Ideas & Evidence & Use of Formative Assessment. The example activity sheet for the "Changes in Matter" lesson is shown in Figure 2.

Changes in Matter!

Theory 1: **Burning a piece of paper is like boiling water. Both paper and water change in their compositions in the same way.**

Theory 2: **Burning a piece of paper is very different from boiling water. Paper changes its composition, but water does not.**

Evidence Statements:

Heat is needed to burn paper and boil water.	Gas is released when water boils and paper burns.
When paper burns ash is left, but when pure water boils away nothing is left behind.	A chemical reaction occurs when reactants change into new products.
As a liquid is heated, its molecules gain energy and move more and more quickly.	Eventually, the bonds between molecules are no longer strong enough to keep the molecules close together.
It is possible to get the liquid water back by condensing the water vapour, but it is not possible to get the paper back after it has been burned.	Burning happens when an element or a compound reacts very vigorously with oxygen.
When matter undergoes phase transitions, it changes its state from solid to liquid to gas.	When matter undergoes phase transitions, it changes its state from solid to liquid to gas.

Figure 2. Student activity sheet on "Changes in Matter" using the competing theories framework to promote ideas, evidence and argument (from Erduran, 2006).

More recently, the production of teaching and learning sequences in argumentation has been a key objective of the Mind the Gap and S-TEAM projects described in more detail in the professional development section of this chapter. Teams of researchers in Santiago de Compostela, Spain and Bristol, England have been collaborating with secondary science teachers to generate resources, some of which have already been published (e.g. Erduran & Yan, 2009; Jimenez-Aleixandre, 2009).

Table 2. Frameworks for Supporting Argumentation in the Science Classroom
(from Osborne, Erduran & Simon, 2004a)

Framework	*Description*
1. Table of Statements	Students are given a table of statements on a particular science topic. They are asked to say if they agree or disagree with the statement and argue for their choices. This idea has been developed from the work on discussing instances of physical phenomena (Gilbert & Watts, 1983)
2. Concept Map of Student Ideas	Students are given a concept map of statements derived from student conceptions of a science topic derived from the research literature. They are then asked to discuss the concepts and links individually and as a group to decide whether they are scientifically correct or false, providing reasons and arguments for their choice. This was an adaptation of the common use of concept mapping (Osborne, 1997)
3. A Report of a Science Experiment Undertaken by Students	Students are given a record of another student's experiment and their conclusions. The experiment is written in a way to intentionally include information that is lacking or in a manner could be improved, so as to stimulate disagreement. Students are asked to provide answers to what they think the experiment and its conclusions could be improved, and why. This idea was drawn from the work of Goldsworthy, Watson and Wood-Robinson (2000)
4. Competing Theories – Cartoons	Students are presented with two or more competing theories in the form of a cartoon. They are asked to state which they believe in and argue why they think they are correct. The work of Keogh and Naylor (Keogh & Naylor, 1999) has been valuable in developing a resource which is an excellent stimulus to engaging children with scientific thinking.
5. Competing Theories – Story	Students are presented competing theories in the form of an engaging story reported in a newspaper. They are then asked to provide evidence for which theory they believe in and why.
6. Competing Theories – Ideas and Evidence	In this approach, students are introduced to a physical phenomenon and then offered two or more, but generally two, competing explanations. In addition, a

	range of statements of evidence that may support one theory, the other, both or neither are provided. In small groups, students are then asked to consider each piece of evidence and evaluate its role and significance. Finally, they must use the evidence to argue for one idea or another. This idea has been adapted from the work of Solomon and colleagues (Solomon, Duveen & Scott, 1992).
7 Constructing an Argument	Students are given an explanation of a physical phenomenon i.e. day and night are caused by a spinning Earth, and a number of data statements (typically 4). They then have to discuss which data statements provides the strongest explanation for the phenomenon and provide an argument why. This is an idea that has been adapted from the innovative work of Garratt and colleagues (Garratt, Overton & Threlfall, 1999) in undergraduate chemistry.
8. Predicting, Observing and Explaining	This activity, drawn from the work of White and Gunstone (1992), involves introducing a phenomenon to children without demonstrating it and asking students to discuss in small groups what they think will happen when the phenomenon is initiated, and justify their reasoning. The phenomenon is then demonstrated and, if what happens is the antithesis of that expected, students are then asked to reconsider and re-evaluate their initial arguments. Discussion focuses on the theory that they advance for their prediction and the evidence to support it.
9. Designing an Experiment	Students are asked to work in pairs to design an experiment to test a hypothesis i.e. that a silver kettle cools faster. Their design needs to specify not only what variable should be measured but how often and what steps should be taken to ensure that the data obtained are reliable. Pairs then meet to discuss their design, to propose alternative procedures and to argue for their relative merits.

In Spain, the RODA Project ("roda" means wheel in Galician, and it is the acronym for "RazonamientO, Debate, Argumentación", or ReasOning, Debate, Argumentation) is a research programme carried out in the University of Santiago de Compostela, supported by consecutive grants from the Spanish Ministry of Science (which under some governments is collapsed with the Ministry of Education) since 1995. It is constituted by a set of classroom-based studies, and its focus has evolved from documenting the conditions for argumentation and the use of evidence, to supporting it through particular learning environments, to outlining learning progressions for argumentation in different disciplinary contexts. The target group are secondary school students, in both compulsory (12–16 year old) and upper secondary school (16–18 year old). However, given the difficulties for longitudinal studies in secondary schools in Spain (where optional subjects cause a rearrangement of groups every year), a three-year longitudinal study with primary school pupils (Jiménez-Aleixandre & López-Rodríguez, 2001; López-Rodríguez & Jiménez-Aleixandre, 2002) was also included. A substantial part of the publications from this project are in Spanish, including a recent book about argumentation and the use of evidence, directed to science teachers (Jiménez-Aleixandre, 2010), but here we will refer to the work published in English.

The RODA Project profiled three main features: first the collaboration among university-based researchers and secondary school teachers. Some of the studies can be framed in action-research or teachers' reflection on action, with a focus on teachers' performed action as the teacher-researcher was studying her or his own classroom (Mena, Sánchez & Tillema, 2009). A second feature is that argumentation is placed on a broader Inquiry Based Science Teaching (IBST) frame, and argumentation learning environments are considered a type of constructivist and IBST environments, with a specific focus on the development of epistemic practices and in particular on the evaluation of knowledge claims (Jiménez-Aleixandre, 2008). A third feature is that argumentation is promoted through engaging students in its practice, rather than by teaching it explicitly.

From a theoretical perspective, the RODA project frames argumentation in scientific practices or epistemic practices. Kelly (2008) defines epistemic practices as:

> "the specific ways members of a community propose, justify, evaluate and legitimize knowledge claims within a disciplinary framework. My argument is that an important aspect of participating in science is learning the epistemic practices associated with producing, communicating and evaluating knowledge." (Kelly, 2008, pp 99–100).

The three types of epistemic practices mentioned by Kelly are intertwined, and argumentation, as characterized in the RODA project, corresponds to the evaluation of knowledge. For these epistemic practices to occur, particular learning environments are needed (Duschl & Grandy, 2008; Jiménez-Aleixandre, 2008). Therefore part of the project's efforts went into designing teaching sequences and learning environments, in close collaboration with the teachers. These teaching sequences are organized around *authentic tasks*, dilemmas drawn from real life, that constitute problems which may have more than a potential solution, which are perceived as being relevant for students' lives and that require students to use inquiry procedures. Five instances of authentic tasks designed and implemented in the project are summarized in Table 3. A relevant constraint in the implementation of the teaching sequence was time, as teachers are concerned with covering all the topics in the Spanish curriculum. So the teaching sequences ranged from 17 sessions during several weeks, to four or five sessions.

Table 3. Instances of authentic problems from the RODA project (from Jiménez-Aleixandre, 2010, translated). Teaching sequences detailed in the Spanish references.

Task, topic, grade	*Problem (summary)*	*References*
Why are farm chickens yellow? Topic: Genetics 9th Grade (14–15 year old)	To explain why farm chickens are born with yellow feathers, instead of the spotted brown of chickens living in the wild. The fictional context is a request from the farm.	Jiménez-Aleixandre, Bugallo & Duschl (2000).
Evaluating environmental management in a wetland Topic: Environmental balance in ecosystems 11th Grade, night shift (16–21 year old)	The Environmental department of the Galician government solicits a report about the construction of a sewage network of underground drain pipes, as part of the project to clean the wetland from pollution. The project combines cleaning benefits and negative impacts on fragile habitats.	Jiménez-Aleixandre & Pereiro-Muñoz (2002). (In Spanish, Aznar & Pereiro, 1999, *Alambique*, 20)
Rescuing the U201-Wolf submarine Topic: Flotation 10th Grade (15–16 year old)	The Vigo city council is opening a competition to get a submarine afloat. The U201-Wolf submarine sunk duringthe 2nd World War. The students need to build a model submarine, to sink it and to get it afloat.	Bernal, Álvarez & Jiménez (1997) Ao rescate do U-201 Wolf: unha experiencia no proxecto RODA. *Boletín das Ciencias* 32: 61– 66. (Galician)
Choosing a heating system Topic: Energy and its uses 12th Grade (17–18 year old)	The University of Santiago de Compostela solicits a report about a heating system and energy sources for the new Medical School. Criteria include having low environmental impact and low cost.	Jiménez-Aleixandre, Eirexas & Agraso (2006). NARST meeting, San Francisco. Jiménez-Aleixandre et al. (2009) in www.rodausc.eu (In Spanish Federico et al., 2007, *Educatio*, 25)
Is it ecologically more sustainable to eat salmon or to eat sardines? Topic: Energy flow and trophic pyramids in ecosystems 10th Grade (15–16 year old)	Students are a NGO helping in a small seaside village after a tornado that destroyed harvests. For some time they should feed on fishing resources. They should design a plan for feeding more people for as long as possible, choosing among fishing mainly sardines and herring or mainly salmon.	Bravo-Torija & Jiménez-Aleixandre, (2012). Modeling marine resources management. (In Spanish, Bravo & Jiménez, 2010, *Alambique*, 63)

The publications of the project combine research papers in English or Spanish, focusing on the findings about argumentation practices, with papers in Spanish and Galician journals with the goal of offering resources for teachers. Some of the teaching sequences are also uploaded to the project website, www.rodausc.eu.

In terms of research focus, the RODA project began by addressing the complexity of classroom discourse by means of a holistic approach, acknowledging the different dimensions that need to be taken into account. Jiménez-Aleixandre et al. (2000) examine the intertwined dimensions of argumentation, epistemic operations (such as definition, appeal to analogy, appeal to consistency) and the 'doing the lesson' / 'doing science' distinction. 'Doing the lesson' is characterized as fulfilling the expectations about what is enacted in school, and 'doing science', as engaging in the production, communication or evaluation of knowledge claims. A goal of argumentation learning environments would be to move classroom discourse away from 'doing the lesson' and towards 'doing science', knowledge evaluation and argumentation.

Students' argumentation is explored in this project in connection with science learning, for instance, the process of data construction by secondary school students, engaged in identifying an unknown sample through the microscope, is examined by Jiménez-Aleixandre, Díaz and Duschl (1999). In order to match their observations with the four options for a suspect of stealing laboratory equipment, students interpreted and reinterpreted their observations in the process of appealing to empirical data to back their claims. The authors understand these shifting interpretations as a process through which data are constructed: 'data' are not equivalent to observation, but to the way these observations are interpreted. Figure 3 summarizes these steps in a students' dyad.

Data construction and argumentation are intertwined, the existence in the sample of one or two cell types is what counts for the students as evidence for their choice of the suspects.

The quality of 4th grade students' arguments along 10 sessions is analyzed in Jiménez-Aleixandre, López and Erduran (2005), as a part of a three-year longitudinal study about argumentation and environmental education from 4th to 6th grades (9 to 12 years). Pupils were required to decide upon the issues to study, the methods and in particular about the behaviour code in a field trip (Jiménez-Aleixandre & López Rodríguez, 2001). The quality and sophistication of students' arguments including rebuttals, rises the question of what features in the classroom environment supported the development of argumentative skills. It is suggested that the sustained enculturation in this particular school and classroom culture provided the environment adequate for argumentative competencies to develop.

Some of the studies in the RODA project examined argumentation in the context of socio-scientific issues. Jiménez-Aleixandre and Pereiro (2002) report about students' collaborative construction of arguments on environmental management in a wetland close to their school. In order to produce their reports about the pros and cons of a sewage network in a polluted area, the students worked with real data sets, maps, and technical projects. An interesting finding is how part of them changed their positions during the 17 sessions, as well as the justifications they gave for the changes (Jiménez-Aleixandre & Pereiro, 2005). In this study students were engaged with a real issue that was causing a social controversy and was significant for their engagement as citizens with scientific issues of social relevance.

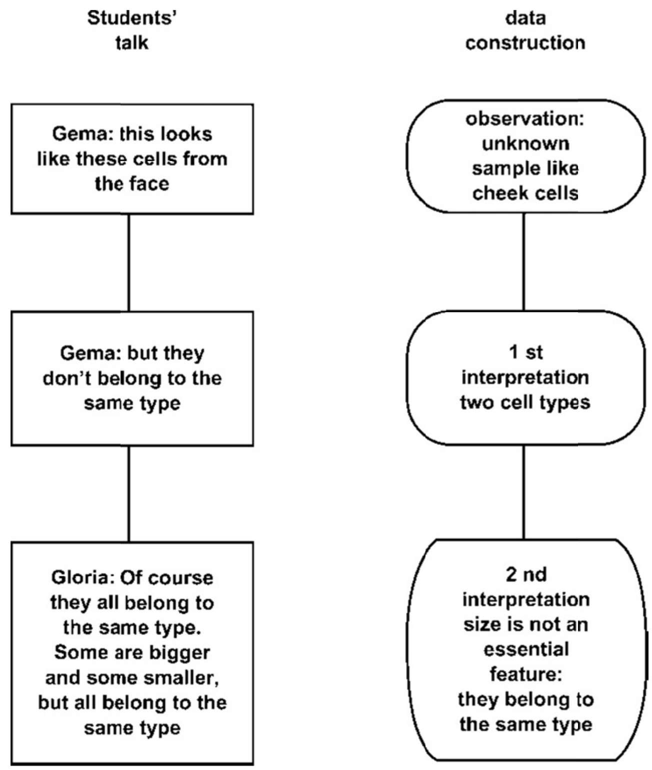

Figure 3 Process of data construction (from Jiménez-Aleixandre, Díaz & Duschl, 1999, modified).

The work of Fins Eirexas (Jiménez-Aleixandre, Eirexas & Agraso, 2006) focuses on a SSI related to energy use and sustainability. Working in groups, students were asked to select a heating system and appropriate energy sources for the buildings of the new Medical School in the University of Santiago de Compostela. Their options needed to meet the criteria of the USC's Environmental Efficiency Plan: low environmental impact and low economic costs. As with the problem about environmental management, there was not a single 'right' solution, a feature that promoted argumentation. The students' reports and their oral debates were analyzed for the epistemic levels in arguments, as well as for the meanings given to concepts as environmental impact and sustainability. The process of decision-making about this same problem of heating systems, by undergraduate students, has been examined in Gurutze Maguregi's doctoral dissertation (Uskola, Maguregi & Jiménez-Aleixandre, 2010). In this study the focus is on the criteria that students utilised to make their choices, and whether or not they considered evidence that was contradictory with their selected option.

Currently the project research focus is on the influence of the different argumentation contexts in the discursive processes and epistemic practices involved in argumentation. Two doctoral studies framed in this issue are those of Blanca Puig and Beatriz Bravo, and the SSI in both of them share a feature: causal explanations are relevant for engaging with the problems, besides ethical or environmental values. Puig and Jiménez-Aleixandre (2010, 2011) examine students understanding about the influence of environment in gene expression, and their positions in relation to biological determinism. In this context, a relevant argumentative process is the identification of evidence or justifications supporting a given claim (for instance a determinist claim about differences in intelligence between races). The authors use the didactical transposition perspective to explore how two teachers taught the model of gene expression and how they dealt with determinism. Bravo and Jiménez-Aleixandre (2012) examine students' participation in the epistemic practices related to modeling and argumentation, while working in a teaching sequence about marine resources management. The study explores how students connected the theoretical model of energy flow, on the one hand to the expressed model, and on the other to the physical world of living beings and actual data from the problem, and how they addressed the issue of sustainability.

As illustrated by these studies, the RODA project goals seek to combine the design of learning environments to promote IBST and argumentation, with the achievement of scientific literacy, that is with an interest in examining both students' engagement in argumentation and in meaning-making. We agree with Wickman and Östman (2002) in conceiving learning as discourse change, achieved as students become participants in new epistemic practices.

INFORMATION AND COMMUNICATION TECHNOLOGIES (ICT) AND ARGUMENTATION

There have been numerous research and development initiatives across Europe to integrate information and communication technologies (ICT) in science education (Kyza, Erduran & Tiberghien, 2009). Some of these initiatives have aimed to support the teaching and learning of argumentation in science classrooms at secondary school level (Monteserin, Schiaffino & Amandi, 2010). A key rationale for the choice of argument and argumentation as a genre in ICT has been based on the notion that learning activities should confront cognition and its foundations (Andriessen, Baker & Suthers, 2003). In this sense, substantial amount of research has been dedicated to how best to scaffold argumentative processes ranging from generating to justification of claims. An aspect that has often been neglected is the minimal attention given to the linearization process and linguistic aspects which are partly due to difficulty in incorporating ideas into the structure demanded and rhetorical goals (Brassart, 1996, Akiguet & Piolat, 1996). In an overview of the scaffolding tools in science teaching and learning, Kyza, Erduran and Tiberghien have summarized the following key aspects of tools that range from scientific visualization tools, databases, data collection and analysis tools, computer-based simulations, and modeling tools (Kyza et al., 2009, pp. 126–128).

Several trends can be detected in the use of ICT in argumentation in schooling across Europe. First, the incorporation of argumentation principles into ICT has been a multi-disciplinary effort across Europe at times involving cognitive psychologists, artificial intelligence experts as well as educators. Some of the key contributors to this interdisciplinary approaches have been funded by the European Union, including projects such as Kaleidoscope (Balacheff, Ludvigsen, de Jong, Lazonder, Barnes, & Montandon, 2009) and ESCALATE (Schwartz & Perret-Clermont, 2008). Second, some of the key research and development projects focused exclusively on science education have used US-based systems and models in their adaptations and development of tools to support argumentation. For example, the Viten (Jorde et al., 2003) and Argue-Wise (Evagorou & Osborne, 2007) projects relied on the principles of the WISE project developed at University of Berkeley in the USA (Linn & Hsi, 2000). Yan and Erduran (2008) have investigated the student-teachers' perceptions of the Belvedere Program developed in the United States by Brian Reiser and colleagues at Northwestern University.

Another trend in the use of ICT in argumentation research has been the contextualization of argumentation in scientific enquiry processes. The ESCALATE project capitalizes on two environments that mediate argumentation and inquiry-based practices (Schwartz & Perret-Clermont, 2008). Argumentation is enabled by the Digalo tool that has been developed in the earlier DUNES project also funded by the European Union. The Digalo tool provides a graphical platform in which participants may collaboratively construct an argument (on one computer or on different computers in a-synchronous mode) or participate in synchronous discussions. The argumentative map produced during the construction or during the discussion is an artifact that participants can exploit in further activities, as opposed to face-to-face discussions from which students cannot "physically" extract previous outcomes.

A further aspect of the argumentation work related to the incorporation of ICT tools has been the adaptation and/or extension of American-based systems. The COSAR (Computer Support for Collaborative and Argumentative Writing), for instance, has used features similar to the Belvedere program. COSAR is an all encompassing tool that supports idea-generation, planning and structuring, text composition and linearization in a collaborative environment (Erkens, Kanselaar, Prangsma, & Jaspers, 2002). It has an individual note area, a chat, a shared text editor for collaborative writing, a diagram tool for "for generating, organizing and relating information units in a graphical knowledge structure comparable to Belvedere" (Erkens et al., 2002, p. 16) using the 'box and link' approach to generate, relate and visually distinguish the simplified components of the argumentation produced (information, position, argument pro, support, argument contra, refutation, and conclusion). One of the important findings of this line of work has been that the planning tools "stimulate a more structured dialogue" (Erkens et al., 2002b, p. 125). The research team also found that argumentation on content, coordination, and metacognitive strategies is related positively to text quality, whereas argumentation on technical aspects of the task and on non-task related topics is related negatively to text quality(Erkens et al., 2002, p. 125).

Argue-WISE is another example of the adaptation of an American software design in application to the European context (Evagorou & Osborne, 2007). It is an online learning environment, which is geared towards key stage 3 and 4 students

(12–16 year-olds), designed within the WISE platform, which makes use of both knowledge representation and discussion-based tools. WISE (Web-based Inquiry Science Environment) is a knowledge integration platform designed by Marcia Linn and her group at the University of California, Berkeley. Evagorou and Osborne argue that the design of such a technology-enhanced environment provides scaffolds for argument construction by making thinking visible, making the structure of argument construction explicit, and structuring both peer-to-peer and group discussion. One of the main goals of Argue-WISE was to design and implement a learning environment to enhance young students' argumentation skills within the context of a controversial science topic and to evaluate the way in which their arguments develop. The design of Argue-WISE is based on the principles of project-based learning: a guided-discovery approach that invites students to work in groups and search for information in order to address a question, usually associated with an authentic everyday problem.

Similar to Argue-WISE, the Viten Project (http://www.viten.no) is a Norwegian research and development project (Jorde, Strømme, Sørborg, Erlien, & Mork, 2003) based on the WISE platform, providing a web-based platform with digital learning resources in science for secondary school. Students in grade 8–12 can work collaboratively on various science topics and each topic range s in duration from 2- 8 science lessons. Three types of programs are available, that engage students in: a) designing solution to problems, e.g. design a greenhouse for growing plants in a spaceship on its way to Mars, b) debating controversial issues, e.g. whether or not there should be wolves in the Norwegian wilderness, c) investigating scientific phenomena, e.g. radioactivity, gene technology. Mork's contribution to the field of science education from this study is a dual approach to analysing argumentation that takes both structure and content into account (Mork, 2005b). The dual approach functioned well as a tool for analysing student utterances and shows that student arguments varied from simple claims, to more elaborated arguments where reasons for claims were backed up by evidence and comparisons or examples. The most elaborated arguments also seem to be associated with correct content however, correct content is also found in less complex arguments. The majority of the utterances in this study contain correct or partly correct content, and students draw on biological, personal/social, political and economic information in their arguments.

ARGUMENTATION IN PROFESSIONAL DEVELOPMENT OF SCIENCE TEACHERS

There is vast amount of research literature in science education in Europe that has extended the work of some American educators. A significant line of work relies on models of professional development based on Lee Shulman' notion of teachers' "pedagogical content knowledge" (e.g. van Driel, Jong, & Verloop, 2002). Other approaches to teacher education have extended the work of educational psychologists such as Diane Kuhn in application to science education (e.g. Zohar, 2004). In the context of argumentation, advocates for effective professional development have argued that the teaching of argumentation requires a model of pedagogy that is based on knowledge construction as opposed to knowlege transmission (Simon & Maloney, 2006; Zohar, 2008). Teachers' enculturation into new models of pedagogy to support argumentation requires systematic and long-term professional development (Simon, Erduran, & Osborne, 2006).

Few studies have been conducted in Europe that traced the development of science teachers in argumentation in a longitudinal fashion. Erduran & Dagher (2007) studied the development of two middle-school science teachers who participated, over 5 years, in various school-based research projects on argumentation ranging from basic research in teaching and learning to the development of professional development programs for training teachers in argumentation. The projects took place between 1999–2004 in the United Kingdom funded by the Economic and Social Research Council (Osborne, Erduran & Simon, 2004a), Nuffield Foundation (Osborne, Erduran & Simon, 2004b) and the Gatsby Foundation (http://www.cpdthroughpoe.com/index.html). The teachers were asked to reflect as a pair on various aspects of teaching and learning of argumentation. The results address the teachers' views and knowledge of argumentation, their perceptions of the goals, constraints and successes in their teaching of argumentation, their perceptions of themselves as learners and teachers, and their reflections on the professional development that they received.

Both teachers displayed sophisticated understanding of argument as well as its teaching and learning. Their recommendations centred around effective professional development to take into account a holistic presentation of teaching scenarios and a range of student abilities. Both teachers indicated that their own success with the project was due to their persistence in learning something new and the nature of the workshops conducted with them and other teachers – which have been summarized, trialled and published subsequently (Osborne et al., 2004a; 2004b). They also indicated that among many teaching strategies, they are now more conscious of doing group work and they view the ability to conduct and coordinate group discussions as a significant skill that can be transferred to other aspect of teaching. When asked to reflect on what kinds of developmental and cognitive skills they would expect students to undergo in the learning of argumentation, both teachers referred to a scheme used in the research project to analyze the quality of student argumentation in group discussions. The scheme derived from a theoretical account of argument based on Toulmin's work (1958) focussed on the use of rebuttals and the use of data and warrants to support one's claim while another person is in opposition to an original claim. Both teachers, whose classroom practices included meta-level language with students about the nature of rebuttals (Simon et al., 2006), indicated that a development in argumentation skills would necessitate the presence of improved skills with rebutting an argument. Teaching of and professional development in argumentation can pose numerous challenges. Curricular goals can hinder the effective implementation of teaching and teacher training if they are not in line with the learning outcomes intended by innovative pedagogical approaches such as argumentation (Erduran, 2006). A further component of complexity in the implementation of effective professional development programmes can be the diversity of interpretations of the national curricula. For example in England and Wales context, the exam boards such as EdExcel and OCR interpret the National Curriculum policy level statements for the design and implementation of teaching. Different exam boards tend to have different interpretations of the "How Science Works" (HSW) agenda, hence the use of argumentation in teaching. There is a review of some of the key exam board specifications on HSW component of the National Science Curriculum in England and Wales in Lavelle & Erduran (2007).

An important distinction to be made in teachers' professional development in argumentation concerns the contrast of pre-service teacher education (TE) and in-service teacher' professional development (PD). In numerous part of Europe, the models of TE rely on the inclusion of mentor teachers in the training of pre-service trainee teachers (e.g. Simon & Maloney, 2006; Erduran, 2006) typically involving both higher education-based training and school-based practical experience. The provision for PD of in-service teachers tends to be more sporadic with few comprehensive trends. In England and Wales, the Science Learning Centres have been instrumental in the delivery of professional development on the HSW component of the curriculum in a systematic way.

In England and Wales, there has been a renewed interest in the incorporation of themes that focus on knowledge construction as opposed to knowledge transmission. The recent revisions in the national science curriculum highlight a recognition that the teaching of science aims not only at conceptual outcomes of science but also the processes of scientific inquiry and communications. The "How Science Works" (HSW) component of the Science National Curriculum (DfES/QCA, 2006) suggests the incorporation of evidence-based reasoning and argumentation in various aspects of science teaching and learning. For instance, not only should pupils learn about coordination of evidence and explanation but also they should be communicating arguments (Table 4).

2006 National Curriculum: How Science Works	
Curriculum descriptor	*Argument skills*
Data, evidence, theories, explanations	Understanding the nature of evidence and justifications in scientific knowledge
Practical and inquiry skills	Justifying procedures, choices for experimental design; generating and applying criteria for evaluation of evidence
Communication skills	Constructing and presenting a case to an audience either verbally or in writing
Applications and implications of science	Applying argument to everyday situations including active social, economic and political debates

Table 4. How Science Works in the Science National Curriculum and potential target skills in argument (from LaVelle & Erduran, 2007).

Whilst policy and research recommendations unite in promoting argumentation in science classrooms, significant gaps remain between educational policy, research and practice in the context of inquiry teaching and in argumentation in particular. Provision for professional development in argumentation is still quite rare (Cetin, Erduran & Kaya, 2010; Zohar, 2008). One approach that has aimed to transform research and policy findings for professional development purposes is the project called *"Mind the Gap: Learning, Teaching and Research in Inquiry-Based Science Teaching"* funded by the European Union (Erduran & Yan, 2010). The project supported 6 in-service teachers from four schools in England to explore the policy and research aspects of argumentation in their classrooms. The programme was implemented in 2008–2009 with six secondary science teachers from four schools near Bristol, England in collaboration with researchers from University of Bristol. In infusing ideas about argumentation into professional development of science teachers, the Bristol team used an evidence-based approach applying some of the key outcomes of research on teacher education. For example, the work of Supovitz and Turner (2000) guided the model of professional development where it was deemed important to engage participants in inquiry, questioning and experimentation in a collaborative manner. Furthermore, the Project relied on the principles of teachers' collaborative exchanges with peers and reflective inquiries into their own teaching. The teachers were recruited by writing to schools about potential involvement in the project and the participating teachers volunteered to join. They were primarily mid-career teachers who specialised in chemistry and physics. Each workshop had input (a) by researchers, in terms of evidence from research evidence on the teaching of argument, and (b) by teachers, in terms of classroom learning and teaching practices. Variety of activities and formats were employed including group discussions and presentations. The professional development aspects of the project are summarised in a DVD (Erduran & Yan, 2009). The clips range in how the teachers addressed the curriculum policy context to the strategies used to support professional development such as evaluating and reflecting on peer teaching. The project teachers indicated a range of ways in which the project has facilitated their professional development. A set of themes suggested by the project data (Erduran & Yan, 2010, Erduran, 2012) are as follows:

Exchange and Communication

"Teaching to some extent, is quite a lonely journey," said by one of the teachers. The teachers appreciated the opportunity to exchange experiences and communicate with the teachers across different schools with different experiences and backgrounds. Furthermore, the friendly environment in the workshops encouraged the participants to critically and reflectively comment on each other's work.

Ownership and Engagement

The participants enjoyed this teacher-oriented programme that focused on their interests or issues. They felt supported to explore their interests in their own teaching situations. The sense of "ownership" motivated them to take on the initiatives. As one of the teacher said, *"it is like to [what we need to] do with the students, this open project allows us to do what we are interested in."*

Clarification and Justification of Curricular Policy

The teachers appreciated this programme for clarifying the justification of the policy initiative from the trainer's introduction and guided peer discussions. As one teacher said that, *"if teachers only see HSW as one of the policy changes in the curriculum, they won't bother to think seriously about it, never mentioned to take on initiative to teach differently in the class."* During the workshops, the teachers had a better idea about the reason why HSW was introduced to the curriculum and what would be the benefits of teaching and learning of science via argumentation. Through the exploration of the gaps between the policy and teaching practice, the teachers' awareness of the issues was raised. They indicated that their understanding of the HSW and argumentation has also been improved through the dynamic discussions in the workshops. Furthermore, the teachers' discussion and sharing has made the idea of HSW clear, explicit and practical in practice.

Awareness of the Role of Argument in Teaching Science

Teachers were appreciative of the infusion of research outcomes in the workshops. They indicated that the teacher's perception of the importance of argumentation might affect their motivation to teach argumentation and their lack of experience might be the obstacle as well. The resources shared by other teachers in the workshops extended their personal experiences and opened up reflective discussions. As one teacher explained, she *"realized that teachers need to model argumentation structure that pupils would understand."*

The work of argumentation in professional development in the Mind the Gap Project has been extended in the S-TEAM Project (Science Teaching Advanced Methods) funded by the European Union. One of the strands of this project has been led by Universidade de Santiago de Compostela (USC), in association with the University of Bristol and the CNRS, Lyon, France. The project will provide resources and strategies to help teachers to create learning environments for argumentation and the learning of discursive practices in science. A key priority of the S-TEAM Project is to disseminate training resources and classroom materials to support the teaching and learning of argumentation in science classrooms and the development of teachers' reasoning about the nature of scientific knowledge. A professional development programme has been designed and implemented to promote coherence and growth in teachers' skills in these aspects. Outcomes in terms of students' argumentation skills will provide proof of the effectiveness of professional development interventions.

One of the outcomes of the S-TEAM project is a report on argumentation and teacher education in Europe (Jiménez-Aleixandre et al., 2010). Intended for policymakers and other stakeholders in education, it seeks to share information about the development of argumentation in Europe. The report's purpose is to review the state of the art about argumentation in Europe, particularly in the 15 countries involved in the project and to draw on published research to suggest lines of improvement. It explores argumentation through three dimensions: policy documents, initial teacher education and teacher's continuous professional development (CPD). We will briefly summarize some results about CPD, although it needs to be noted that responsibility for CPD is attributed to different instances in different countries, from the Ministries of Education, to teacher centres or local authorities, making difficult to draw common pictures of such a complex situation.

Jiménez-Aleixandre et al. report that argumentation is currently part of CPD programs in 13 countries; that is all but two, although with a great diversity in weight and format. The differences range from explicit presence in goals and content, to being embedded in broader topics, such as competences, IBST or reasoning. Even in the case of half of these countries, where argumentation is integrated in CPD in the frame of national programs, the course contents exhibit a great deal of variation, from explicit modules about argument construction and examples of activities to introduce it in the classrooms, to a presence embedded in reasoning, communication or debate.

The report also explores the availability of resources for teachers who may be interested in introducing argumentation in their science classrooms. About this issue there are also great differences, but the data point to an increasing availability of resources. For instance, in Denmark there is a wealth of available resources for teaching argumentation, which suggests a continued interest in the topic in CPD initiatives.

The report points out to some data showing the impact of European projects on the uptake of argumentation in teacher education. One instance may be the introduction of argumentation and IBST in CPD programs, as an effect of S-TEAM, in all the Ministry of Education summer courses in Spain targeted for science teachers. Another is making accessible resources for teaching argumentation, as illustrated by the use of the Mind the Gap resources in England and Wales, Spain and Denmark.

In the University of Santiago de Compostela, the researchers involved in the RODA project viewed the participation in EU projects as an opportunity for directing their attention to making their research accessible for teachers. This is the key idea behind the Mind the Gap project, to bridge existing gaps between research and schools. One of the main resources used both in initial teacher education and in CPD courses in Spain is an argumentation booklet (Jiménez-Aleixandre et al., 2009) produced within Mind the Gap, as well as other resources available in the USC web (www.rodausc.eu). Teaching sequences for argumentation in teacher education, and teachers' guidelines produced in the USC in cooperation with teachers in the S-TEAM project, have also been used in CPD courses. This approach seeks to combine in-depth work with a small focus group with dissemination to the wider community of science teachers. At the University of Bristol, researchers (Erduran, Ingram & Yee, in press) have been producing the professional development approaches and teaching resources on argumentation and its relation to practical work, to be published for wider dissemination in England.

FUTURE DIRECTIONS FOR RESEARCH ON ARGUMENTATION IN SCIENCE EDUCATION IN EUROPE

Our review indicates that cross-national collaborations on argumentation work in science education have already been established across Europe, particularly through projects (e.g. Mind the Gap and S-TEAM) funded by the European Union. There have also been personal collaborations that have led to some insightful syntheses of work across national boundaries, for instance through research visits between academics (e.g. Evagorou et.al., 2012, von Aufschnaiter et al., 2008). However the emphasis of work has been mainly national, not cross-national. Further research and development would be fruitful particularly in comparative analysis of argumentation in different national contexts, an area of work that is scarce. In one study, Castells and colleagues compared the argumentative schemes of primary science trainee teachers' arguments as well as their ideas, conceptions and beliefs on which they base their arguments (Castells, Konstantinidou, & Erduran, 2010). The study was the result of a project funded by the Anglo-Catalan Society and conducted in Barcelona and Bristol. The project included analyses carried at three levels. At the first level, the researchers compared the number of arguments by tasks and by country. At the second level, they analysed arguments and made a comparison between types of argumentative schemes by tasks and by countries. More in depth, qualitative descriptions were carried out in order to illustrate the similarities and differences between the Catalan and English primary student-teachers' arguments and scientific conceptions. Results illustrate that the arguments generated by students are quite similar in both samples in terms of number of arguments and frequencies of types of arguments, but with some differences in the order of these frequencies related to specific tasks. More relevant is the qualitative difference in the way that appeals are made to give evidence and theories, given the identification of premises and argumentative schemes; this favours good understanding of scientific knowledge. Future studies could build on these efforts to gain a deeper appreciation of the cultural and national factors that impact teachers' and learners' argumentation in science classrooms.

Related to the domain of cross-national work, it should be noted that language and language politics are key elements to consider in science education research efforts in Europe. Considering Europe is diverse in languages and cultures, the language variation and its influence on the way that argumentation is taught and learned in the classroom cannot be underestimated. This is particularly relevant for work related to the linguistic aspects of argumentation and the way in which arguments are constructed. There is currently no research dedicated to the learning of argumentation in bilingual and trilingual settings and the way in which arguments interact within and across different languages. Parts of Europe such as Luxembourg and the Netherlands where there is bounty of trilingual schooling (Baker, 2006), there is much potential to investigate the ways in which language variation has an impact on the nature and quality of argumentation.

An aspect of argumentation research that has not been addressed sufficiently in the literature is the relationship between disciplinary content or conceptual knowledge and argument structures and processes. Detailed studies of the relationship between argumentation and the development of scientific knowledge are rare. Jimenez-Aleixandre and Pereiro-Muñoz (2002) found that the involvement of 17- to 21-year-old students in argumentation and decision making about environmental management resulted in them becoming knowledge producers, not because they created new knowledge, but because they applied knowledge to practical contexts, combined ecological concepts, and integrated conceptual knowledge with values. Aufschnaiter and colleagues (2008) have used video and audio documents of small group and classroom discussions to analyse the quality and frequency of students' argumentation using a schema based on the work of Toulmin (1958). In parallel, students' development and use of scientific knowledge was also investigated, drawing on a schema for determining the content and level of abstraction of students' meaning-making. These two complementary analyses enabled an exploration of their impact on each other. The microanalysis of student discourse showed that: (a) when engaging in argumentation students draw on their prior experiences and knowledge; (b) such activity enables students to consolidate their existing knowledge and elaborate their science understanding at relatively high levels of abstraction. The results also suggested that students can acquire a higher quality of argumentation that consists of well-grounded knowledge with a relatively low level of abstraction. The findings further suggest that the main indicator of whether or not a high quality of argument is likely to be attained is students' familiarity and understanding of the content of the task.

A related problem in the argumentation literature is the question of whether or not students engage in meaningful argumentation not just about science concepts but also about socio-scientific issues and whether this process improves their conceptual understanding of science. In a recent study, the Australian researchers Venville and Dawson (2010) investigated the impact of classroom-based argumentation on high school students' argumentation skills, informal reasoning, and conceptual understanding of genetics. Their findings showed that following an invervention study, the argumentation group, but not the comparison group, improved significantly in the complexity and quality of their arguments and gave more explanations showing rational informal reasoning. Both groups improved significantly in their genetics understanding, but the improvement of the argumentation group was significantly better than the comparison group.

Considering the often culture-specific orientation to socio-scientific issues, it would be worthwhile to extend such studies on the interaction between socio-scientific issues, argumentation and scientific knowledge to European countries where language, culture, society, history among other factors are diverse in national contexts.

The study of disciplinary nuances in the subject knowledge itself holds the potential for novel approaches to understanding science education in general and argumentation in particular. The case for domain-specificity and scientific knowledge has been made by cognitive psychologists (e.g. Shunn & Andersson, 1999) and philosophers of science (e.g. Scerri, 1994) for some time. Yet the uptake of this work in science education has been minimal even though disciplinary knowledge can propose particular suggestions for how argumentation can be contextualised in science, as illustrated with a chemistry example briefly revisited here but reported more extensively elsewhere (Erduran, 2007). In school science it is typical practice to emphasize the nature of the Periodic Law within groups of elements in the sense that the elements are assigned similar chemical properties. For example, the properties of alkali metals in water are used to illustrate the increase in reactivity as one goes down the Group 1 Alkali Metals. However students are rarely given the opportunity to argue the case for the approximate nature of trends Thorium, whose valence electron configuration is d2s2 is not placed in IUPAC group 4 with the only other three elements that share this configuration (Ti, Zr and Hf) but rather a group of actinide elements where its only vertical relationship is with Ce, configuration fd2. Meanwhile, IUPAC group 10 contains just three elements with three different valence electron configurations: Ni d8s2, Pd d10 and Pt d9s1. The lack of a universal system of placement of elements in the Periodic Table creates an opportunity for argumentation when the predicted elements do not fit into the observed placements, raising key issues about how knowledge gets constructed and represented in chemistry. Other sciences will pose their own disciplinary orientation to how concepts are problematised and situated in the broader body of knowledge including developmental aspects of learning (e.g. Keil, 2007).

Erduran and Pabuccu (2012) have taken such a disciplinary orientation in situating argumentation in teaching and learning in the context of stories. The resources for teachers and students aim not only to promote argumentation in the discipline of chemistry but also to aid motivation in science in general through engagement by embedding the chemical concepts in interesting contexts.

Despite wealth of research in classroom-based research on argumentation since the mid-1990s, our review suggests that the territory remains ripe for numerous lines of work in the future. Among these, there is surprisingly little dedicated to the exploration of students' and teachers' perceptions of argumentation (e.g. Kaya, Erduran & Cetin, 2010). Likewise, developmental trajectories of teachers in learning argumentation in a longitudinal fashion are virtually nonexistent (e.g. Erduran & Dagher, 2007). A fruitful new territory for argumentation research could draw from 'science studies' – the interdisciplinary studies on science with implications for science education (Duschl, Erduran, Grandy, & Rudolph, 2006).

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12. CLASSROOM DISCOURSE AND SCIENCE LEARNING: ISSUES OF ENGAGEMENT, QUALITY AND OUTCOME

INTRODUCTION

Research into teaching and learning scientific conceptual knowledge has been a prominent line of work in the Centre for Studies in Science and Mathematics Education (CSSME), at the School of Education, University of Leeds, UK for over 25 years. This work was initiated by Rosalind Driver when she set up the Children's Learning in Science Project (CLISP) in 1982.

The first phase of the CLISP programme involved meta-analyses of UK national data sets on science learning collected originally by the Assessment of Performance Unit (APU), with the CLISP team focussing on students' understandings of scientific concepts at age 15. The findings from this research clearly showed the gaps between student understandings and an accepted scientific point of view in relation to key scientific concepts such as energy, the particulate theory of matter and photosynthesis (see, for example, Brook and Driver, 1984). In the context of the particulate theory of matter, for example, it was found that about one-in-five students, after completion of their secondary education in science (aged 15/16 years) were able correctly to apply particle ideas to account for simple physical phenomena. The second phase of the CLISP programme aimed to address these problems in learning scientific conceptual knowledge through the development of teaching approaches based on a constructivist view of learning (see Driver and Oldham, 1985). In essence this involved designing teaching activities to expose and to address directly the student 'alternative conceptions'. For example, the idea that plants get their food, ready-made, from the soil was confronted by students testing soil for the presence of carbohydrate and reaching a null finding. This activity thereby raised the question of where *do* the plants actually get their food from? (see Oldham et al., 1991). Further constructivist teaching schemes were developed for the particulate theory of matter and energy. The third and final phase of the CLISP programme saw the development of teacher professional development materials to support science teachers in adopting constructivist approaches to teaching in the specific concept areas referred to above (see, for example, Johnston and Scott 1990).

The CLISP teaching schemes were designed with conceptual change theory in mind (Posner et al., 1984). Thus researchers working with practising teachers

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developed teaching activities to confront existing student ideas, via conceptual conflict, or to extend existing ideas often through the use of analogies. Scott, Asoko, Driver (1992) provide a review of such conceptual change teaching strategies. A further feature of the CLISP teaching schemes was the opportunity for students to engage in small group discussion activities aimed at bringing to the surface their ideas and understandings. Rather *less* prominent in this programme of work was any analysis of the role played by the teacher, with the focus being very much on the learners and their learning.

This imbalance was addressed with a new post-CLISP programme of research focussing on the role of the teacher in mediating teaching activities. The point here is that teaching activities don't 'work by themselves'. The teacher is needed to mediate each activity and a line of research was developed to address questions about the nature of such mediation. This work was founded on a Vygotskian sociocultural perspective of learning (see Wertsch, 1985) and focussed in particular on characterising the nature and patterns of teacher talk during the teaching and learning of scientific conceptual knowledge (see, for example: Scott, 1996; Scott, 1998). This research was developed through close collaboration with colleagues from the Federal University of Minas Gerais (see: Mortimer and Scott, 2000) leading to the publication of the book, *Meaning Making in Secondary Science Classrooms* (Mortimer and Scott, 2003). This book has been very widely cited and has led to further studies involving the analysis of classroom talk both in the UK and in Brazil (see: Scott et al., 2006; Aguiar et al., 2010; Scott et al., 2010).

In *Meaning Making in Secondary Science Classrooms* the concept of 'communicative approach' is introduced. This involves categorizing the talk between teacher and students along two dimensions. The first dimension represents two forms of interaction, dialogic and authoritative, whilst the second dimension involves the distinction between interactive and non-interactive talk. For the first dimension, dialogic communication involves the teacher and student talk being open to more than one point of view and there is exploration or 'interanimation' (Bakhtin, 1981) of ideas. In general terms, dialogic discourse is open to different perspectives. On the other hand, authoritative communication is focused on just one point of view and there is no exploration of different ideas. For the second dimension, the talk can be interactive in the sense of involving the participation of more than one person, or non-interactive in the sense of involving the participation of only one person, which is usually the teacher. These two dimensions combine to generate four classes of communicative approach: Interactive/dialogic, Non-interactive/dialogic, Interactive/authoritative and Non-interactive/authoritative.

Classroom talk from around the world has been characterised through different categories, including the authoritative and dialogic approaches outlined above. Certain types of talk (e.g. authoritative, presentation, recitation talk) have been observed to dominate more than others (e.g. argument, dialogic, exploratory talk). Furthermore, claims have been made (Alexander, 2008; Lemke, 1990; Mortimer & Scott, 2003; Newton, Driver, & Osborne, 1999; Wells, 1999) that the presence of the latter, more dialogic types, in the ongoing classroom talk is critical to the development of meaningful understandings by students. However, such claims about learning have tended to be more theoretically argued with rather less support from empirical evidence:

> 'a missing crucial component of this body of research is any significant evidence demonstrating that engaging in discursive problem-solving activities leads to enhanced cognition – one of the major goals of any type of education' (Osborne et al., 2004, p. 1016).

It is interesting, however, to note that in the 1960's, research *was* carried out to explore the link between the nature of classroom interactions and teaching effectiveness. These studies found that students of teachers with a teaching style that is both integrative and flexible have more positive attitudes towards school and their teacher, and achieve more, than students who have been exposed to a more dominative teaching style (see: Amidon & Flanders, 1961; Flanders, 1967; Soar, 1965).

Also, in the context of English education in North America, Nystrand (1997) has provided empirical evidence relating the nature of oral classroom interactions to student learning. Nystrand makes the distinction between dialogically-organised versus monologically-organised instruction, where monologically-organised instruction centres on the voice of the teacher, whilst dialogically-organised is open to the students' points of view. He found that the results of written examinations specifically, and surveys, interviews, and class observations generally, indicated the superiority of dialogically-organised over monologically-organised instruction in promoting student learning, even though the findings of the study showed that the classroom discourse was "overwhelmingly monologic" (p. 41).

In the rest of this chapter we present findings from one part of a recent empirical study (Almahrouqi, 2010) from CSSME which is based on the evolving programme of research into classroom talk outlined above, and designed to investigate in detail the relationship between the nature of teacher-student classroom talk and the quality of student learning. This work further extends the geographical compass of the CSSME research programme with the data being collected in the Gulf State of Oman.

OVERVIEW OF THE STUDY

This study was planned with the broad aims of characterising the talk in high school science classes and exploring the nature of any links between the quality of this talk and student learning. In outline, the project involved the first named author working with four science teachers and their grade 9 classes in a girls' high school in Oman. The project was developed in two stages with the first stage focussed on exploring the teachers' *existing practices* in relation to classroom talk. After completion of Stage 1 the participating teachers followed a short training intervention, led by the first author and designed to promote the practice of more dialogic talk in teaching. In Stage 2 the classroom practices of the teachers were once more scrutinised. The Stage 1 lessons involved a short teaching sequence (about 3.5 hours) on 'Physical and Chemical Changes' whilst the Stage 2 lessons focussed on 'Electric Circuits'. All of the lessons were video-taped and the spoken interactions transcribed.

In the first stage of analysis, the different kinds of classroom talk were related to the four classes of communicative approach developed by Mortimer and Scott (2003), as outlined above. In the second part of analysis, the student learning during the lessons was probed both as a *process* and a *product*. In other words, methods were developed both to explore the *ongoing learning* of the students as they progressed through the lessons and to determine their *learning outcomes* at the end of the lessons. The process approach involved collecting evidence not only of the students' developing conceptual understandings (what are the key ideas being represented by the students at this point in the lessons?) but also the nature and quality of the students' intellectual engagement in the learning process during the on-going lessons. Further information about the approaches used to collect this evidence of the various features of learning is provided in the following sections. Suffice it to say for the moment, the exploration of learning carried out in this study involved addressing three aspects. These aspects concern how the nature of the teacher-student interactions (in relation to the authoritative and dialogic communicative approaches) impacted upon:

1. the nature of the students' engagement in the teaching and learning processes;
2. the intellectual quality of those interactions;
3. the student learning outcomes at the end of the lessons.

We now turn to examining one case from the overall study in relation to these three aspects.

FINDINGS FROM A CASE OF ONE TEACHER WORKING WITH HER CLASS

Here we report the findings from just one case consisting of one teacher working with one class across both Stage 1 ('normal practice' prior to the intervention) and Stage 2 ('refined practice' after the intervention). As outlined above, each of the five lessons in both stages was video recorded and the interactions then analysed in terms of the communicative approaches developed by the teacher. The outcomes of this analysis are as follows:

Table 1. Percentage of communicative approach in stages 1 & 2

Class of talk	*Interactive / Authoritative*		*Non-interactive / Authoritative*		*Interactive / Dialogic*		*Non-interactive / Dialogic*	
	1st Stage	*2nd Stage*	*1st Stage*	*2nd Stage*	*1st Stage*	*2nd Stage*	*1st Stage*	*2nd Stage*
Lesson 1	69%	68%	31%	32%	0%	0%	0%	0%
Lesson 2	66%	35%	27%	25%	7%	33%	0%	7%
Lesson 3	68%	8%	32%	2%	0%	74%	0%	16%
Lesson 4	76%	28%	24%	29%	0%	40%	0%	3%
Lesson 5	62%	53%	38%	47%	0%	0%	0%	0%

The data presented here show a big change between the two stages, with an overall shift from the teaching being dominated by authoritative talk in Stage 1 to there being a much greater representation of dialogic talk (alongside the authoritative) in Stage 2. For example, in the second lesson of Stage 2 about one third (33%) of the talk was coded as interactive/dialogic whilst dialogic talk was virtually missing altogether from Stage 1. As such, this case offers an interesting opportunity to investigate the learning outcomes which follow from two strikingly different teaching approaches, whilst maintaining the same combination of teacher plus students (both in relation to conceptually demanding subject matter).

The question which we now pose, therefore, is what can we say about the impact of this broadening of teaching repertoire (Cazden, 1988) on the learning of the students and this question is addressed through the three lines of inquiry identified above. We consider the first aspect relating to the learning in process, by exploring the nature of the students' engagement in Stages 1 and 2.

Learning in Process: the Nature of Student Engagement

The analysis of the classroom interactions from the first stage (focussing on physical and chemical changes), summarised above as taking an almost exclusively authoritative communicative approach, overall gave rise to poor student engagement. The chances for the students to articulate their ideas and to exercise any control over the talk and their learning were limited. Throughout the lessons, the teacher: made frequent, decisive and immediate evaluations to student responses; rarely used a neutral voice in responding to students; offered few invitations for students to elaborate upon and to explain their views; often seemed to neglect the students' thoughts, ideas and observations; talked at much greater length than the students. Additionally in a few incidents, the authoritative talk, because of the closed nature of the questions, prompted responses from the whole class thereby short-circuiting individual participation. The following transcript illustrates this point with all of the responses being made by groups of students calling out together (S_g):

1.T	Did the substance in the filter paper dissolve in water?
2.S_g	No
3.T	Look girls, when any substance dissolves, notice that the resulting colour is transparent like the colour of salt when you dissolve it in water. Have you noticed that there is a white colour?
4.S_g	No
5.T	So, this substance didn't dissolve in water whereas the substance in the second test tube- how was it before?
6.S_g	Dissolved
7.T	Dissolved in water^ (affirmation tone) - how was it before?
8.S_g	Dissolved
9.T	See how it feels, rough or soft?
10.S_g	Rough
11.T	It feels what? Rough….

Here the teacher works with the girls following an interactive/authoritative approach based on I-R-E triads. The teacher does most of the talking and this is punctuated by single words, ‘No’, ‘Dissolved’, ‘Rough’, from the group of students.

In striking contrast, the teaching of Stage 2 (focussing on electric circuits), summarised in Table 1 as incorporating more dialogic talk, showed much higher student engagement. Here, the teacher: welcomed points of view from the students; asked students to elaborate on their points of view; highlighted opposing views; explored students’ ideas without evaluating them. As part of these dialogic approaches, the students were given the opportunity to predict, and/or vote for particular ideas before they were tested empirically. On occasion, students argued persuasively for their points of view even though most of the class seemed not to agree with them and the teacher showed some doubt. Consequently, the students gained confidence and expertise in expressing their agreement or disagreement with specific ideas as is exemplified in the following transcript:

9.T	…So these charges that are moving in the wire might run out one day
10.S_5	Yeah, they run out…
11.T	They run out. So, if I took this wire, Could it run out of charges one day?
12.S_5	Miss. The wire doesn’t have charges. It’s a conductor for the movement.
13.T	It doesn’t have charges. It’s just a conductor for charges. So, where do the charges come from?
14.S_5	Aren’t they coming from the battery !!

21.T	…S_7, I heard you saying something and then you stopped, what do you think?
22.S_7	The wire has neutral charges.
23.T	S_7 is saying that the wire has charges…This means you’re raising a new opinion completely against what S_5 has said. Is this right?
24.S_7	The wire is matter, and all matter has neutral charges.
25.T	So, this wire has charges?
26.S_7	Yes.
27.T	Who believes her?
28.S_8	Yeah right, cos the wire is matter and the battery also has charges…

In these interactions two fundamental models of the electric circuit are proposed. Firstly one of the girls (S_5) argues that the electrical charges originate in the battery and that this store of charges might, at some time, ‘run out’. An alternative point of view is offered by another of the girls (S_7) who suggests that the ‘wire has charges’. In this way two competing ideas are brought together to create a dialogic space (Wegerif, 2007) and the teacher uses this difference in points of view as a starting point to move towards the accepted scientific view (which is in agreement with S_7). In fact, this difference in point of view lies at the very heart of understanding simple electrical circuits and the dialogic approach taken by the teacher has enabled it to be made explicit and explored.

This analysis, as summarised above, demonstrates a big contrast between authoritative and dialogic communicative approaches in supporting learning as a process, reflected in the nature of the student engagement in the ongoing talk. We now examine, in more detail, a range of specific learning opportunities and how they might be supported particularly through dialogic talk.

Opportunity to talk, listen and express personal understandings In short, authoritative communicative approaches offer fewer opportunities for students to talk than dialogic approaches. Thus, for the non-interactive/authoritative lecturing style of teaching, the teacher is the talker and the students are the listeners. In the interactive/authoritative 'recitation' (I-R-E) mode of teaching, the students become talkers but in essence they are talking the talk of the teacher as they are given the job of ventriloquating what the teacher is trying to present. In contrast, through interactive/dialogic practices the students are given the chance to talk, to express their ideas to others, and also to listen to the points of view of others. This chance to talk about their conceptions, Dawes (2004, p. 678) suggests, is to 'provide stimulus to question what is said', describing the students' speaking and listening skills as the basis for working with them to develop their understanding. The analysis of the Stage 2 lessons shows many dialogic episodes in which the teacher and students were exchanging ideas and sharing control in guiding the talk through their contributions. Being able to express your point of view and to reflect on the ideas of others, has been described by Brooks (1999, p. 108) as an 'empowering experience' that 'facilitates the meaning-making process'.

Opportunity to work on understanding Establishing the basic requirements of allowing students to talk and listen, and to express personal understandings is vital in supporting students' learning. It has been argued, however, that it is not enough simply to identify the students' views, as teachers need to work with those ideas in helping students to develop their understanding (Keeley et al., 2007). In defining 'working on understanding', Barnes (2008) wrote: 'Working on understanding is, in essence, the reshaping of old knowledge in the light of new ways of seeing things' (p. 4). The openness of dialogic talk to students' personal views in the analysed examples contributed to revealing their existing understanding, but it is in the course of asking questions of higher cognitive levels through initiation and elaborative follow-up moves that students were encouraged to: think and re-think aloud; predict, put forward assumptions and/or vote for them before they could be tested by experiment; deconstruct their thoughts, analyse them for logic and consistency and organise and develop them towards a more scientific view. In engaging in these activities, the students were working on their understanding, reinforced by the teacher's support, as exemplified by the following transcript in which the teacher and student work together in coming to an understanding of where the energy originates in a circuit and how it is transferred:

47.T	Yes S_{10}, what do you think?
48.S_{10}	The battery gives electrical energy and it passes through the wires.
49.T	How does it pass it through the wires?
50.S_{10}	Cos the wires are connected to the battery, the electrons will move through.
51.T	You said that the battery gives the circuit electrical energy, how?
52.S_{10}	Cos it has chemical substances that help produce electrical energy. So the electrons will move through the wires till they reach the bulb.
53.T	Ok, I agree that the battery gives the circuit electrical energy-then you said the electrons will move through the wires. Where is the link between them?
54S_{10}	Cos everything in life has energy, so the energy from the battery will move through the wires.
55.T	So the energy has the ability to move through the wires?
56.S_{10}	Yeah, it moves yeah.
57.T	Ok, why did you say the charges here?
58.S_{10}	Cos the energy is made up of charges.
59.T	Energy is made up of charges. Let's write your answer-and then the energy …

The task of working on understanding is not straightforward. Indeed, it has been claimed that finding out what students think about taught concepts, stimulating them to question their own ideas as well as those of others, and building on these ideas to get to views more consistent with the scientific explanations, is a challenging task for both the teacher and students (Dawes, 2004; Newton, 2002). This is evident from the above transcript where progress is made in identifying the source of the energy in the circuit (the battery) but confusions then arise over the difference between energy and charge.

Opportunity to develop key intellectual skills As well as addressing matters relating to learning scientific conceptual knowledge, the literature also draws attention to how important it is for students to develop the habits of questioning, thinking, debating, and similar intellectual skills:

> 'Students need to learn to listen carefully to other's ideas, and weigh the evidence before changing their own ideas. They need to learn not to accept a new idea simply because their peers think it is correct. They need to learn how to examine all the ideas, including evidence from investigation and other relevant information sources, before accepting an idea or changing a previously held one' (Keeley et al., 2007, p. 8)

Dawes (2004) argues that being able to identify and articulate their thoughts through dialogic interaction, not only directly benefits the students in their learning, but also has indirect benefits in terms of developing skills of reflection in learning how to question their own thoughts and those of others. Similarly, Scott (1998) argues that dialogic discourse encourages the practice of generative thinking and good habits of mind in questioning and reflecting on the social plane, which might support active, analytic individual thought. While considering the opportunity to work on understanding in the previous section, we referred to the practices of revealing the students' personal views and developing them towards a more scientific one by stimulating thinking. Questioning is the central way of doing so. Dialogic talk appeared to support the emergence of questions and responses of high quality (see section 3.2). These are high level open questions asking for the students' thoughts, followed by elaborative questions requiring high cognitive processes in analysing and justifying these thoughts, and students' responses that often manifested the required high cognitive processes. Questions of high cognitive level have been highlighted for their role in challenging students 'to look beyond the apparent, to delve into issues deeply and broadly, and to form their own understandings of events and phenomena' (Brooks, 1999, p. 110).

Opportunity to value individual differences In the environment of dialogic practice every opinion is welcomed and opposing views are questioned and negotiated without immediate evaluation. Valuing individual differences does not come only from listening to different opinions and accepting them as 'possible' views, but comes also from negotiating and challenging each other's ideas. Dialogic talk appeared to offer both the teacher and the students the chance to question the presented knowledge, analyse what is said, follow the inconsistency or the logic of others' views and evaluate them. Such intellectual processes, which involve the bringing together of ideas lie right at the heart of meaning making. We come to understand ideas fully by recognising what they are not as well as what they are. For example, returning to the example of the work on electric circuits, a full understanding of the working of the circuit involves appreciating that the charges originate in the wires of the circuit and not in the battery. As shown in the earlier transcript, both of these ideas were show-cased in the dialogic exchanges about the circuits. In general terms, meaningful learning is more often than not driven by differences in ideas and from a pedagogic point of view such differences are therefore to be valued.

Finally, it is worth pointing out that the opportunities discussed above should not be viewed solely as providing the students with help in their learning. Equally they offer opportunities for the teacher to support their students' learning. In the end, students' learning is a shared responsibility between teachers and students, and supporting learning involves attending to both sides (teaching and learning) of the pedagogic coin.

Learning in Relation to the Intellectual Quality of Interactions

Here we turn to examining the second aspect of learning in process, which relates to the intellectual quality or cognitive level of the teacher questions and student responses. The central question here concerns whether or not there are any differences in cognitive level of questions and responses when comparing the authoritative episodes of talk from Stage 1 with the dialogic episodes from Stage 2.

To address this question, the cognitive level of the teacher's questions and students' responses were judged in terms of the cognitive process dimension of Bloom's taxonomy (Bloom, 1956). According to the taxonomy, both questions and responses can be classified in relation to six levels: remember, understand, apply, analyse, create and evaluate. Each of these six categories has a number of sub-categories, providing a more detailed description that can help in inferring the cognitive processes employed by the speaker. For the purposes of this study, the categorisation was reduced to a simple hierarchy of two elements: 'Low' and 'High' cognitive processing. The literature shows that a low cognitive level is usually assigned to the process of remembering only (Andre, 1979; Cotton, 1998; Gall, 1970). However, in developing the analysis in this study, some of the data showed questions and responses which could not be classified into the 'remember' category, yet did not indicate high cognitive processes (for example, a statement like 'a simple electric circuit contains one device only' is of low cognitive level and yet cannot be said to reflect the process of remembering, rather it is an example of 'understand: interpret'). Analysing further examples of this kind (see Almahrouqi, 2010) led to identifying the lowest three sub-categories of the cognitive process of 'understand' (interpreting, exemplifying and classifying) as belonging to a low rather than a high cognitive level.

Generally speaking, educators consider that the type of questions which teachers ask has an influence on students' learning. Some research on questioning points to students achieving good learning if the teacher's questions are not limited to factual closed ones (Alexander, 2000; Rojas-Drummond & Mercer, 2003). Earlier research argues, however, that the effects of teachers' questions on students' learning is not really well known (Andre, 1979; Cotton, 1998; Dillon, 1982), and that the claims of 'the goodness of higher-level questions remain wish-fulfilling myths' (Andre, 1979, p. 280). The analysis presented here was not designed to follow the effect of the cognitive complexity of questions (low or high) on students' learning directly. Rather the cognitive complexity of the teacher's questions was related to the complexity of the responses they invited and both of these were linked to the prevailing communicative approach developed by the teacher.

The overall findings show a striking difference in the cognitive levels of the questions and responses in Stages 1 and 2. The following short exchange is typical of the interactions of Stage 1:

7.T	…Another observation you noticed that indicated a chemical change…?	L (Remember; identify)
8.S_2	The rising of bubbles	L (Remember; recognise)
9.T	Bubbles rose?! (Wonder tone)	L (Remember; recognise)
10.S_2	The change of colour	L (Remember; recognise)
11.T	The colour changed ^ (affirmation tone)	L (Remember; identify)

Here the teacher follows an interactive/authoritative communicative approach in which both questions and responses are of low cognitive level, as the teacher asks the student to identify the signs of chemical change that she is looking for.

By way of contrast, the following exchange is from Stage 2:

11.T	What do you think S_2?	H (Create; hypothesize)
12.S_2	Maybe the charges are basically moving on their own right from the beginning.	H (Create; hypothesize')
13.T	Do you agree or disagree with S_1?	H (Evaluate; judge)
14.S_2	A little-Basically it has -- the charges are moving there from the beginning.	H (Create; hypothesize)
15.T	Where do they move?	H (Understand; explain)
16.S_2	They move in the wire and go to the bulb.	H (Understand; explain)

Here the teacher takes a dialogic approach and both questions and responses are of high cognitive level, as the teacher probes the students' ideas and the students respond accordingly.

The following table provides a summary of the overall numbers of questions and responses in relation to their cognitive level for all the analysed authoritative examples from Stage 1 and the dialogic episodes from Stage 2 in the reported case.

Table 2. Summary of the cognitive level of questions and responses in authoritative and dialogic episodes

	Number of Questions		*Number of Responses*	
	Low	*High*	*Low*	*High*
Stage 1 (authoritative episodes)	49	6	71	6
Stage 2 (dialogic episodes)	7	53	31	37

These results show that the dialogic talk in Stage 2 supports the emergence of questions and responses of high cognitive level, whereas the authoritative talk in Stage 1 does not. The authoritative talk resulted in a ratio of 49 low to 6 high level questions, while the dialogic led to a ratio of 7 low to 53 high level questions. Such numbers indicate quite clearly the superiority of the dialogic oriented talk in supporting the emergence of questions of high cognitive level and also stimulating responses of relatively high cognitive level (71 low/6 high responses in authoritative – 31 low/37 high responses in dialogic).

Focusing on the quality of the responses generated by authoritative and dialogic talk, however, raises an interesting point of difference. For the authoritative talk of Stage 1, dominated by questions of low cognitive level, the findings point to a constant cognitive correspondence between the levels of the teacher's questions and students' responses. That is, more questions of low cognitive level (49/6) have invited more responses of low cognitive level (71/6). However, for the dialogic talk of Stage 2, dominated by questions of high cognitive level, the findings do not show a similar cognitive correspondence. Here more questions of high cognitive level (7/53) have not necessarily invited responses of solely high cognitive level (31/37), although they have encouraged more of them.

The findings from this case thus indicate the potential of teaching approaches with more dialogic talk to invite questions and responses of high cognitive level and the lower potential of authoritative teaching approaches to do so. It is widely reported that the persistent practice of traditional authoritative teaching is dominated by closed, factual, low level questioning that invites responses of the same level (e.g. Carlsen, 1991; Dillon, 1982; Hardman, 2008). Alternatively, the questioning in dialogic teaching approaches is used to explore students' thinking and to support them in working on their ideas, and so is more likely to generate high levels of thinking (Chin, 2006, 2007).

From the cognitive correspondence standpoint, as outlined earlier, research from elsewhere has reported a non-correspondence between high level questions and responses (Andre, 1979; Cotton, 1998; Dillon, 1982). In Dillon's words: 'Ask a higher-level question, get any-level answer' (p. 549). However, the finding that dialogic talk does not solely lead to responses of high cognitive level, neither undermines the positive influences of dialogic talk on learning, nor undermines the significance of high cognitive questions as suggested by some studies (see Andre, 1979).

The results of this study, for teaching approaches with more dialogic talk, support the finding of the non-cognitive correspondence between questions and responses of high level, but also demonstrate a *tendency* for high level questions to generate high level responses, supporting the assumption that the types of questions the teachers ask 'can, to some extent, influence the cognitive processes that students engage in as they grapple with the process of constructing scientific knowledge' (Chin, 2006, p. 816).

Learning as a Product

In the last of the three approaches to probing learning across the two stages of this case, we turn to consider the *products* of learning at the end of the teaching sequence. The key question here is whether or not there are any discernible differences in learning outcomes after the largely authoritative teaching of Stage 1 as compared with the more dialogic teaching of Stage 2. The students' conceptual understanding was probed at the end of Stage 1 and 2 through two approaches. Firstly by analysing the students' individual responses to bubble dialogue exercises, which involve 'concept cartoon' like drawings of relevant scientific problems to which the students write down their thoughts individually, and secondly by talking with focus groups of students from the class (see Almahrouqi, 2010). By these means some idea of the knowledge shared by the students was identified for each of the topics.

What, then, was the shared knowledge outcome (as identified through the bubble dialogue and focus group activities) for each of the teaching sequences? Following the authoritative teaching approaches for the 'Physical and Chemical Changes' topic, the students shared some factual knowledge relating to the general definitions of physical and chemical changes and indicators of chemical change. In addition they displayed other scientific conceptions that go beyond factual knowledge such as recognising change of colour as not necessarily being an indicator of chemical change. On the less positive side, there was lack of understanding of several important insights such as recognising that changes in colour/temperature and formation of gas/precipitate provide evidence of chemical change only if they involve the formation of a new substance. In fact, the absence of such insights was reflected in the many conceptual difficulties that virtually all of the participating students displayed, and which led eventually to the students giving incorrect judgments on whether some changes were physical or chemical, as well as offering mistaken justifications that revealed a 'fragile' understanding of the topic overall. Even those students, who presented views more compatible with scientific ones, appeared not very convincing in their understanding at times and were not able to defend their views robustly. The following short excerpt from the focus group discussion reflects the 'fragile' understanding of students as they still cannot recognise the tearing of paper as a physical change after 5 taught lessons on substance changes:

> S_1: …physical (tearing paper) -- but it might be chemical cos we can't get it back, cos if you glue it, it will mix with new substances.
>
> S_3: …it can be. We might add water with starch…
>
> S_1: …but this will change its features.
>
> S_3: …we might put it in some kind of machine…
>
> S_1: …but for now, we don't have this machine.

Here the girls are incorrectly using the criterion of 'irreversibility' to categorise paper tearing as a chemical change.

On the other hand, the students demonstrated an overall very good understanding following the more dialogic approach to teaching the conceptually difficult topic 'Electric Circuits' in Stage 2. Here there was no reference to typical alternative conceptions such as the charges originating in the battery and not in the wires, and the bulb consuming the charges (Brna, 1988; Engelhardt & Beichner, 2004; Tsai, Chen, Chou, & Lain, 2009). Quite the opposite, scientific conceptions such as the wire as the source of charges, the battery as the source of energy, and the bulb as transferring energy to light and heat, were frequently used by the students during their discussions, as demonstrated by the following extracts from the focus group talk, and bubble dialogue writings, respectively:

> S_3: …the battery just organises the charges and supplies them with energy…
>
> S_4: … but we've said that the charges in the wires move…but basically, the charges are there in the wire.
>
> S_2: …it (bulb) consumes the energy and transforms it from electrical energy to heat and light.

The following is the writing of S4, while taking the roles of Muna and Salma in one bubble dialogue scene:

> Muna: …what do you think Salma if we changed the position of the green bulb so it will be closer to the battery and it will light more?
>
> Salma: No…cos it will be the same, the red bulb will light…cos the role of the battery is to provide the charges with energy and organise their movement and the charges are there basically in the wire…maybe there is something wrong with the bulb itself , so it's least bright.

Such responses give the impression of these scientific ideas being regarded by the students as taken-for-granted and unquestioned in understanding the working of electric circuits. The analysis also showed the students having a firm understanding of more difficult scientific explanations such as the simultaneous movement and conservation of charges, the instant lighting of bulbs on the completion of a circuit, and the constant size of current around the circuit. The students largely agreed upon this range of scientific conceptions and explanations. Nevertheless, some conceptual difficulties in understanding the working of electric circuits were shared by some students, and could be traced back to difficulties in understanding the basic entity of energy, and how it is transferred in the circuit.

Overall, the findings point to the tendency of the teaching with more dialogic talk to result in a deeper scientific understanding as compared with the learning outcome from the teaching with more authoritative talk. In other words, from these data it seems that teaching approaches with explicit dialogic episodes (alongside authoritative episodes) is more likely to lead to student understandings with more scientific conceptions and explanations and fewer misconceptions and conceptual difficulties.

FINAL COMMENTS

In this chapter we have reported on part of an empirical study (Almahrouqi, 2010) to characterize the talk in high school science lessons and explore the nature of any links between different kinds of talk and student learning. The findings reported here show that the nature of classroom talk does have an influence on student learning, and further suggest that widening the nature, and improving the quality, of talk are of crucial importance if teaching practice is to have a significant impact on learning. The analyses of the three aspects of learning which have been addressed in this chapter all point to the importance of dialogic talk in this regard. The first level of analysis highlights the nature of the student engagement in a variety of learning processes which are made available through dialogic talk. These have been summarized as opportunities for the students to: talk, listen and express personal understandings; work on understanding; develop key intellectual skills; value individual differences. The second level of analysis offers persuasive evidence to indicate that the intellectual quality of the teacher's questions and many of the students' responses is raised through dialogic interactions, as compared with authoritative interactions. Finally, the findings in relation to learning outcomes at the end of the teaching indicate a deeper, and more consistent, level of student understanding following the more dialogic talk of Stage 2.

On reflection, it is not too difficult to see the connections between these three findings. Dialogic talk offers students a wider and deeper engagement in classroom interactions, it leads to talk which is pitched at a higher cognitive level, and such enhancement of the learning process leads to stronger learning outcomes. It is with these findings in mind that we see this study as a further contribution to the gathering body of data which addresses Osborne et al's (2004) concern about lack of evidence linking discursive problem-solving activities to enhanced cognition.

One important point to bear in mind with the analysis presented here is that the electric circuit lessons of Stage 2 did not solely involve dialogic communicative approaches (see Table 1). In fact there was a mix of approaches with most of the 5 lessons containing both authoritative and dialogic interactions and it was this mix of approaches which led to the impressive learning outcomes documented here. We, along with Alexander (2000), are not arguing for teaching which is based entirely on dialogic talk, but for dialogic teaching which contains both authoritative and dialogic communicative approaches. Whilst dialogic talk allows students to engage in learning in the ways described here, authoritative talk also has a role to play in 'getting the scientific message across'.

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13. SCHOOL HEALTH EDUCATION NOWADAYS: CHALLENGES AND TRENDS

School health education has been viewed in a large variety of perspectives. In this chapter we present, in a historic approach, the biomedical model, the holistic view as well as the health promotion, autonomy and citizenship perspectives of health education. The aims of the health promoting school and the relevance of partnerships with the health sector, the pupils, their families and the community in health education are emphasised. Social representations, ethics and values in health education are referred. Special attention is given to models of school health education, the nature of knowledge in health education, prevention of health risks, effectiveness of health education practices and also to teachers' practices and their role and training in health education.

HISTORIC APPROACH TO HEALTH EDUCATION

The Origin of Health Education – the Hygienic Approach

Health has always been regarded as a major individual and social concern. By the end of the 18th century the public authorities of European countries initiated social health measures in a large social policy. Although not called yet "Public health", these measures associated the medical knowledge at that time with the social wellbeing, so that doctors, in addition to treating the ill, became interested in looking at the physical and social environment, housing and health working conditions.

Association of pathologies with work was earlier reported by Bernardini Ramazzini, already in 1701, when studying Italian artisans (Faure, 2002). At that time diseases could often be identified but there were no efficient means for treatment. It was at the end of the 18th century that the first vaccine appeared with the work of the English scientist, Edward Jenner in 1798 (Scott, 1996) on the smallpox or *Variolae vaccinae*. The anti-variole vaccination was a matter of great importance in Western European countries as it was the way to set up an efficient and modern health service (Darmon, 1986). In the second part of the 19th century Louis Pasteur, in France, provided evidence for the existence of microorganisms responsible for infectious diseases (in particular, rabies and diphtheria) and Robert Koch, in Germany, discovered the Koch bacillus responsible for tuberculosis (Faure, 2002). In this period medicine was guided towards prevention.

It was in this context of fighting against infectious diseases that the hygienist approach of health education emerged. This approach focused on individual

Doris Jorde and Justin Dillon (Eds.), Science Education Research and Practice in Europe: Retrospective and Prospective, 309–340.

behaviour, following the social elite's discourses regarding the deprived lay people (Faure, 2002: 22): *The people must be educated like a child by telling them what they must do and not do*. Instructions concentrated on individual behaviour (absence of hygiene, deficient/unhealthy feeding) whereas social factors (poverty and social context) were not taken into account.

Health education in schools appears by the end of the 19th century, by introducing in some countries (for example in France, Spain and Portugal) the "lessons of morale" and "lessons of the things" (Csergo, 2002), concerning three main themes: hygiene, tuberculosis and alcoholism. The health messages were presented in the form of injunctive/authoritative prescriptions, *i.e.* rules to be obeyed.

The Biomedical Model of Health

The biomedical model of health has grown with the development of the rationalism where science determines the knowledge and understanding of the world, in particular the perception about health and disease (Naidoo & Wills 1994). According to Foucault (referred by Revel, 2002) the rationalism period was characterised by a despotic use of science and technology, which gained more and more influence on the productive sector and on policy makers, leading to a type of State rationalism. It created forms of governance and processes of control as well as a kind of behaviour rationalism, determining social normative measures and deviations to them. In this way the notion of "normal" (*versus* "abnormal") was established and the moral value that "normal corresponds to good" (*versus* "abnormal corresponds to evil") was assigned.

In this model of health education, the body is assumed as working like a machine (Doyal & Doyal, 1984):

– All parts of the body are connected but they can be isolated and treated separately;
– Being healthy is to have all parts of the body in good working conditions;
– Being ill is to have parts of the body working deficiently;
– Illness is caused by internal processes (age degeneration or deficient self-regulation) or external processes (body invasion by pathogenic microorganisms);
– Medical treatment aims to restore the normal body work, or health.

The biomedical model is centred in the disease, focusing on the causes of diseases their treatment and their prevention. Health professionals – having the knowledge for disease identification, cause and respective treatment – play a dominant role, often using persuasive and paternalistic methods (Ewles & Simnett, 1999). In this model, it is the health professionals' responsibility to ensure patients comply with the medical prescriptions and preventive procedures are encouraged as they can contribute to reducing disease.

Within this biomedical model, health education is seen as a preventive procedure aiming at persons' behaviour change to healthier lifestyles in order to avoid becoming sick. There are two main trends in the biomedical model of health education: the informative and the preventive approaches:

- Having the curative perspective, health education is reduced to instruction consisting of information focused on scientific knowledge. Messages in informative/inciting style are used.
- Having the preventive perspective, health education aims at a specific risk, by using fear in order to impose the rules (of living, of hygiene, of behaviour) to be followed. Messages in injunctive/authoritative style are often used.

Based in this biomedical model, school health education aims at teaching children and young people how to keep their body in good working condition and how to avoid diseases. Health messages are informative, injunctive/authoritative and explicative (Sandrin-Berthon, 2000). The implicit idea is that informing about an unhealthy behaviour and understanding it, is enough for the behaviour change or for avoiding unhealthy behaviours.

From the Biomedical Model to the Holistic View of Health Education

In an opposite perspective to the dominant biomedical model, Antonovsky (1987) was interested not really in the causes of disease but, on the contrary, on what keeps people healthy, in a so called "salutogenic" (health seeking) approach. In this framework, attention is focused (Katz & Peberdy, 1998: 31):

> on why some people remained healthy and emphasised that stressors and disruption were unavoidable aspects of life rather than the demons they are portrayed to be in the pathogenic account.

In this salutogenic paradigm, the dynamic relationship between the persons and their environment is essential and emphasis is given to the personal resources to cope with the challenges they face. To acquire competences to deal with stressors, one needs to create "a sense of coherence" by integrating the three components *(1)* comprehensibility, *(2)* manageability and *(3)* meaningfulness, Antonovsky (1987: 19):

> *(1) the stimuli deriving from one's internal and external environments in the course of living are structured, predictable and explicable;*
> *(2) the resources are available to one to meet the demands passed by the stimuli; and*
> *(3) these demands are challenges worthy of investment and engagement".*

Managing the relationship with the environment depends not only on personal resources but also on human relationships, social support and supportive environments (Carvalho, 2006).

The salutogenic paradigm makes an interesting bridge between the biomedical model and the social model of health, which assumes a holistic perspective of health and gives emphasis to persons and environment interaction and adopts the logic of multi-causal theories of health and assumes health as being influenced not only by biological factors but also by political, economic, social, psychological, cultural and environmental factors (Naidoo & Wills, 1994; Katz & Peberdy, 1998; Ewles & Simnett, 1999; Carvalho, 2006; Berger *et al.*, 2011; Carvalho *et al.,* 2011; Caussidier *et al.*, 2011).

The social model of health does not dispense with medicine; it rather assumes that the medical model is just a part of the answer. To improve persons' health, it recognises the need for refocus upstream on the causes of ill-health in persons and communities, such as socio-economic, housing, nutrition, social and individual hygiene factors (Katz & Peberdy, 1998).

Within the holistic view of health, the aim of health education is to develop positive attitudes and behaviours towards health and wellbeing. The purpose may also be a behaviour change towards a healthier lifestyle to improve health but not focused in the prevention of diseases, as it is in the biomedical model of health education. The educational approach not only aims at giving information, ensuring knowledge and understanding of health issues, and enabling well-informed decisions to be made but also helps people to explore their values and attitudes (Carvalho *et al.,* 2008). More than acquiring scientific information, school health education should put the emphasis on helping children and young people to develop competences of healthy living (Ewles & Simnett, 1999; Carvalho 2002; Carvalho & Carvalho, 2006).

Taking the example of smoking, in this holistic perspective of health education the aim is to help people understand the effects of smoking on health, thus helping them to make a decision to smoking or not. Emphasis is on the activity to give them information about the whole effects of smoking, helping people to explore their own values and attitudes and come to a decision. If they want to stop smoking then they should learn how to do it.

School health education, in this holistic view, has a much broader view than the traditional biomedical health education that focuses only on formal classroom activities. The holistic school health education addresses also the development of healthy lifestyles, including the required changes in the school to make the social and physical environment more health enhancing. This is a matter of further discussion below.

Health Promotion, Autonomy and Citizenship

The traditional view of health as the *"absence of disease"* derives from a medical concept of disease as a pathologic condition – or deviation from measurable variables which represent *"normal"* parameters in the *"healthy"* body – that can be diagnosed and categorised (Katz & Peberdy, 1998). By contrast, the early definition by the World Health Organization (WHO, 1948) assumes health as a *state of complete physical, mental and social well-being*, in a wider perspective of welfare.

Within this view of health, the health education aim is no more to simply transmit knowledge about the human body but it also touches other fields like physical education, arts education and activities promoting interpersonal relationship skills (Carvalho, 2002; Carvalho 2006; Carvalho & Carvalho, 2006).

In early 1970s most western countries experienced a crisis in the health sector due to the escalation of treatment costs, so that the therapeutic era was being challenged and a New Public Health Movement emerged (Ashton & Seymour 1988). This international movement called for social change and political action by presenting a view *which brings together environmental change and personal preventive measures with appropriate therapeutic interventions* (Ashton & Seymour, 1988: 21).

One decade later the *First International Conference on Health Promotion* held in Ottawa (Canada) in 1986, made progress on the earlier Declaration of Alma-Ata (former USSR, in 1978) and produced the well known Ottawa Charter, which projects the view that health is a personal struggle and a goal to be worked towards by a community, by assuming health as (WHO, 1986: 1):

> *a resource for everyday life, not the objective of living: it is a positive concept emphasizing social and personal resources as well as physical capabilities.*

The concept of health promotion was then stated as being:

> *the process of enabling people to increase control over, and to improve, their health. To reach a state of complete physical, mental and social wellbeing, an individual or group must be able to identify and to realise aspirations, to satisfy needs, and to change or cope with the environment.*

The model of *autonomy and citizenship* referred by Eymard (2005) focuses on the self-consciousness within a psycho-social approach, where self-esteem and self-confidence are important features to help the person to feel self-assured in conducting his/her own life, being the guide of his/her own project of healthy life and quality of life. This person's ability to act upon his/her environment leads to the notion of empowerment (Naidoo & Wills, 1994; Tones & Tilford, 1994; Katz & Peberdy, 1998; Ewles & Simnett, 1999).

The New Public Health Movement together with the WHO's progressive view of health promotion have been changing the emphasis of health promotion practice from the traditional *"problem-based approach"* to a *"setting-based approach"* (Ashton & Seymour, 1988; Barić, 1994). In fact, conventional health education and health promotion practice endeavours to reduce or solve problems that are identified by etiological and epidemiological studies (*e.g.* distribution of lung cancer in smokers).

Thus health educators and health promoters, following the members of the medical and paramedical professions, have been engaged in providing health care and preventing diseases within the "medical model" framework (Barić, 1994). In contrast, in the "setting-based approach" health promoters are seen as partners of the management team in the setting, which is the main decision-maker. In this way, the new concept of "health promoting institution" is seen as the setting in which people live, work or play. In short Barić (1994: 203) declares:

> *"[it] means that we look at a population within a particular setting and find out what kind of health problems they are exposed to and what kind of health*

> *needs they experience and deal with them by means of health promotion and health education".*

The concept of a Health Promoting School is based on the WHO view of health education and health promotion within a setting-based approach. Therefore, it has a much broader view than the traditional school health education that focuses only on formal classroom activities.

SCHOOL HEALTH PROMOTION

Children and young people spend a large part of their lives in school during their formative years. In this environment they eat, drink, smoke, fall in love, speak about AIDS and about drugs, face stress, experience emotions, etc. To tackle these issues and to prevent physical and mental health problems, actions of health education must be undertaken in the school setting. The school influences the daily life of children and young people, by means of the learning conditions which contribute for their personal and social identity (Mérini *et al.*, 2000).

Health education is one of the main school missions but it must take into account its specificity. The school is, first of all, a place of cognitive and social learning, not really a place for healing. Therefore it should not be focused on health risks and diseases but rather on developing skills and experiences, which enable children and young people to build competencies in taking action to improve their own health and well-being and that of others in their community, which also enhances their learning outcomes (IUHPE, 2008a).

An earlier well-known definition of health education by Tones e Tilford (1994: 11) refers to the learning gains not only in knowledge and ways of thinking but also in values clarification and attitudes and behaviour change, as follows:

> *"Health education is any intentional activity which is designed to achieve health or illness related learning, i.e. some relatively permanent change in an individuals' capability or disposition. Effective health education may, thus, produce changes in knowledge and understanding or ways of thinking; it may influence or clarify values; it may bring about some shift in belief or attitude; it may even effect changes in behaviour or lifestyle".*

Changing to healthier behaviours is a rather complex process which depends, among other factors, on one's personal attitude towards general health, health risks and health topics (nutrition, sexuality, etc.). Attitudes are, in this context, judgments more or less favourable to health issues. These judgements depend on one's knowledge (health subject matters), beliefs and social representations, as well as the generated emotional reactions and intended reactions (Laure *et al.*, 2000).

The International Union for Health Promotion and Education (IUHPE) has clarified the concepts of "health education" and "health promotion" in school. The former, health education, is (IUHPE, 2008b:3):

> *a communication activity and involves learning and teaching pertaining to knowledge, beliefs, attitudes, values, skills and competencies.*

the latter, health promotion, is (IUHPE, 2008b:3):

> *any activity undertaken to protect or improve the health of all school users.*

Although both concepts of health education and of health promotion emphasise the participative approach to learning, the latter is a broader concept that goes beyond the classroom activities or curriculum implementation.

Aims of the Health Promoting School

The concept of a Health Promoting School is based on the WHO view of health education and health promotion within a setting-based approach. Therefore it has a much broader view than the traditional school health education that focuses only on formal classroom activities. Although there are many models of a health promoting school, they are all based on the five strategies of the Ottawa Charter (WHO, 1986) albeit adapted to the school setting (WHO, 1991 – referred by Colquhoun, 1997):

– *Health Promoting Policy* – by developing coherent curricula in education for health which brings biological ecological and social dimensions to a process of environmental health;
– *Creating Supportive Environments* – by utilising the setting of the school to encourage reciprocal support between teachers, pupils and parents;
– *Strengthening Community Action* – by drawing on existing human and material resources in the community in which the school is set and involving that community in practical aspects of the decisions, plan actions pertaining to the project;
– *Developing Personal Skills* – by providing information, education for health and opportunities to enhance life skills in the setting of the school community;
– *Reorienting Health Services* – by involving the school health service in project activities aimed at the promotion of health by utilising the skills of school health professionals on a broader basis than the traditional roles.

The European Network of Health Promoting Schools (ENHPS) was launched in 1991 as a joint and collaborative effort between the WHO Regional Office for Europe, the Commission of European Communities (CEC) and the Council of Europe (CE). According to the WHO Regional Office for Europe (WHO, 1995, quoted by Parsons *et al.,* 1996):

> *The health promoting school aims at achieving healthy lifestyles for the total school population by developing supportive environments conductive to the*

> *promotion of health. It offers opportunities for, and requires commitments to, the provision of a safe and health-enhancing environment.*

The aim of the ENHPS (1997a:1) initiative is:

> *To influence and have impact of policy and decision making in the development, implementation and sustainability of health promoting schools in European countries. This aim is achieved through capacity building, resource development, research and evaluation, advocacy and dissemination.*

Despite the diversity in culture and educational settings throughout Europe, there is a general agreement on the aims of health promoting schools which can be synthesised in 10 items (Barnekow et al., 2002:13):

– To establish a broad view of health;
– To give students tools to enable them to make healthy choices;
– To provide a healthier environment engaging students, teachers and parents, using interactive learning methods, building better communication and seeking partners and allies in the community;
– To be understood clearly by all members of the school community (students, their parents, teachers and all other people working in the environment), the "real value of health" (physical, psychosocial and environmental) in the present and in the future and how to promote it for the well-being of all;
– To be an effective (perhaps the most effective) long-term workshop for practising and learning humanity and democracy;
– To increase students' action competence within health, meaning to empower them to take action – individually and collectively – for a healthier life and healthier living conditions locally as well as globally;
– To make healthier choices easier choices for all members of the school community;
– To promote the health and well-being of students and school staff;
– To enable people to deal with themselves and the external environment in a positive way and to facilitate healthy behaviour through policies; and
– To increase the quality of life.

The Schools for Health in Europe (SHE) network is the continuation of ENHPS, having started in January 2007. Currently, SHE network is present in 43 European countries aiming at supporting organisations and professionals in Europe who work in the field of school health promotion, intending to share good practice, expertise and skills (SHE, 2008).

The health promoting schools involved in SHE network are intended to value and develop (SHE, 2008):

– *Equity* – equal access for all to the full range of educational opportunities;
– *Participation* – a sense of ownership is encourage by pupils' participation;
– *Empowerment* – foster pupils in developing their own ideas about healthy lifestyles and making active and healthy choices;

– *A healthy environment – including the physical environment, the quality of the relationships among pupils, among staff, with parents and the community;*
– *Effective policies – developed locally and reflecting local interests, problems and priorities.*

There is growing evidence that the health promoting school approach has a positive impact on the primary teaching and learning processes of the school, including higher academic achievement, reducing early school leaving, as well as higher job satisfaction (Mérini *et al.*, 2000; Barnekow *et al.*, 2002; Leger *et al.*, 2007; SHE, 2008).

Partnership in School Health Promotion

Depending on individual countries, health is not taken into account in educational policies in the same way because of general political organisation, priorities, organisation and goals of education systems (Pommier & Jourdan, 2007). In some countries, health education is a national matter with national guidelines, standards and curricula. In other countries, the regional or local authorities have the responsibility of developing health education policies.

Although there are country differences regarding the organisation of both health and education sectors resources, the fact is that both are inextricably linked. This also means that improving effectiveness in one sector can potentially benefit the other. This makes the school an important and rather complex setting to implement health promotion and health education. Figure 1 is an adaptation of the eco-holistic model of the health promoting school adapted from Parsons *et al.* (1996). This model locates the health promoting school in the context of international influences (1 – see Figure 1) as well as national (2), regional (3) and local (4) health and education legislation and initiatives, which interact with each other. In an inner circle there is the management, planning and allocation of roles (5) and links with outside agencies, the family and community (6). They both are in close association with the core of this organisational model composed of the formal curriculum (7), the model of the health promotion adopted by the school (8) and the social and physical environment – contextual curriculum (9). All these items are put in place in order to address pupils' feelings, attitudes, values, competencies and health promoting behaviour (10), which is the main goal of the school health promotion.

As shown in this model, putting into practice a health promoting project in a school contributes, at this level, to the implementation of Public Health policies and Educational policies, in a close articulation between them (see 1 to 4, in Figure 1). A critical issue for effectively promoting health in schools is that all stakeholders have a sense of ownership and involvement in the process. The main partners are the following:

– The education sector, with special reference to teachers;
– The health sector, in particular the school health promoters;
– Children and young people;
– Families and communities;
– Health promotion researchers.

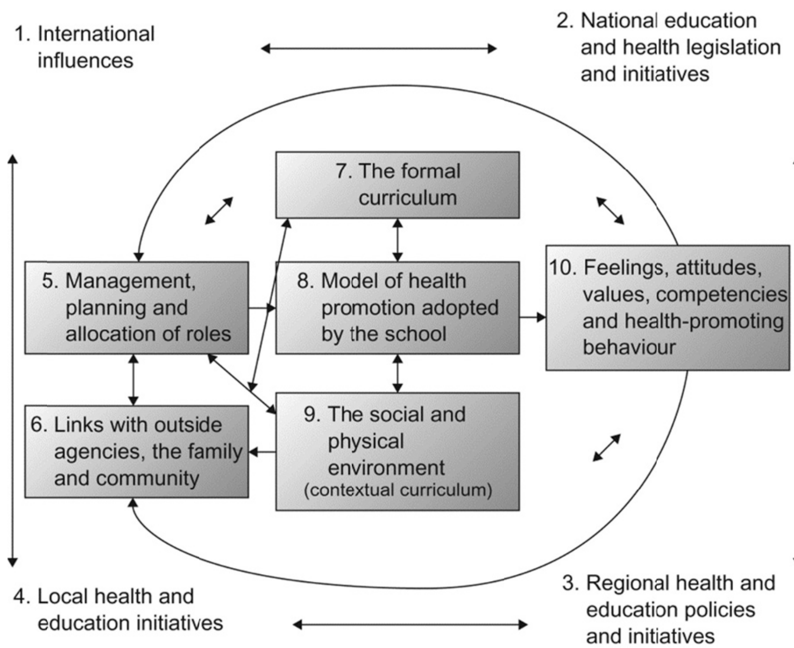

Figure 1. An eco-holistic model of the health promoting school. (Adapted from Parsons et al., 1996).

Therefore the setting up of the management, planning and allocation of roles (5) as well as the links with outside agencies, the family and community (6) are crucial for implementing effectively health promoting schools.

Education sector and health sector partnership. In all countries the school curriculum has always been influenced by the policy makers to introduce priority topics in relation to the education of children and young people and the needs for society. This "external didactic transposition" (Clément, 2006) is therefore a vehicle to respond to national needs and to tackle "crisis" such as the AIDS epidemic or the escalation of substance abuse.

Nowadays, in most European countries, the education in schools is regarded in a broad perspective, and the curriculum (7, in Figure 1) is taken in a holistic view, defining it in terms of the totality of learning experiences that the school offers to its students, i.e. the formal and the informal curriculum. In this context, the effective school is perceived as a learning community that sees learning as a shared responsibility, enabling pupils to be disposed to have a commitment to learning, respect and care for self and for others, and a sense of social responsibility (Barnekow *et al.*, 2002). This current wide vision of the school ethos and social climate has been assumed by the education sector as increasing the learning outcomes in the classroom.

This holistic view of the curriculum by the education sector fits well with the health promotion approach set down by the health sector. However tensions can arise in the limited time made available for the various formal curriculum areas and health issues may be pushed to a peripheral position. It is encouraging to find that the current broader view of the informal curriculum supports the health promotion approach as point out by the health sector (Barnekow *et al.*, 2002).

The health services are the local or regional school-linked or school-based health services which have a responsibility for child and young people health care and promotion, through the provision of direct services to students or schools or in partnership with schools (IUHPE, 2008a). In addition to screening and assessment by licensed and qualified practitioners, the health services in some countries include the provision and monitoring of healthy food for students and staff, as well as mental health services to promote students' social and emotional development and improve social interactions for all students.

Different language from specialists of education and the health sectors may be a cause of sensitive situations when working in partnership (Kemm, 2006). Taking the example of the curriculum: for the education sector the term curriculum can mean the totality of the learning experiences the school offers to children and young people (the formal and informal curriculum as referred before); for the health sector the term curriculum is usually taken as the syllabus guidelines or the classroom teaching and learning activities, and the wider influence of the school is encompassed within the whole-school effect or health promoting school.

Moreover, naturally the education sector gives priority to education, as schools are in the education sector, whereas the health sector gives priority to health which is their working purpose. These are different starting points, generating different priorities and possibly different perspective for the model of the health promotion to be adopted by the school (8, in Figure 1). The partnership between both education and health sectors requires their respective professionals be aware of these difficulties and work in an open and positive attitude towards their slightly different aims. More recently this tension between both sectors has been diminishing with the evidence that health promotion initiatives cause positive impact on the learning outcomes (Mérini et al., 2000; Barnekow et al., 2002; Leger et al., 2007; SHE, 2008).

Children / Young people partnership. The health promoting school concept puts great emphasis on empowering pupils and building their capacities in health behaviours, policies and knowledge (Leger et al., 2007). Therefore children and young people can have an important role in healthy school initiatives – such as in the canteen and other food services, in physical environmental actions, in policies concerning bullying – addressed collectively in order to have a general health impact. Taking into account the children's and young people's biological, cognitive, cultural and social developmental stages, the great challenge is to build "action competencies" as proposed by Jensen & Simovska (2005) for the following four reasons:

– Being active in health promotion activities, contributes to develop children's and young people' reflection about the process and improve their sense of ownership of learning. In this way it is more likely the activities lead to changes in children's and young people's practice, behaviour or action;
– Participatory educational approaches promote democracy-upbringing, i.e. children's and young people's participation and awareness about joint responsibility, rights and duties in society contribute to intellectual freedom, equality and democracy;
– There is the ethical obligation to involve participants (children and young people) in decisions on health issues directly related to their own lives;
– There is the need for individuals (children and young people) to clarify the understanding about terminology, aims and general framework of improving health, which often is not coincident between health and education professionals. The former often emphasize the efficiency justification whereas the latter ones focus on the democracy-upbringing justification. These reasons are not necessarily in conflict but they are imbedded in different rationales, priorities and values.

According to the guidelines of the International Union for Health Promotion and Education (IUHPE, 2008a:1), individual health skills and competencies:

> *refers to both the formal and informal curriculum and associated activities where students gain age-related knowledge, understandings, skills and experiences, which enable them to build competencies in taking action to improve the health and well-being of themselves and others in their community, and which enhances their learning outcomes.*

Well-being in the school context addresses both cognitive and affective outcomes in school, being the affective one referring to attitudes the students have towards the school and learning. Children's and young people's evaluation of the school well-being has been carried out by Konu and Lintonen (2006) by looking at the four categories that define the school well-being model (Konu & Rimpelä, 2002): 'school conditions', 'social relationships in school', 'means for self-fulfilment in school' and 'health status'.

Parents, families and community partnership. School partnership with the pupils' families as well as with key local groups of individuals are important links for appropriate consultation and participation with these stakeholders, providing children and young people with a context and support for their actions (IUHPE, 2008a).

When parents are actively involved in promoting the health of their children, positive outcomes are more likely (Barnekow *et al.*, 2006). Studies have shown, for example, that parents actively involved in healthy-eating initiatives in schools produce more impact on the behaviour of young people in relation to food preparation (Perry *et al.*, 1988; Young, 2004).

The concept of health promoting school embraces the idea of the school and its wider community and environment. There is evidence suggesting that multiple health initiatives involving the community, local groups, relevant agencies, professionals have stronger effects in pupils' health behaviour change than a classroom-only approach (Leger, 2007). The school surrounding environment must reflect the values being developed in the school, so that several examples of supportive community initiatives have been introduced (Barnekow *et al.*, 2006: 22):

– Facilitating safe and active routes to schools;
– Restricting the sale and advertising of unhealthy products near the school entrance;
– Providing drop-in social centres for young people where they can raise issues confidentially; and
– Providing attractive play and sports facilities in the school catchment area.

SOCIAL REPRESENTATIONS AND VALUES IN HEALTH EDUCATION

Social Representations

Social representations are a kind of current knowledge, also called common sense, which is characterised by the following three features (Jodelet, 1991):

– They are created and shared socially – they are constructed from the persons' experience as well as the acquired knowledge, thinking models transmitted by tradition, education and the media;
– They target practices of organisation – intending to control the environment as well as behaviours and communications;
– They participate in the construction of a common reality – a specific social community or a specific culture.

Social representations allow people to understand their environment, to facilitate their integration and to guide people's behaviours. The social representations are often embedded in social practices and are a kind of practical knowledge (Fischer, 1987) which is constructed throughout the daily experience, with the interaction with the object and, within this process, it is constructed and defined. Therefore they are interpretations of the reality and of the complex phenomena which have a sense in the social interaction. The social representations, which are in the interface of the psychology and the sociology, are constructed individually but they are rooted in the overall community which support them. Such representations are called social (Flament *et al.*, 1998) because they are created from the social codes and the values recognised by the society. Thus, they reflect the society and persons are determined by the social dominant representations where they grow up.

The social representations have a *cognitive purpose* as they facilitate people to integrate new data in their thinking frameworks. They are, therefore, a way of thinking and of interpreting the world and the daily life. The context and the values where the representations are constructed have influence on the mental construction of the reality. For the construction of the social representations there is always a part of individual creation and a part of the collective creation. This is why the social representations are not fixed in the time; they tend to evolve albeit gradually.

Another purpose of the social representations is *guiding people's behaviours*, as they carry the notion of sense and create rules of conducting in society to aid people to communicate, to guide themselves within the environment and to act (Abric, 1997). Therefore they guide the attitudes, the opinions and the behaviours. The social representations have also a prescriptive function by defining what is licit, tolerable or inacceptable in a given context.

The social representations have also an *identity purpose*, by allowing the elaboration of one's gratifying personal and social identification, which is attuned with the systems of values and of rules socially determined (Mugny *et al.*, 1985, referred by Abric, 1997).

They also serve to *justify the practices* as being linked to the above purposes. The social representations concern mainly the relations between different groups and the representations of each group towards the other ones, justifying *a posteriori* their attitudes and behaviour (Abric, 1997).

In the field of health education, the social representations are important determinants in the sense that they influence the choices of health education and their approaches in possible confront of the scientific knowledge with the long-established personal and social practices that are determined by the social representations which can be in contrary to the scientific knowledge.

Individual and Social Competences

Improving personal and psychosocial competencies results in developing resources *"enabling people to increase control over, and to improve, their health"* (WHO, 1986: 1) and facilitates the adoption of healthy attitudes and behaviours. Broussouloux & Houzelle-Marchal, (2006) have split personal competences in two groups:

– Self-esteem, one's self-confidence, one's feeling of his/her personal efficacy, one's feeling that the others have confidence on him/herself, psychological security;
– Body regard, understanding the body sensations (pain, pleasure, etc.), understanding physical expression of feelings (anger, fear, etc.), understanding physiological needs (feeding, sleep, etc.).
– The same authors have separated the psychosocial competences in three groups:
– Towards the others, respect for the others, accepting the differences of living rules in society, etc.
– Conflict management, to privilege the dialogue in the case of disagreement, etc.
– Confidence in one's judgement, resistance to pairs' negative influence and the media.

Psychosocial competences have an important role in health promotion not only assumed in its large sense of *"physical mental and social wellbeing"* (WHO, 1986: 1) but also when health problems are associated to behaviours and when the behaviour is linked to an incapacity to answer efficiently to the stress and to important elements of the daily life. The ten psychosocial competencies can be grouped in pairs as follows:

– to be able to solve problems; to be able to make decisions;
– to have creative thinking; to have critical thinking;
– to be able to communicate efficiently; to be clever in interpersonal relationships;
– to have consciousness of oneself; to have empathy towards the others;
– To be able to manage his/her own stress; to be able to manage his/her emotions.

The concept of empowerment – which is not specific of health education – is often used in the sense of a process by which people, organizations and communities gain mastery over their affairs (Restrepo, 2000). Adjusting this concept of empowerment to children and young people, Tones & Tilford (1994) and Green *et al.* (1996) have assumed that empowerment aims at giving pupils' the tools enabling them to make their own informed choices and allowing them to practise them in order to realise their aspirations. Therefore health education is seen as an education towards autonomy and decision making in order to facilitate children and young people to become actors of their own life.

Ethics in Health Education

Working on improving personal and psycho-social competencies, on educating for decision-making, on developing personal empowerment requires the previous reflection about associated ethical issues (Tones, 1986). First of all, because health education implies the interaction with one's personal sphere (the person intimacy, his/her family) and the public one (the school, the public health). It is not to contrast a scientific truth with the family practices neither it is to interfere in the private life by reproaching any behaviour; it is rather to create favourable conditions for the emergence of attitudes leading to healthier behaviours.

It is generally accepted that families are responsible for their children and young people's health education, however in the case of deprived families it is usually assumed that school should take responsibility for these children and young people's health education (San Marco *et al.*, 2000). In other words, school health education does not replace the families' intervention, but it helps them, reassures them, guides them and complements them in their health actions (Tubiana, 2004).

The borders between informing and persuading, between convincing and constraining, are rather delicate. Educators must determine their acceptable limits for carrying out actions to convince children and young people to adopt healthier behaviours, *i.e.* they must understand what the criteria are beyond which one might declare: *"it is bad to wish the good"* (Massé, 2003: 2). This is a fundamental ethical issue which establishes the acceptable limits for the implementation of healthy practices, having in mind the tensions between promoting the superior interest of the people' health and the person's right for his/her autonomy to decide what is pertinent for him/her.

Four ethical principles, currently well accepted, have been originally expressed by Beauchamps & Childress (1995):

– Respect for autonomy, respect for the rights of people and their right to determine their own lives.
– Non-maleficence, not doing harm.
– Beneficence, doing good.
– Justice, being fair and equitable; how to respect everyone and the way the harm and good are distributed.

Often, Public Health appears like a *"new profane morality"* replacing the religion and the law of the modern world, working like a culture with a *set of rules, of values and of knowledge concerning the body management* (Fassin, 1996: 270). Health education – and more widely Health Promotion which is founded on Public Health and epidemiology – keeps trying to define the normative criteria that are associated to behavioural risk factors and unhealthy lifestyles. Persons being away from these rules get exposed to evitable risks and they are submitting themselves consciously to health risks, resulting in the so-called *"victim-blaming"* (Naidoo & Wills, 1994; Katz & Peberdy, 1998; Ewles & Simnett, 1999). Blaming people for their own ill-health is an ethical issue that educators need to face, since often people are the victims of their circumstances (Ewles & Simnett, 1999). The rules, the normative criteria, are social constructions shared within a community carrying subjacent values, often implicit ones, which one must question about in order to place them as ethical issues to be work with.

Values in Health Education

Values are a main issue in the health education global approach. There is no single agreed definition for the term *"value"* (Rennie, 2007), but in a large sense values can be expressed as *"principles taken by the society or the persons to make their choices"* (Raynal & Rieunier, 1997: 375). They are linked to beliefs and attitudes which guide person's behaviour as it has been adequately stated by Halstead (1996: 5):

> *principles, fundamental convictions, ideals, standards, or life stances which act as general guides or as points of reference in decision-making or the evaluation of beliefs or actions and which are closely connected to personal integrity and personal identity.*

Education carries inexorably the notion of values to be transmitted, often expressed in an implicit way (Reiss, 2007). When associated to health education, values have been stated as (Massé, 2003: 47):

> *the prescriptive or proscriptive beliefs helping to determine the acceptability or the desirable features of the aims and of the means of social interventions.*

There is no education without the idea of selecting some issues that are preferable to other ones, and the learning process requires the appropriate knowledge and methods to produce an effective conceptual change towards a higher level of knowledge and better skills acquisition. To educate is to guide someone to go to a better state (at least, one estimates it is a better one), to achieve better skills, to understand better, to be better. This word "better" includes the notion of values.

Values are relative, they depend on the person development, his/her socio-cultural environment and learning context. Therefore, rules and values are strongly linked, in permanent interaction and registered in a continuous process associated to education. In this context, health education carries values that often are in conformity with those conveyed by families and some social and cultural organisations.

Previous studies have identified six axes of values, characterised by several pairs of poles (Carvalho & Carvalho, 2008):

– *Social/individual:* Global–Individual; Social change–Individual change; Social pressure–Individual free option; Social responsibility–Individual responsibility; Solidarity–Non-solidarity;
– *Salutogenic/Pathogenic*: Attitude–Technicism; Citizenship–Medicalisation; Dynamics–Statics; Positive–Negative; Resource–Finality; Subjective–Objective;
– *Holistic/Reductionist*: Cyclic–Linear; Coherence–Disarticulation; Multisectorial–Unisectorial; Process–Activities; Systemic–Monocausal;
– *Equity/Inequity*: Inclusion–Exclusion; Social justice–Social injustice; Tolerance–Discrimination; Universality–Partiality;
– *Autonomy/Dependence:* Active/Passive; Self-control–Hetero-control; Self-care–Hetero-care; Empowerment–Prescription; Literacy–Inculcation; Participation–Indifference;
– *Democratic/Autocratic*: Cooperation–Agreement; Bottom-up–Top-down; Lay person–Specialist; Informed option–Paternalism; Free option–Cohersive; Sharing–Absolute power.

Often tensions arise between social values (such as solidarity, respect for others) and individual values (such as autonomy, privacy) and in most societies, the social common values transcend the individual ones on the bases of democratic values, which are liberty, equality, justice, solidarity (Larue *et al.*, 2000). Being health a matter of social and individual challenges, health education is also a process involving the education for the values.

In the view of Meirieu (1993: 146) *it is in the heart of each educational activity that values can be appraised – maybe – transmitted*. He insists in the fact that it is not a mechanic transmission; it is a continuous practice, which depends on the organisation of the learning situation and which as not the goal of imposing any values but rather giving opportunity to pupils and young people to be aware of the values involved in particular situations, by interacting with the others, and to facilitate them to adhere to more appropriate values.

Nowadays, the construction of one's personal identity cannot be done by inculcation of a set of values and knowledge, it is rather to train for the *"conflict of ideas"*, allowing children and young people to express their contradictory worries about current and personal issues (sexuality, drugs addition, risk behaviours, etc.) in order to allow everyone to define his/her values and norms of behaviour (Galichet & Manderscheid, 1996).

Having all this in mind, health education cannot be carried out without an education for debate and learning how to manage conflicts. Often the conflicts are more than just differences of opinion or interests; they may be conflicts about legitimacy and norms. This education by debate requires, first of all, that children and young people acknowledge Health as a relevant issue for their lives. Health must be viewed as a permanent life issue, presenting a variety of aspects that can be a cause of health problems, which must be prevented or solved as early as possible. Therefore, every child and young people should become aware of this and construct his/her own values and behavioural norms by interaction with the others. It is in this context that health education contributes effectively in citizenship education, by allowing everyone to respect the other's values and, in this way, to understand them better.

HEALTH EDUCATION IN SCHOOL

Models of School Health Education

School education has been viewed in a large variety of perspectives. Recently, Eymard (2004) has described three models of education that can be associated with three models of health. *Instruction* is the traditional education model, where the learner is submitted to the current social norms, and the instruction aims at transmitting current knowledge (Nourisson, 2002; Eymard, 2004). The *personal development* model of health is based upon the constructivist perspective of learning (Eymard, 2004), where the learner assumes the role of promoting his/her own development, not only by using the acquired knowledge but also by having in mind both social needs and his/her own needs (Maslow, 1989). The third model of health education, *social interactions*, refers to socio-constructivism and aims at developing the learner's awareness of his/her autonomy and his/her social competences to make informed choices (Eymard, 2004).

The association of these three models of education (instruction, personal development and social interactions) with the three models of health referred above (see item 1 of this chapter) is helpful to identify the aims (or intentions for the activities) and the activities (or mobilisation of the educational and health resources) as presented in Table 1 (Pizon, 2008).

Table 1. Relation between educational models (Instruction, personal development and socio-interactions) and health models (biomedical, global and positive, and autonomy and citizenship).

Educational models		Health models: Biomedical	Health models: Global and positive	Health models: Autonomy and citizenship
Instruction (transmission model)		Transmission of health knowledge to individuals and the group		
	Aim	To prevent disease	To promote a global health	To help organising one's life style
	Activity	To inform about diseases	To develop one's positive attitudes based on the knowledge	To allow one's decision based on the knowledge
Personal development (constructivist model)		Establish a pedagogical relationship on health with individuals and the group		
	Aim	To guide against the diseases	To guide behaviours to adjust to the social rules	To facilitate one's decision making having in mind the social environment
	Activity	To develop one's knowledge	To develop one's knowledge and society knowledge	To help one to know oneself and the world
Social interactions (socio-constructivist model)		Make the health issue a personal and collective project		
	Aim	To make people query in order to control the absence of disease and the wellbeing	To lead to conform the attitudes and behaviours with the social rules	To let one's to make individual and collective choices, having in mind an ecological approach to health problems
	Activity	To develop the individual and collective awareness of the problems of the fight against diseases	To develop the individual awareness to make one to be adapt to the environment	To develop one's autonomy to facilitate the individual and collective decision making regarding the individual and social health

*Adapted from Pizon, 2008.

In this view health education contributes to promoting the feeling of responsibility of one's own and the others' health, enabling each one to perceive critically each actual situation in order to adopt the most appropriate and efficient behaviour. In this view, health education is an education for the life of persons and communities, contributing for the learning of how to improve not only one's own physical health but also the interpersonal relationships, leading to a general improvement of the collective well-being (Laure *et al.*, 2000). Health education is addressed to the person as a whole, mobilises knowledge, beliefs, social representations, behaviours, interactions with the physical and social environment. It is not to say what one must do, but rather to inform and to create the conditions for the person to acquire the competences for making (as much as possible) free choices for what he/she estimates it is healthier for him/her as well as for the others.

Several axes have been identified for the design and implementation of a school health education project (Jourdan & Victor, 1998). On one hand, to put into practice a health education project at the school global level implies to reflect about the whole school community, staff and pupils all together, and on the other hand to design classroom pedagogic activities appropriate to each school grade. For each health education activity one should have in mind the children's and young people's conceptions and their references of social practices, since health education touches the intimacy and the relationship of the body with him/herself as well as with his/her fears, anxieties, etc. In addition to all these personal issues, there are also aspects like the culture, the religion, the socio-economic conditions that have to be taken into account. The individual conceptions and beliefs may work as obstacles to the adoption of healthy behaviours. Therefore, asking questions or organising debates may allow children and young people to confront their points of view and what sustain them, i.e. their knowledge, their beliefs and their attitudes towards health risks or health problems.

Jourdan and Victor (1998) advocate the need for an ethical reflection within the school before the implementation of any school health project. It is not to impose behaviours that seem to be healthy to the educator nor to blame unhealthy behaviours. In the school it is important to respect the differences and the families' and pupils' free choices.

School health education is developed towards a global project, taking into account the children's and young people's physical, psychological and social dimensions and having the aim of promoting the well-being which is an important underneath condition for enhancing children's and young people's learning outcomes: building specific and generic competencies in knowledge and understanding, analysing and synthesising information and in creating solutions for local and global issues (IUHPE, 2008a).

The Nature of Knowledge in Health Education

The nature of knowledge in health education is rather particular for several reasons. Firstly, health issues are usually acquired by traditional means, mainly following family practices, and empirical knowledge, having little scientific bases. Often this traditional knowledge is an epistemological obstacle (Bachelard, 1938; Astolfi *et al.,* 1997) to the acquisition of new scientific knowledge.

Secondly, the source of the scientific knowledge to be transmitted in the field of health education is the biomedical knowledge, which, traditionally, is not devoted to the education perspective. Moreover, biomedical advices are usually formulated by reference to the current health problems, which often show up to be controversial with time (Sandrin-Berthon, 1997; Ewles & Simnett, 1999).

Thirdly, scientific knowledge concerning health issues is often manipulated by commercial lobbies, mainly from the agriculture, food and pharmacological sectors, addressing health misinformation in products advertising and propaganda (Souccar & Robard, 2004).

Finally, health scientific knowledge is usually statistically validated at the population level – Epidemiology, Public Health – identifying determining factors (age, sex, lifestyle, environment) for each disease, aiming at establishing a causal link between these factors and the disease growth (Vetter & Matthews, 1999; Helman, 2000). What is true in terms of the probability of a disease growth in a population cannot be applied be for a person individually.

Health education tends to be based on a topic approach, which means to work separately on issues like eating, safety, sexuality and relationships, substance use (smoking, tobacco, other drugs) bullying, etc. This topic approach has been criticised for several reasons: it can be *problematic or ineffective as such approaches are sometimes based on assumptions relating to human behaviour, which are difficult to justify and not supported by evidence* (IUHPE, 2008b: 4); adding up the teaching sequences of such diversity of topics represents a huge amount of time, which imposes limits to the teacher's action who tend to transmit information only (Pizon, 2008). Therefore, instead of an exhaustive approach, topic by topic, a more effective approach is to develop children and young people's life skills and competencies, enabling them to consider the different health topics in the reality of social and environmental contexts of their lives (IUHPE, 2008b).

Uniting themes, such as "learning how to take care of oneself and of the others" and "Preventing health risk behaviours", can cut across topics at a theoretical and pedagogical level (Table 2).

Table 2. Educative action aiming at "Learning how to take care of oneself and of the others" and at "Preventing health risk behaviours".

An educative action that promotes pupils' abilities • to make informed and responsible free choices • to develop their autonomy in health issues	
Learning how to take care of oneself and of the others	Preventing health risk behaviours
"Take care" do not lead to a standardised lifestyle. The educative action must not be normative since the weight of the social determinants and de diversity of the human situations is great. The person must not be taken as the only responsible for his/her choices nor, in contrast, be considered as the victim of the social determinants that areabove his/her control. This idea of "take care" does not carry any moralist feature, it is rather centred on the ability of making choices and the responsibilities that are citizen's	The health risk behaviours may be defined as "the person's exposition to a non negligenciable probability of being hurt or death, of damage his/her personal future or of put in danger is/her health". They can be just isolated acts or long term installed habits. This definition has nothing to do with the legal or ilegal characteristics of the behaviours This approach to the health risk behaviours has not a normative character and does not refer to a life "with no risk". It does not carry any moralist feature, it is

competencies. Health is not the objective of living, it is a resource for everyday life. In contrast to the health risk beahviours, the concerned health themes are not necessarily linked with the acute social problems.	rather centred on the ability of making choices and the responsibilities that are citizen's competencies. The concerned health themes are usually linked with the acute social problems.
– Eating – Hygiene – Life rhythm – Sexuality – Physical activity – Safety (at home, in road, at work) – First aid – Use of the health services – …	– Use of psychoactive substances, legal or iligal (substance abuse, risk consumption) – Violence addressed against oneself or the others – Dangerous behaviour on the roads and in the sportif activities – Sex risk behaviours – …
In both cases it is not possible to refer an univoque csuality. There are always interactions between the behaviours and the persons' specificities, their life history and the environmental determinants.	
In both cases, the school action refers to the citizenship and to learn how to live together. It is inscribed in the double goal of creating conditions for pupils to learn and to develop their personal competencies.	

*Adapted from Pizon, 2008.

Prevention of Health Risks

Being the health education aim not centred on the disease neither on the risk behaviours but rather on the people's empowerment, it means that just transmitting knowledge about the different risk behaviours in the classroom is not enough. The basis to undergo a sustainable and effective prevention to health risks is mostly centred in how a person is able to keep his/her freedom towards an unhealthy product or behaviour, by developing this or that responsible attitude in relation to him/her and to the others (Pizon, 2008).

Some theories (Bantuelle & Demeulemeester, 2008) have helped to clarify about the interacting factors that may facilitate the development of risky behaviours, and three factors have been recognised (Marcelli & Braconnier 2000):

i) *Associated to the person*, it refers to a historic moment of the person with week self-esteem, self-depreciation, timidity, excessive emotionality, difficulties to face daily events, difficulties to establish stable and satisfying relationships, difficulties to solve interpersonal problems.

ii) *Associated to the type of risk behaviour*, it refers to the three types of substance consumption: *occasional* or *festive*, for new sensations and getting the feeling of group belonging; *self-therapeutic*, usually consumed in privacy, to reduce anxiety or sleeping trouble; drug-addiction, looking for an anaesthetic effect, either in privacy or in group, often leading to the marginalisation or exclusion from the social system.

iii) Associated to the environment, it refers to the family and pairs close influence as well as the wider socio-cultural and media influences.

For the prevention of risk behaviours the above factors must be considered. Educators must have in mind all the above factors when implementing pedagogic activities on the prevention of risk behaviours in the classroom, which are associated to knowledge, attitudes and awareness. These three approaches are shown in Figure 2 and can be described as follows:

i) To approach the problems caused by substance misuse – scientific knowledge: implement pedagogical approaches on physical, psychological and social dimensions of the risk behaviours effects, based in scientific knowledge. Attention must be paid to ethical issues concerning potential effects of the approach regarding the stigmatisation of the smoker, the drunken or the drug-abuser.

ii) *To develop personal and social competencies – Attitudes*: developing self-esteem, stress management, risk management, conflict management. These competencies empower children and young people to make informed decisions, to make choices, to take actions and to develop positive attitudes facing health risks.

iii) To approach the environmental context – awareness: making children and young people aware of their specific familiar and close social environment to identify critical situations facilitating the risky behaviour. It implies developing critical thinking.

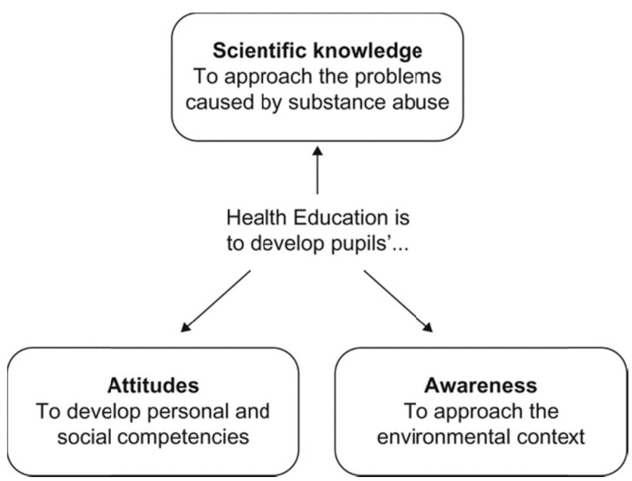

Figure 2. Dimensions to have into account in school activities for the prevention of health risk behaviours.

Effectiveness of Health Education Practices

Assessment of the effectiveness of health education practices has been a matter of some evolution. In the decade of the 80s it was strongly connected to *evidence-based practices*, which is based on the experimental methodology currently used in epidemiology and uses prominently quantitative methods such as randomized clinical trials (RCT) (Vetter & Matthews, 1999; Helman, 2000; McQueen, 2007). It assumes, for example, that effective programmes in a given classroom situation can be directly transferable to another one.

More recently, *good practices* is a matter of great attention, being mainly a qualitative approach in study cases (Barnekow et al., 2006), assuming that health education (as well as prevention of risk behaviours) is determined by the socio-cultural context, considering that it is not correct to generalise data emerged from a given situation.

Between these two poles there are several evaluation methodologies that have been implemented attempting to get relevant information concerning the efficacy of health education programmes. In the past decades there has been a tendency to apply multiple approaches to assess effectiveness of health education/health promotion initiatives, so that in addition to RCT, other methodological approaches have been put into practice such as quasi-experimental designs, observational studies and story-telling (Naidoo & Wills, 1994; Katz & Peberdy, 1998; Ewles & Simnett, 1999; Barnekow *et al.*, 2006; Campostrini, 2007; Dooris *et al.*, 2007; Leger *et al.*, 2007; McQueen, 2007; Mittelmark, *et al.*, 2007; Potvin *et al.*, 2007; Ridde *et al.*, 2007; Rootman, 2007; Salazar *et al.*, 2007).

Behavioural change evaluation has been a common way to establish the relevance of health education programmes. However, this is a rather reductionist approach and other elements of evaluation must be added (INSERM, 2001):

- Knowledge acquisition;
- Attitude changes - with a gradation of responses;
- An assumed/expressed behaviour change;
- The acquisition of competencies to react towards challenging situations;
- Change of several personal features – such as the intention to acquire a given behaviour, the feeling of efficiency to react face a challenging situation, the self-esteem – which can be quantified by using validated psychometric scales.

A vast amount of efforts has been employed intending to classify the types of interventions or programmes in the prevention of health risks (reviewed by Pizon, 2008). Battjes (1985) has proposed four approaches: rational approach, developing approach, social rules approach, and the social reinforcement approach. Hansen (1992) has enumerated a list of 12 items concerning information, decision, engagement, values clarification, definition of objectives, stress management, self-esteem, resilience, general competencies, rules awareness, coaching and alternative activities. Tolber (1997) has distinguished interactive programmes from non-interactive ones.

In general, studies on the effectiveness of the prevention of health risk behaviours have shown contrasting results (St Léger, 1998; Lister-Sharp *et al.* 1999; INSERM, 2001; WHO 2006): certain pedagogical activities have some positive effect, others have no effect at all and yet other ones have a negative effect. Therefore the great challenge is to identify better not only the nature of the teaching practices impact but also the school social context, especially health promotion, which represents an important scientific issue.

Paradigms Underlying Teachers' Health Education Practices

Several works (Joudan & Vitor, 1998; Mérini et al., 2000; Berger & Jourdan, 2008) have shown that in teachers' view, to work in health education is a question of state of spirit, which is reflected in the school practices by endorsing the dialogue, the positive attitudes, the respect for the rules of living together, the increase of pupils' learning and development, all this in a friendly atmosphere within a framework of health promotion.

Recent research has identified four paradigms underlying the teachers' interventions in health education (Fortin, 2004): the rational, the humanist, the social-dialectic and the ecological paradigms.

The *rational paradigm* is based on the transmission of information from the teacher to the pupils, in a vertical perspective. It is an approach of health education where it is assumed that the acquisition of knowledge is the important issue to develop appropriate attitudes and behaviours towards health risks. This paradigm is inspired on the biomedical model of health, using the discourse of advising about diseases and prevention of diseases. It comes from a scientific model of thinking which postulates the rationalisation of the attitudes as being taken outside the context and the affective dimensions. Being within the biomedical model (see item 1.2 of this chapter), where the power is given to the professionals, there is no space for people to decide for themselves. People are supposed to submit to the norms and the victims of disease are often blamed for having not complied with the norms, the well-known expression: "victim-blaming" (see also item 3.3 of this chapter). This paradigm has inspirited health education interventions envisaging the information concerning the health risks and the adoption of appropriate behaviours to prevent them. This is a linear view of cause – effect (Fortin, 2004).

In contrast, in the *humanist paradigm*, in which persons participate in their knowledge construction to which they add their life experience. A person's wishes, emotions and perceptions are taken into account. This paradigm envisages the development of one's personal and social competences, having in mind one's values. Thus the goal is the development of a person's self-esteem and social skills. The aim is one's autonomy, associated to a freedom for self development. In this model, persons are responsible for their health and they assume their conduct and behaviour, even those at risk. It is intended to develop motivating and deciding factors so that persons are able to adopt recommended healthy lifestyles. A health risk challenge is assumed as a motivational factor by increasing fear to the unhealthy situation. In extreme situations this model may rise freedom issues since some persons' responses may go up to "refusing the treatment, refusing to live" (Fortin, 2004: 60).

The *social-dialectic paradigm* concerns the person's relationship with his/her social environment regarding the degree of freedom within a social group. This model is interested in the person's ability to manage his/her life and to change or cope with the environment. The weight of the socio-cultural context is taken as an important factor in the learning process, leading to a contextualization of the educative practices which are imbedded in the individual and collective living experience. This paradigm, inspired in the socio-cognitive models, gives priority to the person's affective dimension and its role in interpersonal relationships. The teacher has a central role in facilitating pupils' cognitive, emotional and social development (Favre, 2007; Lenoir & Vanhulle, 2008). The concept of empowerment (Naidoo & Wills, 1994; Tones & Tilford, 1994; Katz & Peberdy, 1998; Ewles & Simnett, 1999; see item 1.4 of this chapter) is included in this paradigm of health education and health promotion, which is based on the:

> *process of enabling people to increase control over, and to improve, their health. To reach a state of complete physical, mental and social well-being, an individual or group must be able to identify and to realize aspirations, to satisfy needs, and to change or cope with the environment (WHO, 1986: 1).*

Finally, the *ecological paradigm* is interested in the person, seen as a whole, and in the person's relation with the overall environment (ecosystem). This paradigm is based in the Edgar Morin (1994)'s reflections about the systemic process and its complexity. It retakes the previous paradigms features but it adds up a dynamic and contextual dimension, as earlier described for the health promoting schools (see item 2.1 of this chapter). This holistic model of health education underlines the difficulties and limits of the rationalisation for the human behaviours. It emphasises emotions and desire, which are usually ignored by health education teachers, due to their difficulties in managing these issues. This model gives particular attention to the persons' attitudes in relation to the health issues. Teachers are not centred in the pupils' changes to healthier behaviours; they are rather working with the pupils towards their awareness of the health issues (including health risks) and help them to develop conscious healthy attitudes and to become empowered for making informed decisions for adopting or not healthy behaviours, having in mind the whole pupils' life context, either individually or in group (ecosystem).

Each one of these health education paradigms implies a set of pedagogical practices tightly linked to the conception of health, of health education and of the school role in health education. As schools are not primarily concerned with the improvement of children's health, health education is rather dependent of the way teachers perceive their mission, as well as the whole school setting.

Teachers' Role and Teachers' Training in Health Education

Several factors influence the way in which health education and health promotion programmes are developed and implemented in school, being the teachers' beliefs and their motivation for health education a decisive factor for effective implementation of such health education programmes. Therefore technical support (training and assistance) given to teachers is critical for a sustainable school health education. This is why teachers' training is often considered to be a central factor linked to the quality of health projects implementation. Several studies have shown that teachers who have received health promotion training tend to be involved more frequently in health promotion projects and have a more comprehensive approach to health education (Anastácio et al., 2005; 2008; Jourdan et al., 2008).

For a teacher, who has many priorities in school affairs, including building literacy and numeracy skills; scientific and artistic competencies; societal, historical and cultural dimensions, and who have in fact to provide the means for all to succeed, it is not easy to have a clear view of his/her own contribution to health promotion (Jourdan et al., 2008). School systems are essentially based in subject matters (or disciplinary approaches) in contrast to the holistic feature of health education which requires an interdisciplinary approach, putting together the knowledge from different disciplines and the development of personal and social competencies. The hard issue for the teachers is not so much to teach the knowledge but to develop pupils' attitudes, to discuss values and choices in order to promote healthy habits. It is to put into place pedagogical situations where pupils can elaborate *"rational opinions"* based in scientific knowledge and to allow pupils to become aware of this or that burning health issue and to promote appropriate conditions for pupils to develop skills to face these health issues. In this process of health education, each pupil mobilises, for each health issue, his/her acquired knowledge, system of values and representations. Therefore this pedagogical approach represents a rupture with the traditional subject matter teaching and learning process.

In this perspective of health education, defining the teacher's role is rather delicate for several reasons. Firstly, health and health education lies at the intersection between the private (pupils' family) and public domains (public health policies), related to behavioural issues which are determined culturally and to the most intimate of personal decisions. Furthermore, in health domains, recommendations change over the years given the extraordinary progress in knowledge and the construction of new scientific models as well as fashions governing what is considered to be moral and what is considered to be immoral. In addition, in the contemporary world, where the importance of appearance is becoming more pronounced, where many consider a perfect body and perfect health to be the ultimate aim, can it be hoped that schools will contribute to the promotion of a single healthy mode of living or a body cult?

In the field it is not easy to identify the school's mission in an environment marked by the power of the models transmitted by Medias. The position of teaching staff is, therefore, difficult to maintain. The first aim of teacher training in health promotion is then to help them to have a clear view of their mission and its ethical limits. Before giving them methodological tools, teacher training aims at helping them build their professional identity (Jourdan et al., 2008).

The way in which health promotion is organised and implemented in each country differs depending on the history, objectives and structures of that country's school system (Pommier & Jourdan, 2007). Developing research, affirming and reinforcing the work done in teachers' training in health education are major issues to promote teachers' competencies for providing opportunities to children and young people to be more empowered about health and health risks as they grow up.

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14. SCIENCE EDUCATION RESEARCH IN TURKEY: A CONTENT ANALYSIS OF SELECTED FEATURES OF PUBLISHED PAPERS

INTRODUCTION

Science is taught as a core subject through schools around the world. While the content and subject sequences are more or less similar, every country has developed along different paths as a result of unique cultural and political influences. It is important to study not only the present international science education content and pedagogy curriculum, but to understand the developmental path that has led each country to this point. Like many countries, Turkey has given special attention and importance to the teaching of science (Turkmen & Bonnstetter, 2007). In this sense, this chapter focuses on the development of science education research in Turkey. The chapter starts with a brief introduction to the Turkish educational system and attention then moves to the place of science in reforms that have taken place in the educational system in Turkish history and the development of science education research in Turkey. In the latter part, a content analysis of science education research papers published at national and international level by Turkish science educators is provided and the results are discussed.

Turkey, with a population of over 70 million, is a bridge between Europe and Asia. The Republic of Turkey was established in 1923, after the Ottoman Empire collapsed at the end of the First World War. Since the foundation of the new state in 1923, educational development has been regarded as the most important factor in reaching the level of the civilized countries (Grossman, Onkol, & Sands, 2007). The Turkish Educational System was centralized by the act of 'Law of Unification of Instruction' in 1924. The *madrasas* (formal education schools) were abolished and all schools, except military schools, were taken over by the Ministry of National Education (MONE), while military schools were taken over by the Ministry of Defence. The Turkish Education System was built in accordance with the Ataturk Reforms after the Turkish War of Independence. Ataturk was the founder of the Republic of Turkey. Turkey has a state supervised system designed to produce a skilful professional class for the social and economic welfare of the nation (Özelli, 1974). Since 1924, there have been several reforms in the education system including the acceptance of Latin characters as the official script in 1928 instead of Arabic characters, expansion of secularism in the social, educational,

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and legal areas (Turkmen & Bonnstetter, 2007), implementation of new curriculums (Ayas, Çepni, & Akdeniz, 1993; Turkmen & Bonnstetter, 2007) and reforms in teacher training (Turkmen, 2007). The results of these reforms have been impressive (Grossman et al., 2007). Schooling consists of four main components: elementary education (age 6–9), middle (age 10-13), secondary education (lycees or senior high schools including vocational and technical schools, age 14–18, 4 years); and higher education (universities). The first 12 years are compulsory from 2012.

SCIENCE AND SCIENCE EDUCATION IN TURKISH HISTORY

Events during two thousand years of Turkish history have influenced education, such as; the dispersion of Turks from Central Asia to the Indian peninsula, around the Caspian Sea, and the west, and converting to the Islamic religion in the 9th century (Turkmen, 2007). It is known that the first Turkish alphabet was created and used in the Turkish state of Gokturks. The Gokturks left written texts on tombstones located in the Orhon River region (presently northern Mongolia), dating to around 700 AC. This finding marks the beginning of formal education for Turks (Akyüz, 1993). There is very little information about the place of science in Turkish education history until Turks convert to Islam. When Turks converted to Islam, this new religion impacted every aspect of life including education (Lewis, 1961; cited in Turkmen & Bonnstetter, 2007). An extended account of the history of Turkish education and science education during the power of Great Seljuk Empire, Anatolian Seljuk State, Ottoman Empire can be found elsewhere (e.g. Akyüz, 1993; Binbaşıoğlu, 2005; Çaksu, 2001; Ergin, 1977; Nuhoğlu, 2001) and Turkmen and Bonnstetter (2007) provides a summary.

Although there were various educational institutions in the Ottoman Empire, formal education was commonly given in two types of schools. Primary education in the classical Ottoman educational system was predominantly religious, provided by Sıbyan Mekteps (primary schools) which were either in or near mosques. Sıbyan Mekteps, also called local or district schools, accepted boys and girls at the ages of 5–6 and taught them for 3–4 years (Demirel, 2009). Secondary and higher education at university level was given in madrasas. Although the madrasas provided mainly religious education, there were also courses such as science, mathematics, medical sciences and astronomy especially during 15th and 16th centuries (Bahadır, 1996). On the other hand, *mosques* and *tekkes* were among the important informal education institutions in the Ottoman Empire (Kazıcı, 2004).

From the 17th century, the quality of education provided by the madrasas began to degenerate as they neglected scientific developments around the world and dropped science and mathematics courses. Therefore, the madrasas started to fail the needs of society, causing a decline in the Ottoman Empire (Demirel, 2009). When the Empire began to see its decline compared to Europe, the search began to find the reasons. It was determined that one of the major factors was the military superiority of Western Europe. In order to meet the Ottoman Empire's military needs the first modern military schools providing education at a higher, university, level, *Mühendishane-i Bahr-i Hümayün* (Imperial Naval Engineering School) (1775) (Ihsanoglu, 2004) and *Mühendishane-i Berr-i Hümayün* (Imperial Engineering School of Land Forces) (1793), were founded in the eighteenth century (Demirel, 2009) which marked the first time that education was not directly affiliated with religion and the beginning of a new phase of schooling in the Ottoman Empire (Lewis, 1961; cited in Turkmen & Bonnstetter, 2007). The decree in 1839 is a turning point in Turkish history and it heralded increasing Westernization (the Noble Rescript, *tanzimat fermani* in Turkish), marked the beginning of Rushdiyahs (middle schools) which accepted students aged 10 to 18. Although the focus was on religious education, the curriculum went beyond religion to include subjects such as mathematics, geometry and geography (Demirel, 2002). It was also recommended that French should be taught as mathematics, geometry and geography books were only available in French. Rushdiyahs were followed by the opening of Îdâdis, an upper level middle school or high school, in 1874 (Demirel, 2010, p. 15; Yücel, 1994). Natural sciences were taught as a separate subject in these schools. The Îdâdi's curriculum in 1892 shows that the total percentage of science courses such as basic science, physics and chemistry was 5 percent in the whole curricula (Demirel, 2010, p. 109).

The first teacher training school (Dârülmuallimîn-i Rüşdî) in the history of Turkish education was founded in 1848 (Öztürk, 1998). The school curriculum did not include science courses initially, however it was revised in the following years to provide middle and elementary school teacher training and science courses were included in the curriculum (Öztürk, 1996). On the other hand, as reported by Akyüz (1993) and Ergun (1996; cited in Turkmen & Bonnstetter, 2007), a modern style higher education institution was established with branches that included the natural sciences in 1863 although it was burned down by religious activists and had to be re-opened in 1869. These times also saw the founding of the Association of Ottoman Science which published the first scientific journal called the *Journal of Science*. Foreign instructors and specialists, especially from France, were employed in this new institution. The establishment of this new institution and the 1839 decree led to the establishment of closer relationships with several western countries, in particular France and Great Britain. These relationships included sending students to those countries to study and also the translation of many foreign books into Turkish; in particular medicine, and the sciences, found their way into the classrooms. For example, Hoca Ishak Efendi, as an instructor in the school of mathematics, translated four volumes covering the European knowledge of mathematical and physical sciences (Lewis, 1961 cited in Turkmen & Bonnstetter, 2007).

The collapse of the Ottoman Empire and the emergence of the Republic of Turkey in 1923 led to society-wide reforms, especially in education. One of the important aims of the young Turkish republic was to disseminate basic education to all citizens since the majority of people living in rural areas were still illiterate. Therefore, it was decided that elementary education should be provided nationwide, including more science and health education. On the other hand, the new republic was inviting foreign experts to Turkey, such as John Dewey in 1924, to get their advice to overcome education problems. In Dewey's report, it was mentioned that in rural areas it was necessary to open another type of village teacher school to meet the needs of local people (Türkmen, 2007). This recommendation led to the establishment of village teacher training schools in 1927. These schools aimed to train teachers to educate villagers and their curricula included more agricultural courses than science courses. John Dewey's visit to Turkey in the 1930's created another science education curricular shift as elements of experimentalism and pragmatism were added to the Turkish science curriculum. The next major science education development occurred after the Second World War, when Turkey became a full member of NATO and expanded its connections with western countries, especially the USA. This influence helped to create what was called the modern science curriculum. During the 1960's, many countries followed the lead of the USA, Australia and the UK in adopting big-budget, discipline-knowledge based curriculum movement such as Chemical Education Material Study (CHEM Study), Physical Sciences Study Committee (PSSC), Biological Sciences Curriculum Study (BSCS), Chemical Bond Approach (CBA) (all in the US), Nuffield Science (UK), and the Australian Science Education Project (ASEP). Turkey was among those countries that translated some US curricula into Turkish, but this curriculum implementation was not successful throughout the country (Ayas et al., 1993). In fact, MONE and the Turkish Scientific and Technological Research Council (TUBITAK) made a great effort to adapt the new science curricula, such as opening a science lab classroom in every secondary school (Türkmen, 1997). A discussion about the reasons why this curriculum implementation was unsuccessful can be found in Ayas et al. (1993) and Türkmen (1997) and the history of Turkish teacher training at the late republican era are summarized in a the Higher Education Council (HEC) report written by Kavak, Aydın and Akbaba-Altun (2007).

Although numerous improvements were made during the Republican Era and applied with a great deal of excitement, unfortunately, science education problems were not completely solved (Özden, 2007). The most recent major effort to improve the educational system was made through a multi-phased comprehensive reform of the sector introduced during the 1990s. The National Education Development Project (NEDP) was developed as another step toward improving the quality of teacher education in Turkey. It was implemented under the loan agreement concluded between the Turkish Government and the World Bank. The NEDP was funded by the World Bank and administered by HEC (Grossman et al., 2007; Güven, 2007; Kavak et al., 2007; Tercanlioglu, 2004). The objective was to contribute to the improvement of pre-service teacher education. The focus of the project was curriculum development and materials production, the development of student-teacher experience in schools, the establishment of a system of faculty-school partnerships, and the development of a set of standards in teacher education. It also assisted with the provision of long-term and short-term fellowships and in upgrading the facilities of all schools of teacher education. The development of this project in Turkey has built on considerable change and development in teacher education in recent years. As a result of NEDP, schools of teacher education (the name of courses and academic structures of teacher training colleges) and curricula (the content of courses) were set up across the nation in 1998 (Türkmen, 2007). In 2003–2004, four years after the end of the project and the restructuring, a major study of their effects was conducted (Grossman et al., 2007). This study suggested that the "participation [which] occurred in the project implementation was insufficient by itself to offset concerns about the top-down nature of the reform effort in the teacher education community. Nonetheless, participation had a positive effect on a person's view of reform, reducing the power-coercive aspect especially with regard to the specific reform in question" (p. 149). Some restructuring has been carried out in the programs following the 2006 review.

The second most important part of this new educational reform initiative is the gradual implementation of a new primary curriculum starting in 2004 (MONE, 2004) and a secondary curriculum starting in 2008 (MONE, 2007). The reforms were fully in operation by 2011. The new primary and secondary curricula were based on the philosophy of constructivism and student-centred active learning.

Reconstitutions of teaching curricula have been made in the education system several times since the foundation of the Turkish Republic. After the foundation of the Republic in 1923, basic reconstitution of the primary school curriculum were carried out in 1924, 1926, 1936, 1948, 1962 and 1968. However, none of them lived up to the expectancy of society for various reasons (see Ayas et al., 1993). On the other hand, the five years of compulsory primary education were increased to eight years in 1997 as part of this new educational reform movement. Later, in 2005, secondary education was also extended from three to four years. More recently, compulsary education has been lengthened to 12 years starting from 2012–2013. There is, no comprehensive evaluation of the long-term effects of the new curriculum implementation. However there are some studies about teachers' views of the new curriculum reform movement which suggest that, although the new curriculums are more student-centred and aimed to help to improve scientific literacy, there are problems that there is no synchronization between the new curriculum and the centralised exam system used in the country. While new curricula are encouraging student-centred active learning approaches, the centralised exam systems enforce memorisation. In addition, teachers felt less prepared for the new curricula which suggest an inadequacy in the in-service training (İzci, Özden, & Tekin, 2008).

DEVELOPMENT OF SCIENCE EDUCATION RESEARCH IN TURKEY

Science education has little history (Keeves, 1998) compared to the history of science, which, as a human endeavour and enterprise to explain the physical universe, could be traced back to the beginning of human kind. However, research in science education is a relatively new enterprise. While some studies were undertaken during the beginning of the twentieth century, they commonly failed to acknowledge the universality of science education. As Jenkins (2001) argues, there are many examples of research undertaken in the first half of the twentieth century that can be categorized as science education, but much of it has been the work of individuals or quasi-governmental committees. The development of research in science education is strongly affected by curriculum developments. Therefore, research studies carried out during the 1960s were often linked to curriculum development work which sought to explore the advantages of a new curriculum, or parts thereof, over an existing or previous one (Kempa, 1991). Many other studies were focused on difficulties in teaching new curriculum issues and the use of new teaching strategies. However, in the 1980s reform, new perspectives on teaching and learning caused a shift in the interest of many researchers towards studies of students' alternative conceptions and ways of reasoning (De Jong, 2007). The science education literature has been dominated by research findings concerned with children's understanding and learning of scientific phenomena in the last couple of decades (Jenkins, 2001). In line with this interest, more and more studies focused on students' learning process in terms of conceptual change. There was also a growth in studies of the social and cultural dimensions of knowledge acquirement, for instance, by investigating the discourses between teachers and students in the classroom. Other trends were the growth in interest in studies of laboratory work, especially (open) inquiry, the implementation and use of problem solving strategies, and the use of the internet, computer software, and interactive multimedia (De Jong, 2007).

Contrary to the international developments mentioned above, research in science education was lacking before 1990 in Turkey. The bibliography compiled by Bağ, Kara and Uşak (2002) and the review carried out by Sozbilir and Canpolat (2006) suggest that there were few publications in the form of books focused on teaching science or papers focused on science education research. The recent educational reform movement started in 1990's, reported above, increased interest in science education research in Turkey. At the same time, the first research papers focusing on science education started to appear in national journals and then increased dramatically on the national (see i.e. Sozbilir & Canpolat, 2006; Sozbilir & Kutu, 2008) and international stages (see i.e. Chang, Chang, & Tseng, 2010; Lee, Wu, & Tsai, 2009). The first and second National Symposium on Science Education [UFBES] had been organized in 1994 and 1995 respectively in Turkey (UFBES, 1994; 1995). These symposia received little attention. There were only 64 presentations in the first UFBES and 69 presentations in the second UFBES compared with the 2012 (the tenth) National Science and Mathematics Education Conference (UFBMEK) (UFBMEK, 2012) at which over 700 presentations, posters, discussions and workshops were selected from over 1000 submitted abstracts. In addition, Turkey hosted several international conferences, such as the 18th ICCE (International Conference on Chemical Education) in 2004, the 9th ECRICE (European Conference on Research in Chemical Education) and the 13th IOSTE (International Organization for Science and Technology Education) in 2008 and the ESERA (European Science Education Research Association) Conference in 2009. All these conferences involved significant input from the Turkish science education research community together with foreign researchers indicating the establishment of research in science education as a discipline. Several journals (mainly education faculties' journals) publish science education research papers at national level (see Sozbilir & Kutu, 2008) together with some international online journals such as the *Journal of Turkish Science Education* (TUSED), the *Eurasian Journal of Educational Research* (EJER), the *Eurasia Journal of Mathematics, Science & Technology Education* (EURASIA) and the *International Journal of Environmental & Science Education* (IJESE). Although science education is quite a new research area, it is difficult not to be impressed by the wide range of topics that Turkish researchers have chosen to investigate in the last decade and the number of publication starting to appear.

As the volume of published educational research increases, so the number of reviews increases in order to help researchers following the developments in different fields of educational research. Content analyses were carried out in terms of the subject matters studied, the research methods employed, and the data analyses processes commonly used (e.g., Elmore & Woehlke, 1988, 1998; Hsu, 2005; Keselman et al., 1998). Identification of data-analytic practices may provide researchers with a basis for recommending improvements in research and also a guide for the types of inferential procedures that should be taught in methodological courses so that students have adequate skills to interpret the published literature of a discipline and carry out their own projects (Keselman et al., 1998).

Some research reviews (e.g., Chang et al., 2010; Eybe & Schmidt, 2001; Lee et al., 2009; Rennie, 1998; Tsai & Wen, 2005; White, 1997) which systematically examine the research papers published in science education internationally have appeared in recent years. Perhaps the first content analysis of journal articles was conducted to examine changes and trends in science education by White (1997). He used science education research articles in the Education Resources Information Center (ERIC) database and the journal *Research in Science Education* (RISE) from 1965 to 1995 as sources of data. The investigation of research style trends was across three decennial reference points of 1975, 1985, and 1995. White's analysis concluded that science education research has shifted from laboratory-style experiments to observation and description of classroom practice while interviewing as a research tool has become common. Rennie (1998) surveyed research articles in five English-language science education journals the *Journal of Research in Science Teaching* (JRST), the *International Journal of Science Education* (IJSE), *Research in Science Education*, *Research in Science and Technological Education* (RSTE), and *Science Education* (SE) published in 1996 to illustrate the quality of quantitative research articles. Rennie discussed problems associated with the use of statistically significant testing and made several recommendations such as how to improve the research quality of related papers, including the use of correct terminology, the provision of sufficient information about the data to enable replications to be made, and the reporting and interpretation of effect magnitudes.

Eybe and Schmidt (2001) examined research papers in chemistry education specifically, based upon the quality criteria of publication from academic journals, reports, and documents. Eighty-one chemical education studies from 1991 to 1997 published in IJSE and JRST were selected. The review was performed in terms of six quality categories and corresponding criteria: theory relatedness, quality of the research question, methods, presentation and interpretation of results, implications for practice, and competence in chemistry. These reports have given specific guidance for science education researchers on how to conduct research and to publish quality articles.

Tsai and Wen (2005) conducted a content analysis in terms of the authors' nationality, research types and topics of total of 802 articles published by IJSE, SE, and JRST from 1998 to 2002. Given that the majority of the articles are published by the authors from the English-speaking countries, there were a significant number of papers published by authors from non-English speaking countries indicating that science education research may have progressively become an important field recognized by the international academic community. The findings of the content analyses also showed that most of the published articles were categorized as empirical studies, while position, theoretical and review papers were rarely presented. The authors argued that although students' conceptions and conceptual change were the most frequently investigated topic in these five years, a declining trend was observed when analysed by year. Moreover, in 1998–2002, the research topics related to student learning contexts, and social, cultural and gender issues also received relatively more attention among science educators.

In a follow-up study, a total of 869 papers published in the three journals (IJSE, SE and JRST) from 2003 to 2007 were analysed by Lee et al. (2009). The results were compared with those of Tsai and Wen (2005). The results showed that authors from other than English-speaking countries (i.e. the USA, the UK, Australia and Canada) published an increasing number of papers. Although science educators displayed more interest in studies involving context of student learning, the trend is shifting from students' ideas and conceptual change to student learning contexts. The follow-up study also included the information that studies focused on argumentation had gained quite high citations during 1998–2002 and 2003–2007 periods. This study also revealed an important aspect in terms of development of science education in non-English speaking countries. The total contribution of the four major English speaking countries were 71.7% during 1998–2002 period (Tsai & Wen, 2005) which decreased to 62.5% in the following five year period (Lee et al., 2009).

Most recently Chang et al. (2010) conducted a more comprehensive study into trends in science education research through published articles in four main journals (IJSE, JRST, RISE and SE) from 1990 to 2007 using automatic content analysis. This study used multi-stage clustering techniques to investigate the topics, the development trends, and the authorship of journal publications that constructed a science education research field. The results of this study are in good agreement with Lee et al.'s study that conceptual change is still among the widely studied topics although it started to decline in the 2000's. On the other hand, the nature of science, socio-scientific issues and professional development are among those topics that show an increase in researcher interest.

Lee et al. (2009) and Chang et al. (2010) indicated an important improvement in terms of the development of science education research in Turkey. The figures show that Turkey is among the top ten countries in terms of the science education research papers published in IJSE, JRST, RISE and SE. This finding marks an important improvement in science education research in Turkey. This result is also supported by the finding that Turkish academics' performance in the international league has been increasing over the last decade (Glänzel, 2008; Gokceoglu, Okay, & Sezer, 2008; Karasözen, Bayram, & Zan, 2009) although this sharp increase in international publications by Turkish researchers was not accompanied by increasing impact as measured by citation frequency (Gokceoğlu et al., 2008).

Regarding the development of science education research in Turkey, there are two reviews carried out by Sozbilir and Canpolat (2006), and Sozbilir and Kutu (2008). Sozbilir and Canpolat (2006) summarized the developments in science education research in the world after the Second World War and the paradigmatic changes in educational research methods, and emphasized their effects on science teaching. They also performed a content analysis on the limited number of science education research studies published in Turkey and compared it with the international science education research compiled by Duit (2006). The study showed that the history of science education research in Turkey does not really start until the beginning of the1990s. However, the number of research papers shows a sharp increase following the 1997 re-structuring of the teacher training system. The authors also argued that the Turkish science education community is facing challenging issues such as methodological deficiencies and the tendency to follow world trends rather than develop independent lines of research.

In a subsequent study, Sozbilir and Kutu (2008) attempted to determine the status and the trends of subject matter investigated, research methods/design and data analysis procedures used in science education research papers published in Turkey. For this purpose, a content analysis of 413 papers covering science education from 28 different journals publishing educational research in Turkey, was carried out. The results of this content analysis indicated that, although science education research is a new research enterprise for Turkey, starting in 1990s, it received great attention from educational researchers. Although there are great similarities with the international trends, there are differences in terms of the frequently studied subjects and research methods. Studying the identification of misconceptions is declining while teaching studies are increasing. On the other hand, quantitative research methods still dominate Turkish science education research while qualitative and mixed method research is increasing in attention worldwide. The major deficiency of this study was that it covered papers in journals published only in Turkey and contributions of Turkish educators to the international journals were excluded. This omission perhaps misleads the correct identification of the trends in science education research in Turkey. Therefore, a more comprehensive content analysis of publications may be helpful in revealing the contributions of Turkish educators to science education at national and international levels and identifying the trends of science education research in Turkey.

In addition to the two studies mentioned above, a recent content analysis study investigated environmental education research in Turkey conducted in Grades K-8 and published during the period 1997–2007 (Erdogan, Marcinkowski, & Ok, 2009). A total of 53 papers were subjected to content analysis in terms of features of the research method, the socio-demographic characteristics of the subjects and components of environmental literacy. The results showed that mostly quantitative surveys were employed and greater attention was paid to the age, grade level, gender and residence of participating students. Regarding the analysis, attention was focused on knowledge of ecology and natural history, and knowledge of environmental problems and issues with less attention paid to components of affect, and very little attention was paid to socio-political-economic knowledge, cognitive skills and environmentally responsible behaviour.

It is important not only to conduct relevant science education research to help science teachers improve their classroom practice and play better roles in enhancing scientific literacy, but also to understand what has been studied in the past in order to know what could be explored further in the future (Chang et al., 2010). Osborne (2007) suggested that researchers might conduct more syntheses to better understand what happened in the past to guide future research. It is recognized that systematic reviews of qualitative research, secondary analyses, and metasyntheses are useful for increasing interest among policy makers and others in deciding critical issues, policy coverage, and intervention effectiveness in science education (Rossman & Yore, 2009). This study is intended to illuminate what science education research has been done in Turkey so far and compare the result with international trends and help Turkish science educators, policy makers and others to set sustainable policies in science education.

PURPOSE AND RESEARCH QUESTIONS

The above reviews indicate a need for an extended and in-depth study to cover science education research carried out by Turkish scientists to understand the content covered, emerging trends, and the methods employed in science education. Such a content analysis could help develop an understanding of the nature and status of science education research in Turkey, and also provide opportunities to compare results with international trends to identify to what extent their research products are in line with international researchers or to meet the country's needs and set sustainable policies. Therefore, this study is aimed at determining the status of science education research and the content covered, trends in subject matters investigated, research methods/design and data analyses procedures used in science education research papers published by Turkish science educators at national and international level. Specifically, this study was designed to address the following research questions:

- What subject matters in science education research are frequently investigated by Turkish science educators?
- What research methods/designs in science education research are frequently used by Turkish science educators?

– What data collection tools in science education research are frequently used by Turkish science educators?
– What samples and sample sizes in science education research are frequently used by Turkish science educators?
– What data analyses methods in science education research are frequently used by Turkish science educators?

The results of this study should be of concern not just to journal editors publishing science education research in Turkey and practitioners of educational research, but also to the instructors of research methodology and policy-makers. In particular, new researchers, who are both consumers of research publications and/or the potential conductors of quality research, may benefit in selecting the subject matter to study and also designing their research methods and data analyses procedures.

METHOD

This is a content analysis study. Content analysis is commonly used in qualitative studies and described by Bauer (2003) as follows:

> While most classical content analyses culminate in numerical descriptions of some features of the text corpus, considerably thought is given to the 'kinds', 'qualities' and 'distinctions' in the text before any quantification takes place. In this way, content analysis bridges statistical formalism and the qualitative analysis of the materials. In the quantity/quality divide in social research, content analysis is a hybrid technique that can mediate in this unproductive dispute over virtues and methods (p. 132).

Content analysis is used to develop objective inferences about a subject of interest in any type of communication (Kondracki, Wellman, Fada, & Amundson, 2002). In this study, content analysis is meant to be a process for systematically analysing papers. Science education papers published by Turkish science educators were subjected to a content analysis in terms of the main discipline to which papers belonged, the frequently-studied subjects, research methods/designs employed and data analysis procedures applied.

DATA SOURCE

Data for the present study were obtained from 1249 papers focussing on various areas of science education published by Turkish science educators in 67 different journals (30 national and 37 international). A list of the journals and the number of papers selected from each journal are given in Appendix 1. Papers selected for analysis were accessed either through hard copies of the journals in various university libraries or electronically, through electronic databases and the worldwide web in the case of open access journals. In addition, authors were requested to provide a copy of the paper if it was not possible to access it in a particular journal. Traditionally, in Turkey, educational research papers were mostly published in education faculty journals such as *Hacettepe University Journal of Education* and *Gazi University Journal of Gazi Education Faculty* and other independent journals such as *Education and Science*, *Contemporary Education* and *National Education Journal*. In the last decade. together with the increasing interest in educational research, several new faculty journals such as *Abant İzzet Baysal University Journal of Education Faculty* and some independent journals such as the *Turkish Journal of Science Education* and *Elementary Education Online* were established. Although it is almost impossible to reach all of the papers published so far, the sample selected is representive of the majority of the papers published in science education as all major journals were reviewed. There are some well-established journals such as *Ankara University Journal of Faculty of Educational Sciences,* established in 1968, but these journals traditionally prefer publishing more papers on other areas of educational sciences rather than science education. As research in science education is a respectively new research area in Turkey, the majority of the national journals reviewed were established after 2000. This phenomenon is not limited to Turkey.

DATA COLLECTION INSTRUMENT

Each paper selected was subjected to a content analysis using the '*Paper Classification Form* (PCF)' developed by the first author. PCF is given in Appendix 2. The form composed of seven components.

Part A of the form captures some descriptive information about the identification of the paper. *Part B* requires classification of the paper according to the main discipline it belonged to such as biology, physics, chemistry, science and technology, environmental sciences, mixes of those disciplines or any other discipline that is associated with science education. *Part C* of the PCF concerned the subject matter studied. Each paper is categorized into *only* one (best fit) of the following 14 categories: (1) learning; (2) teaching; (3) teacher-training; (4) development of teaching materials; (5) computer-aided teaching; (6) general educational problems and issues; (7) concept analysis; (8) attitude and perception of science; (9) environmental education; (10) curriculum studies; (11) tests/scales development or translation from another language to Turkish; (12) studies focussed on the development of new research methods; (13) the nature of science; and (14) other subjects covering science education. This classification was developed by the first author in the light of experiences gained in previous studies (Sozbilir & Canpolat, 2006; Sozbilir & Kutu, 2008). In some cases, a particular paper contained more than one of the subject matters. For instance, it was common to investigate both the effect of a particular teaching intervention on any science topic and also its effect on students' attitudes towards science. Such papers were classified as (2) teaching paper as the main emphasis was teaching.

Regarding the research design/methods, in *Part D*, each paper was categorized as quantitative, qualitative or mixed in nature. The papers were then categorized according to one of 24 research methods given in the PCF. The development of this categorization is mainly based on the classification of research methods described by McMillan & Schumacher (2006). However, some modification had to be made such as the inclusion of reviews and metasynthesis in the light of experiences gained in the previous content analysis studies carried out by the first author.

Part E deals with the data-collection tools used. They were divided into eight main groups: (1) questionnaires; (2) achievement tests; (3) aptitude, attitude, perception, personality, etc. tests; (4) interviews; (5) observations; (6) alternative assessment tools (diagnostic tests, concept maps, portfolio, etc.); (7) documents; and (8) other data collection tools.

The samples from which data were collected were also divided into ten groups in *Part F*. These are: (1) pre-school (2) primary (grades 1–5); (3) primary (grades 6–8); (4) secondary (grades 9–12); (5) undergraduate; (6) postgraduate; (7) teachers; (8) administrators, (9) parents; and (10) other samples that data were collected. The samples sizes were also classified into six groups as seen in PCF.

Finally, *Part G* covered the data analyses methods and techniques employed in the study. The data analysis is performed under three methods as descriptive, inferential and qualitative. Each of them had different techniques as listed in the PCF.

DATA ANALYSIS

In order to achieve a reliable classification of the papers, the authors initially worked together. Sets of papers selected from national and international journals and also from different subject matters were classified together. The disagreements were discussed and resolved, and then the rest of the papers were classified by collaborative work of the second and third author. Again, any disagreement was resolved by the leadership of the first author. Following content analysis, all data were recorded in a database. Recorded data were transferred to Microsoft Excel and controlled against errors such as spelling, duplications and missing data. Once the mistakes were recognised and fixed, the data were transferred to SPPS 16.0 and the results were analysed. The results are presented in a descriptive manner as frequencies, percentages tables and charts.

RESULTS

Results for each research question will be presented respectively. The majority of papers (70%) were published in Turkish, the remainder in English. A few science education research papers are published in French and German by Turkish scientists, however those papers were not included in the content analysis as the authors had no access to those languages or to the papers. Regarding the nationality of the authors, a small number of researchers have international collaborations which resulted in co-publication.

Table 1 shows that a significant proportion of papers (41%) are published in science and technology education, which covers general science. Papers focused on chemistry education make up 23% of the total, followed by physics education

(14%) and biology education (12%). Papers belonging to more than one discipline are classified as mixed. Environmental education represents about 4%. Five papers classified as other were in astronomy and technical education.

Table 1. Descriptive statistics for the papers subjected to content analysis (N = 1249)

Language of the papers	*f*	*%*
Turkish	868	69,5
English	381	30,5
Total	1249	100
Nationality of the authors		
Turkish	1188	95,1
Mixed	61	4,9
Total	1249	100
Discipline that paper belonged		
Science & Technology Education	516	41,3
Chemistry Education	286	22,9
Physics Education	173	13,9
Biology Education	149	11,9
Mixed	66	5,3
Environmental Education	54	4,3
Other	5	0,4
Total	1249	100

The development of science education in Turkey is demonstrated in Figure 1. The first paper was published in 1973 and the second not until 1987. These two papers were published by the same author. The first paper (Özinönü, 1973) was about the status of science education in USA and published in an international journal. The second paper (Özinönü, 1987) discussed science education policies in Turkey and was published in a national journal.

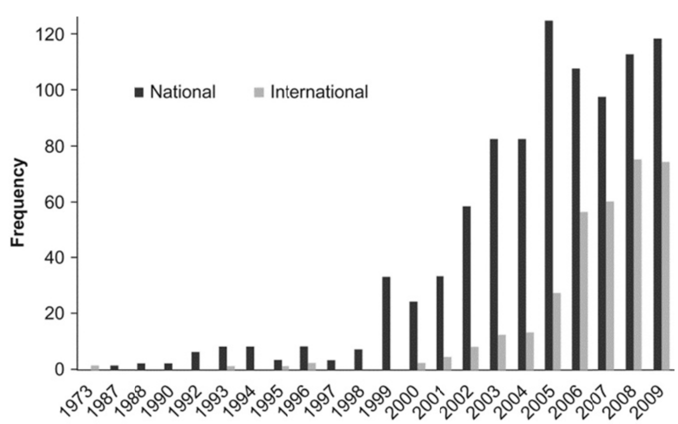

Figure 1. Number of national and international papers published across years (1973–2009).

As can be seen from Figure 1, science education research shows a rapid increase in 1999 and the number of papers published reaches a peak in 2005. This increasing interest in science education research follows the structural reform that took place in 1990s in the structure of educational faculties as part of the NEDP reported above. Publications in international journals started a few years later with a steady increase until 2009. This finding is in good agreement with Sozbilir and Kutu (2008) who reported that the number of papers reached a peak in 2005 and supports the Lee et al. (2009), Chang et al. (2010) and White et al. (2009) studies that Turkey is among the top ten contributors of publications in science education research internationally. It is also reported by Treagust (2006) that, in general, there is an increasing tendency by non-English speaking academics to write in English. Increasing interest in publication of papers in international journals by Turkish science educators is also reported by Glänzel (2008), Gokceoglu, et al. (2008) and Karasözen et al. (2009). This interest originates from the policy enforced by HEC that academics working in universities and research institutions have to publish in internationally recognised journals in order to be promoted. In addition, TUBITAK provides financial support to authors of each paper published in internationally-recognised journals which is indexed by SCI, SCI-Expanded, AHCI and SSCI and listed in the Journal Citation Reports provided by Thompson Scientific.

FREQUENTLY INVESTIGATED SUBJECT MATTERS

Concerning the first research question which relates to the most frequently investigated subject matter in science education in Turkey, Table 2 shows that there are three main areas that dominate 60% of all studies. These are studies focusing on teaching (22.5%) and learning (21.2%) various science topics and identification of students' attitudes toward science and their perceptions of science (15,7%).

Table 2. Frequently investigated subject matter by science education researches in Turkey

	f	%
Teaching	281	22.5
Learning	265	21.2
Attitude/perception studies	196	15.7
Concept analysis	76	6.1
Studies on teaching materials	72	5.8
Nature of science	61	4.9
Computer-aided instruction	52	4.2
General educational problems	48	3.8
Curriculum studies	48	3.8
Tests/scales development or translation	37	3.0
Teacher training	26	2.1
Environmental education	22	1.8
Other subjects	65	5.2
Total	1249	100

When teaching studies are investigated in detail, almost two thirds investigated the effect of a particular teaching intervention on students' academic achievement (61%), improving students' attitudes toward science (26%), improving students' scientific process skills (8%), and the other 5% compared the effectiveness of different teaching interventions. Regarding the learning studies, identification of misconceptions in various science topics dominated this field with 70%. The rest of the studies in this domain are focused on determining students' academic achievements (10%) and identification of their learning styles (7%) together with some other areas such as problem solving, cognitive structures, mental models, etc.

Table 2 also shows that there are other subject matters such as concept analysis, studies on development and tests of effectiveness of teaching materials, nature of science studies, computer-aided instruction, curriculum studies, test/scales development or translation of tests/scales from other languages to Turkish, teacher training and environmental education studies ranging from two to six percent. There are studies such as informal science education, special education, measurement and assessment and policy studies classified as other subjects (5%).

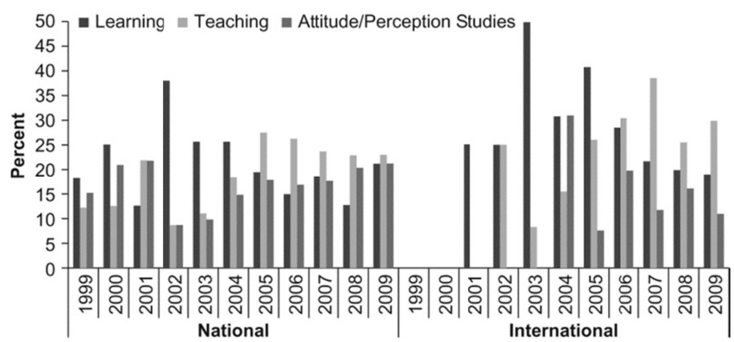

Figure 2. Percentages of most frequently studied subject matters at national and international level across years (1999–2009).

Figure 2 indicates a shift between studies focused on teaching and learning. As shown by the chart, initially science educators in Turkey focussed on studying students' learning of science concepts and ideas. Learning studies started to significantly increase until 2005 and then a decrease was observed. Although studies that focused on teaching science dominated learning studies since 2005–2006, there are still a significant proportion of learning studies published in both national and international journals. However. it should be noticed that there is a general decrease in the total number of papers published after a peak in 2005 shown in Figure 1. On the other hand, an interesting result appears in terms of the number of papers published at national and international level on the determination of students' attitudes and perceptions of science. When Figure 2 is carefully investigated it could easily be identified that the majority of the papers concerning attitudes and perception studies are published in national journals rather than international journals indicating a mismatch between the trends at national and international level. Chang et al.'s (2010) study found that only about 5% of the studies in science education are focussed on attitude and gender issues. This result may provide guidance to both researchers and journal editors in terms of keeping up with the international trends

FREQUENTLY USED RESEARCH DESIGNS/METHODS

The research designs used in the science education research papers published by Turkish science educators are summarised in Table 3. As Table 3 shows, more than two thirds of the papers (67%) employed quantitative and another 30% qualitative research traditions. Only a small amount of papers (~3%) followed newly emerging mixed method research approaches.

Table 3. Frequently used research design/methods by science education researchers

	Research Design	*Research Methods*	*f*	*%*
QUANTITATIVE	Experimental	True-experimental	0	0
		Quasi-experimental	255	20.4
		Pre-experimental	43	3.4
		Single subject	0	0.0
		Sub-total	*298*	*23.9*
	Non-Experimental	Descriptive	173	13.9
		Comparative	62	5.0
		Correlational	43	3.4
		Survey	255	20.4
		Ex-post facto	0	0.0
		Secondary data analysis	3	0.2
		Sub-total	*536*	*42.9*
QUALITATIVE	Interactive	Ethnographic study	2	0.2
		Phenomenographic study	9	0.7
		Case study	136	10.9
		Grounded theory	2	0.2
		Critical studies	0	0.0
		Others	1	0.1
		Sub-total	*150*	*12.0*
	Non-Interactive	Historical analysis	22	1.8
		Concept analysis	68	5.4
		Review	83	6.6
		Metasynthesis	8	0.6
		Others	44	3.5
		Sub-total	*225*	*18.0*
MIXED	Mixed	Explanatory (Quan to Qual)	22	1.8
		Exploratory (Qual to Quan)	3	0.2
		Triangulation (Quan + Qual)	15	1.2
		Sub-total	*40*	*3.2*
		Total	1249	100

Regarding the research design preferred by Turkish science educators, Table 3 indicates that non-experimental design (43%) dominantes followed by experimental research. The most common type of experimental research method is quasi-experimental (20.4%) with few pre-experimental research methods, but there is no true experimental and single subject research done in science education in Turkey. This result may be expected as science education research is mainly carried out by either teachers or in schools with already determined groups, i.e. the classes, so the commonality of quasi-experimental research method is understandable. The lack of true-experimental research is also an expected result as random allocation of subjects into control and experiment groups is possible and necessary in psychological researches rather than general science education research. In addition, the majority of the non-experimental research consisted of surveys (20,4%) and descriptive methods (13,9%) together with a small amount of comparative and correlational research.

On the other hand, qualitative studies are mostly carried out by non-interactive design and only 12% of the studies employed interactive qualitative research. The most commonly used qualitative research methods are case studes (10.9%), reviews (6.6%) and concept analysis (5.4%). Concept analyses studies are those describing and discussing the different meanings and appropriate use of the educational and scientific concepts. These studies do not require the collection of experimental data and are mostly written on the basis of the researchers' knowledge and experience. It is also common to use documents as data collection tools in this method.

Qualitative research methods such as ethnography, phenomenography, critical studies, grounded theory, historical analysis and metasynthesis, and mixed methods are rarely used. This result indicates a lack of qualitative and mixed method research knowledge and skills among Turkish science educators.

Trends in research designs across years are illustrated in Figure 3 to identify whether there is any significant shift in use of different research designs. As seen from Figure 3, experimental, non-experimental and non-interactive research designs which were highly common initially started to lose their commonality although they are still dominant, while interactive and mixed designs are slightly increasing in recent years.

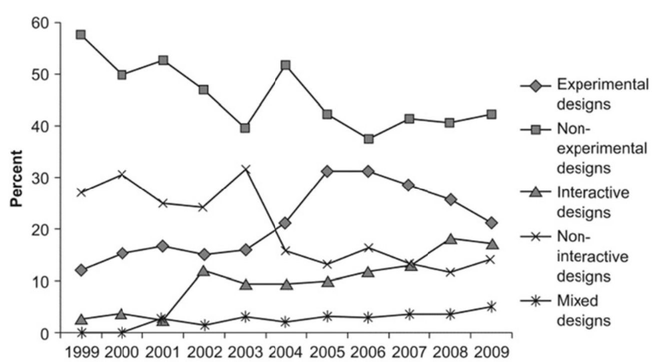

Figure 3. Trends in research desings across years (1999–2009).

FREQUENTLY USED DATA COLLECTION TOOLS

Data collection tools frequently used in science education research papers are presented in Table 4. The total numbers of data collection tools are not calculated as more than one data collection tool could be used in a single study. The percentages calculated are arranged according to the total number of papers (N=1249) subjected to content analysis.

Table 4. Frequently used data collection tools in science education researches

Type of data collection tools	*f*	*%*
Achievement tests	452	36.2
Multiple choice	*262*	*21.0*
Open-ended	*152*	*12.2*
Others	*38*	*3.0*
Questionnaires	313	25.0
Likert type	*159*	*12,7*
Open-ended	*85*	*6.8*
Others	*69*	*5.5*
Aptitude, attitude, perception, personality etc. tests	308	24.7
Interviews	220	17.6
Structured	*14*	*1.1*
Semi-structured	*114*	*9.1*
Unstructured	*2*	*0.2*
Focus group	*8*	*0.6*
Not-reported	*82*	*6.6*
Alternative assessment tools	126	10.1
Documents	108	8.6
Observations	64	5.1
Other data collection tools	28	2.2

Table 4 indicates that the most common data collection tools used by Turkish science educators are achievement tests (36.2%), questionnaires (25.1%) and tests used to measure aptitude, attitude, perceptions, personality, etc. (24.7%). Interviews (17.6%) are among the most commonly-used qualitative data collection tools together with documents (10.1%). Alternative assessment tools such as concept maps, POE (predict-observe-explain, portfolios, diagnostic tests (10.1%) are also widely used. The least used data collection tool is observation (5.1%).

When table 4 is investigated, it appears that the open-ended and multiple choice type achievement tests are widely used. These tests are rather easy to prepare, administer and mark compared to the alternative tests such as two/three tier diagnostic tests, concept maps, POE (Predict-observe-explain) and portfolios, and also require less experience. Therefore, their uses are fairly common. The use of Likert-type questionnaires are the most common amongst the data collection tools used throughout the world and Turkey is not an exception in this respect.

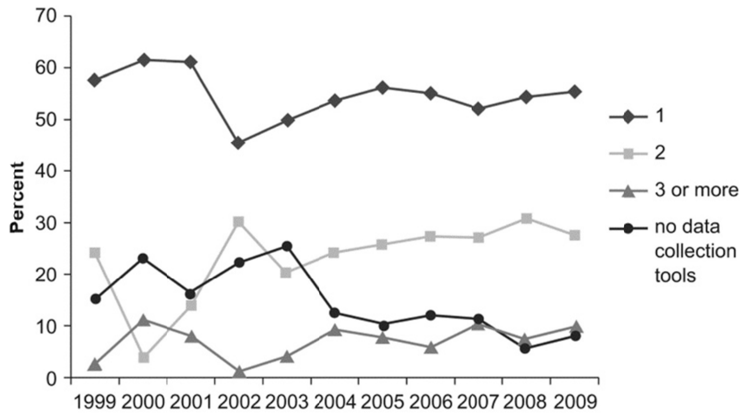

Figure 4. Number of different data collection tools used across years (1999–2009).

Figure 4 illustrates the number of different data collection tools used in each study subjected to content analysis across years. The numbers of data collection tools partly provides information about the reliability and validity of a study. One way of achieving high reliability and validity in a study is triangulation of data collection tools. This notion is mostly ignored in the science education research published. It is quite interesting to see that more than half of the studies relied on a single data collection tool and this trend continues. About a quarter of the studies used two data collection tools and this pattern is relatively steady since 2003. Three or more data collection tools are quite rare, although there is a slight increase in recent years. In terms of increasing reliability it could be suggested that researchers need to avoid 'single shot research' with only one data collection tool applied once to a particular sample. It is also important to recognise that there was a significant proportion of studies in the early years of science education research in Turkey that used no data collection tools. These studies are classified as concept analysis studies that do not require data collection, instead they are only written on the basis of the authors' knowledge and experience. However, this trend is in decline. This finding is also consistent with the result presented in Figure 3, that there is a decline in the proportion of non-interactive qualitative studies which include historical analysis, concept analysis, reviews and metasynthesis.

FREQUENTLY USED SAMPLES AND SAMPLE SIZES

The following two figures (Figures 5 and 6) show the frequently studied samples and sample sizes. Figure 5 indicates that most of data for the science education research are collected from undergraduate (34%) and secondary students (20%). There are also studies focusing on the second level of elementary education (16%). Significant proportions (13%) of the studies collected data from teachers. Figure 5 also shows that science education research is rare at the first level of primary education as science is only taught as a separate subject at grades 4 and 5 in Turkey.

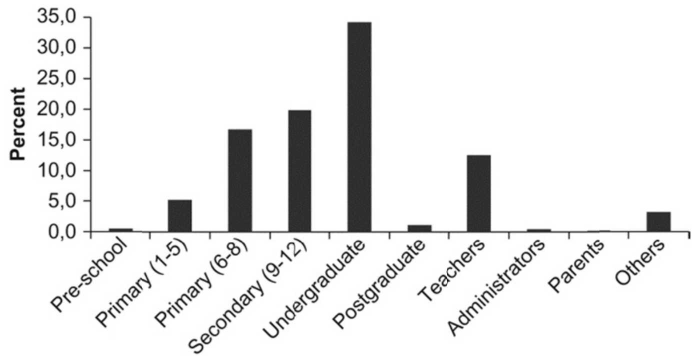

Figure 5. Frequently studied samples.

Regarding how sample sizes have changed, Figure 6 indicates a parallel with the research methods. As the proportion of non-experimental quantitative and non-interactive qualitative research designs were similar, the sample sizes match this finding that the most commonly selected sample sizes were 31–100 participants (34%). Studies with these sample sizes are expected as quasi-experimental studies are performed with mainly control and experimental groups and the class sizes in general vary from 25 to 40 at secondary level and 30–100 in undergraduate level in Turkey. In addition, as other non-experimental studies are generally carried out in researchers' own classes or adjacent classes, these sample sizes are understandable. On the other hand, as surveys and descriptive studies generally use relatively large sample sizes compared to experimental studies, sample sizes over 100 can be expected. However, the minority of very large sample sizes, such as over 1000 participants, indicates a lack of nationwide and long-term extended research. Moreover, studyies involving small sample sizes, such as less than 30 subjects, indicates the existence of interactive qualitative studies although the proportion of them is about 10%.

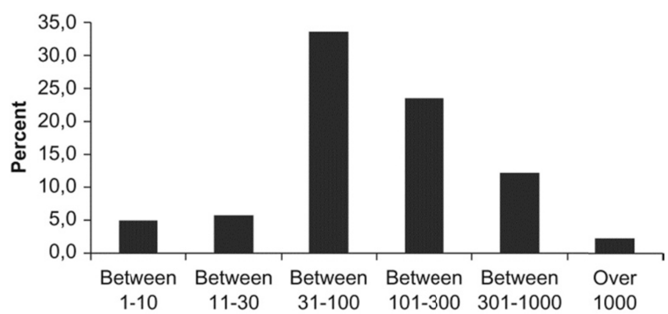

Figure 6. Frequently studied sample sizes.

FREQUENTLY USED DATA ANALYSIS METHODS

The range of data analysis methods and techniques used by Turkish science education researchers are shown in Figure 7. As can be seen from the figure, descriptive data analysis methods are frequently used and the results are presented as tables of frequencies, percentages (52%), central tendency measures such as mean, mode, median, standard deviation are used in 45% of the studies. Among the descriptive studies, 13% used charts to present the results. Use of inferential data analysis methods are of the second order. Among them, correlation tests, ANOVA/ANCOVA and t-test are the most common. There were few samples of MANOVA/MANCOVA, regression, factor analysis, regression and non-parametric tests indicating simplicity of data analysis methods employed. Regarding the qualitative data analysis, descriptive data analysis (12%) together with content analysis (7%) is widely used. As science education is in its development stages in Turkey, a significant number of the researchers publishing papers lack basic knowledge and skills required to perform research in science education, therefore simple data analysis methods are frequently preferred. However, as can be seen from Figure 8, descriptive data analyis approaches are in decline while qualitative data analyses are increasing. Doing high quality research is much more demanding in terms of having knowledge and skills in research methods in a particular area.

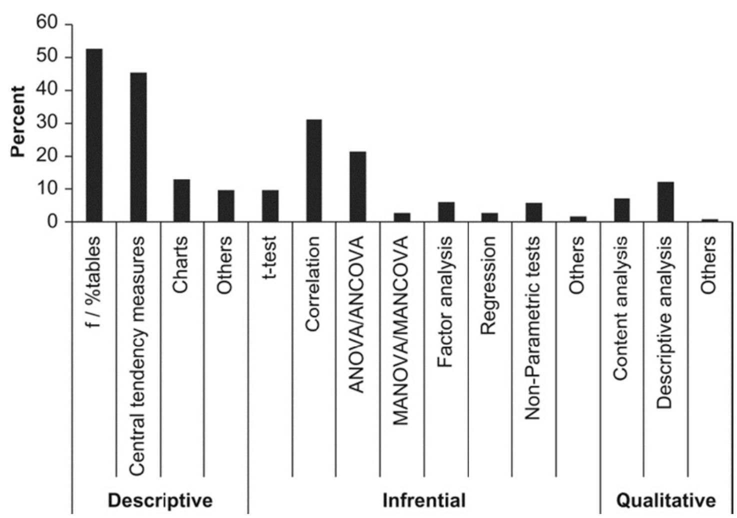

Figure 7. Frequently used data analysis methods and techniques.

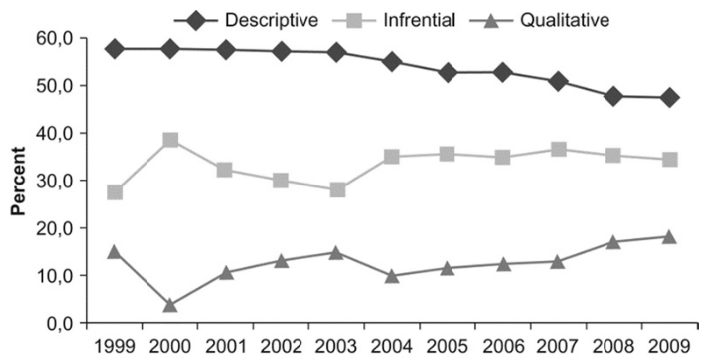

Figure 8. Trends in frequently used data analysis methods.

Regarding the use of combinations of different data analysis methods of descriptive, inferential statistics and qualitative analysis, Figure 9 shows that the combined use of two data analysis approaches is most frequently preferred. As only mixed methods studies require use of a combination of all three data analysis approaches, its proportion is quite low as mixed method research is rarely employed by Turkish science educators.

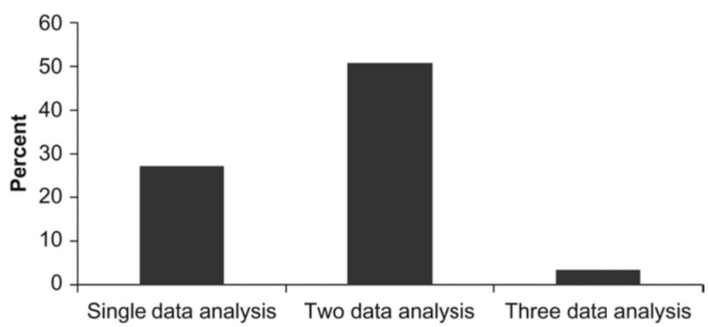

Figure 9. Number of different data analysis methods combined in a study.

DISCUSSIONS AND IMPLICATIONS FOR PRACTICE

Interest in science education research in Turkey started over 20 years ago as can be seen from Figure 1. During this time, the number of people who have devoted their careers to research on teaching and learning of science has increased significantly. There have also been significant developments in the subject matters studied and methodology for doing research in science education area and in the sophistication of the questions being investigated in the world (Sozbilir & Kutu, 2008). This chapter focused on the development of science education research in Turkey. In order to determine the status of research in science education in Turkey, papers concerning science education published by Turkish authors in national and international journals were subjected to a content analysis in terms of subject matters investigated and research methods/designs and data analyses procedures used in science education research papers.

This content analysis showed that science education research showed increasing interest since 1999 although there were few studies (49 out of 1249) published irregularly before 1999. Since then, a significant increase has been observed in the number of science education research papers published in Turkey, peaking in 2005. This interest in research in science education is in line with with the re-structuring of schools of teacher education in terms of their functions and departmental structures by the HEC (Güven, 2007; Tercanlioglu, 2004; Türkmen 2007). Before 1997, most of the academics employed by schools of teacher education were performing research in disciplines such as chemistry, physics, biology or history instead of focusing on research in teaching and learning of their main disciplines. After the reform in the teacher training programs, academic staff in schools of teacher education directed their attention towards carrying out more educational research than discipline-based research. In addition, HEC follows a policy of providing an international postgraduate scholarship program for students to study abroad particularly for areas that are weak in Turkey. This policy also had a significant effect on the increase of number of papers in science education as it did in other areas.

As well as an increase in the number of research papers in science education there has been an increase in the number of journals publishing science education research. This re-structuring initially caused some inconvenience but in a couple of years many people chose to do educational research starting with the establishment of science education as a new research area in Turkey. This shift also raised concerns about the quality of research published. Many people had experienced difficulties in conducting and publishing research in science education as they moved from discipline-based research to science education. This transition is evident in Figure 3 in that initially the proportion of non-experimental quantitative and non-interactive qualitative research was quite high. This is because most of the non-experimental quantitative research was descriptive and involved survey studies that are relatively easy to conduct, analyse and report. Moreover, the majority of the non-interactive qualitative studies were concept analysis studies that are also relatively easy compared to interactive qualitative studies such as phenomenology, ethnography and grounded theory. As can be seen from Figure 3, although there is an increasing trend in mixed method and interactive qualitative research their total proportion compared to other research designs are quite low (less then one in third). Therefore it could be suggested that there continues to be a need to improve research methods courses at graduate level to help new researchers learn qualitative research methods and also improve their knowledge and skills in quantitative researches.

Science education research is not conducted within one paradigm because there are too many fundamental differences concerning the nature of science education itself (Treagust, 2006). General areas of interest to science educators around the world are learning, teaching, educational technology, curriculum, learning environments, teacher education, environmental education, assessment and evaluation, equity, history and philosophy of science, scientific literacy, nature of science, and socio-cultural issues in science. However, the areas of interest to Turkish science educators are teaching, learning and studies on attitudes in general. Teaching (as an intervention), concept analysis, determining students' attitudes and interest towards science and identifying students' misconceptions about various scientific concepts make up two-thirds of the total studies carried out by the Turkish science education research community. This result is more or less similar throughout the world although there are shifts in the trends (Chang et al., 2010; Lee et al., 2009). In this sense, science education in Turkey could be seen as keeping up with the international trends. However, the shortage of the number of studies focusing on nature of science, research methods, teacher-training, curriculum studies, integration of ICT into teaching, environmental education, socio-cultural issues in science, assessment in science education, etc., indicates that there are problems with following the current trends in science education in the world.

In recent years, research on the impact of technology on teaching has been of key importance as the use of computers in schools increases. There is still a need to investigate how students learn science with computers. In addition, there is an increase in on-line resources but there is a question as to how beneficial they are to learning science, as Treagust (2006) suggests. On the other hand, interest is increasing in studies focussing on scientific literacy, as many international studies such as TIMSS and PISA suggest that students' level of scientific literacy is alarming in many countries including Turkey. As seen from Table 2 there is a shortage of research in this area in Turkey.

As Figure 2 illustrates, there has been a shift in the number of studies focussed on the identification of students' learning in science and studies examining teaching science. While there were initially more learning studies this trend changed in favour of teaching studies. On the other hand, when the content of teaching studies was investigated in detail, it appears that they are dominated by quantitative analyses of quasi-experimental intervention studies. As Fensham (2009) reported, there was a similar trend in science education research in the US, England and Australia. It is interesting to see similar moves in science education research in Turkey, too. This is perhaps due to the ease of transferring the experimental skills of researchers with a science background to the context of science education research. Focussing widely on a few areas in science education results in missing the research in other areas such as scientific literacy, nature of science, socio-scientific issues, cultural studies of science education, science-technology-society studies, the professional development of teachers, and policy and evaluation research, all of which are gaining attention in other parts of the world. Although some of those research areas are evident in Turkey, they are not significant enough in number to have an impact on practice. For instance, there is almost no study on evaluation of new curricula which have been in practice since 2005 with only a few studies reflecting practitioners' views. In this sense, it could be suggested that the Turkish science education research community should closely follow international trends. One way of doing this includes developing existing international collaborations. Another possibility would be carrying out regularl review studies, such as this one, to follow closely what kind of research is carried out inside and outside the country and sharing the knowledge gained with novice and young researchers. Perhaps the most important initiative would be to set up national research priorities in science education following the trends in the rest of the world to create Turkey's own research interests reflecting the country's characteristics, virtues and needs as a society.

Regarding frequently-used methods, quasi-experimental, survey, descriptive studies and case studies make up two thirds of all research. Qualitative research methods (i.e. ethnography, phenomenology, grounded theory, critical studies) and some quantitative methods (i.e. *ex-post facto* and secondary data analysis) are either rarely observed or not used at all by Turkish science education researchers. However, as seen in Figure 3, there has been a slow change in trends in terms of research methods in favour of mixed method and interactive qualitative research such as ethnography, phenomenology. Although it is slow, this shift is paralleled by the international trend shifting from quantitative to qualitative methodologies in the last two decades (Kelly & Lesh, 2000) and more recently to mixed methods by combining qualitative and quantitative approaches (Johnson & Onwuegbuzie, 2004; Kelle, 2006). However, the quality of the qualitative studies in the world is mixed because most students in education do not have enough knowledge and training in these methods (Hsu, 2005). In fact, good qualitative studies are not easy to produce because, unlike quantitative studies, with its established steps to follow, the unique situations of qualitative studies require judgment decisions that inexperienced researchers may not be able to make properly (Harry, Sturges, & Klinger, 2005). Moreover, interpretation of qualitative results is especially challenging to new researchers. Therefore, in order to keep up with this methodological shift there is undoubtedly a need to strengthen the instruction of qualitative-related methods at graduate level method course in Turkey.

In supporting the findings above, most of the science education research papers were based on the data collected through achievement tests and questionnaires (see Table 4) and also a majority of the studies, as seen from Figure 4, are based on data collected through *only* one or *at best* two different data collection tools. These results suggest possible methodological weaknesses and lack of knowledge and skills in combining and using different research methods and integrating different data collection tools in order to strengthen the validity and reliability of the studies.

As expected with the trends in educational research in the world (Hsu, 2005) science education research papers in Turkey included mainly descriptive and inferential statistics methods (see Figure 7). Among those methods use of frequencies, percentages, central tendency measure, charts, together with correlation, ANOVA/ANCOVA, were most common. There are some other data analysis procedures such as t-test, factor analysis, regression and non-parametric tests. Much of the qualitative data analysis methods were descriptive together with a small number of content analysis. From the methodological perspective, it could be suggested that using multiple methods and multiple data analysis procedures may help to increase the validity and reliability of studies resulting in more high quality research papers. This shift would also help to increase the acceptance rate of papers in international journals with high impact factors.

As a result, to be good consumers of research, students should be able to understand and interpret concepts related to research methods/analyses frequently used in science education research. Thus it is highly recommended that method courses should constitute the basic cores of knowledge needed for all graduate students in science education together with the subject knowledge itself.

It is hoped that this content analysis will provide some guidance for science educators, particularly new researchers, in making appropriate decisions and broadening their scope when conducting research and writing academic publications in the future. It is also recommended that a similar study be repeated in future years; science education researchers can then monitor and review the research trends, and possibly make more international contributions to the field and encourage some shifts in research trends. It is also recommended that there is a shortage of review studies which identify the quality of the research papers published and also more reviews are needed in every area of subject matter that is studied in order to help new researchers to see what has been achieved and what needs to be done.

It is also important to recognize that, as asserted by White (1997), revolutions do not necessarily follow a linear course, nor do they go on for ever. The trends picked out here and reported in other papers might not continue. New ones could emerge suddenly, or there could be a period of consolidation, or worse, stagnation or regression.

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APPENDIX 1. LIST OF JOURNALS

Title of Journal	*Journal Type*	*f*	*%*
Asia-Pacific Forum on Science Learning and Teaching	International	42	3.4
Turkish Online Journal of Educational Technology	International	41	3.3
International Journal of Science Education	International	29	2.3
Journal of Science Education and Technology	International	28	2.2
International Journal of Environmental and Science Education	International	27	2.2
Journal of Baltic Science Education	International	26	2.1
Educational Sciences: Theory and Practice	International	25	2.0
Eurasia Journal of Math., Science & Tech. Education	International	18	1.4
Chemistry Education Research and Practice	International	16	1.3
Journal of Chemical Education	International	16	1.3
Turkish Online Journal of Distance Education	International	14	1.1
Eurasia Journal of Educational Research	International	13	1.0
Journal of Research in Science Teaching	International	11	0.9
Research in Science & Technological Education	International	11	0.9
International Journal of Science and Mathematics Education	International	10	0.8
Essays in Education	International	9	0.7
Research in Science Education	International	9	0.7
Science Education	International	9	0.7
Journal of Science Teacher Education	International	6	0.5
Physics Education	International	6	0.5
Biochemistry and Molecular Biology Education	International	5	0.4
The Physics Teacher	International	5	0.4
Other International Journals (less than 5 papers from each)	International	24	1.9
Hacettepe University Journal of Education	National	128	10.2
Education and Science	National	68	5.4
National Education Journal	National	65	5.2
Journal of Turkish Science Education	National	62	5.0
Kastamonu University Journal of Education Faculty	National	60	4.8
Gazi University Journal of Gazi Education Faculty	National	59	4.7
Dokuz Eylül University Journal of Buca Education Faculty	National	54	4.3
Elementary Education Online	National	50	4.0
Pamukkale University Journal of Education Faculty	National	50	4.0
Marmara Univ. Ataturk Educ. Fac. Journal of Educ. Sci.	National	31	2.5
Erzincan University Journal of Education Faculty	National	25	2.0
Ondokuz Mayıs University Journal of Education Faculty	National	25	2.0
Ahi Evran University Journal of Kırşehir Education Faculty	National	23	1.8
Turkish Educational Sciences Journal	National	18	1.4
Abant İzzet Baysal University Journal of Education Faculty	National	15	1.2
Contemporary Education	National	15	1.2
Çukurova University Journal of Education Faculty	National	14	1.1
Electronic Social Sciences Journal	National	14	1.1
Balikesir Uni. Necatibey Educ. Fac. Elec. J. Sci. & Math. Educ.	National	14	1.1
İnönü University Journal of Education Faculty	National	12	1.0
Uludağ University Journal of Education Faculty	National	11	0.9
Yüzüncü Yıl University Journal of Education Faculty	National	8	0.6
Boğaziçi University Journal of Education	National	7	0.6
Ankara University Journal of Faculty of Educational Sciences	National	6	0.5
Mersin University Journal of Education Faculty	National	6	0.5
Other National Journals (less than 5 papers from each)	National	9	0.7
Total		*1249*	*100*

APPENDIX 2. PAPER CLASSIFICATION FORM

A. INFORMATION ABOUT PAPER

1.Title:

2.Author/s:

3.Auth.Nation. a.TR ☐ b.Foreign ☐ c.Mixed ☐

4.Journal Name:

5.Journal Type: a.International ☐ National ☐

a.Year: | b.Volume: | c.Issue: | d. Pages:

6.Language a.Eng. ☐ b.Turkish ☐ c.Other ☐

7. Indexes: a.SCI/SSCI: ☐ b.ERIC-BEI-EI-AEI: ☐ c. ULAKBİM SBVT ☐ d.No Index ☐ e.Other ☐

B. MAIN DISCIPLINE THAT PAPER BELONGED

☐ 1. Biology ☐ 2. Physics ☐ 3. Chemistry ☐ 4. Sci & Tech. ☐ 5. Envt.Educ. ☐ 6. Mixed ☐ 7. Other

C. SUBJECT OF THE PAPER

1. ☐ Learning
   O Mis O LS O Ach. O Other
2. ☐ Teaching
   O MC O Att. O Ach. O SPS
3. ☐ Teacher training
   O PTE O IT O Other
4. ☐ Study on teaching materials
5. ☐ Computer-aided teaching
6. ☐ General educational probl.
7. ☐ Concept analysis
8. ☐ Attitude, perception research
9. ☐ Environmental education
10. ☐ Curriculum studies
11. ☐ Test, scale development or translation
12. ☐ Research methods studies
13. ☐ Nature of science
    O SPS O SL O ATS O SiEL
14. ☐ Other……………………………

D. RESEARCH METHODS/DESIGNS

QUANTITATIVE

1. Experimental

11. ☐ True-experimen.
12. ☐ Quasi-experim.
13. ☐ Pre-Experimen.
14. ☐ Single subject

2. Non-Experimental

21. ☐ Descriptive
    O Longitudinal
    O Cross-age
22. ☐ Comparative
23. ☐ Correlational
24. ☐ Survey
25. ☐ Ex-post facto
26. ☐ Sec. Data analy.

QUALITATIVE

3. Interactive

31. ☐ Etnography
32. ☐ Phenomenography
33. ☐ Case study
34. ☐ Grounded theory
35. ☐ Critical studies
36. ☐ Other …………….

4. Non-Interactive

41. ☐ Historical analy.
42. ☐ Kavram an.
43. ☐ Review
44. ☐ Metasynthesis
45. ☐ Other ………..

MIXED

5. Mixed

51. ☐ Explanatory (QuanèQual)
52. ☐ Exploratory (QualèQuan)
53. ☐ Triangulation (Quan+Qual)

E. DATA COLLECTION TOOLS

1. ☐ Questionnaire
   O Open-end. O Likert O Other
2. ☐ Achievement test
   O Open-end. O Mulp. choice O Other
3. ☐ Aptitude, attitude, perception, personality etc. tests
   Please write the title ……………………………
4. ☐ Interview …………………………
   O Structured O Semi-Str O Unstructure. O Focus G
5. ☐ Observation
   O Participant O Non-participant
6. ☐ Alternative assessment tools
   (Diagnostic tests, concept map., portfolio etc.)
7. ☐ Documents
8. ☐ Others (please provide title) …………………………

F. SAMPLE

a. Sample

1. ☐ Pre-school
2. ☐ Primary (1-5)
3. ☐ Primary (6-8)
4. ☐ Secondary (9-12)
5. ☐ Undergraduate
6. ☐ Post-graduate
7. ☐ Teachers
8. ☐ Administratives
9. ☐ Parents
10. ☐ Others ……………

b. Sample Size

1. ☐ Between 1 to 10
2. ☐ Between 11 to 30
3. ☐ Between 31 to100
4. ☐ Between 101 to 300
5. ☐ Between 301 to 1000
6. ☐ Over 1000

G. DATA ANALYSIS

QUANTITATIVE DATA ANALYSIS

1. Descriptive Statistics

11. ☐ Frequency/percentage tables
12. ☐ Central tendency measures
13. ☐ Charts
14. ☐ Others…………………

2. Infrential Statistics

21. ☐ t-test
22. ☐ Correlation
23. ☐ ANOVA/ANCOVA
24. ☐ MANOVA/MANCOVA
25. ☐ Factor analysis
26. ☐ Regression
27. ☐ Non-Parametric tests
28. ☐ Others…………………..

QUALITATIVE DATA ANALYSIS

3. Qualitative Analysis

31. ☐ Content analysis
32. ☐ Descriptive analysis
33. ☐ Other …………………

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MATTHIAS STADLER AND DORIS JORDE

15. IMPROVING SCIENCE EDUCATION THROUGH EUROPEAN MODELS OF SUSTAINABLE TEACHER PROFESSIONAL DEVELOPMENT

INTRODUCTION

Science education research, especially in Europe, is strongly linked to the improvement of teaching practice. When considering how to improve teaching practice we think about the school system, the curriculum, teachers and students – all of which are intricately woven together in the classroom. In this chapter, we will consider the role of teacher professional development (TPD) in improving science teaching. We look at how capacities for more effective and more sustainable models of TPD may be developed, looking at examples from European countries where cultural diversity is large. Our experiences are based on two European projects: Mind the Gap and Science-Teacher Education Advanced Methods (S-TEAM).

THE CURRENT SITUATION FOR SCIENCE EDUCATION IN EUROPE

Within the last 15 years, international studies of educational systems have caused concerns about the outcomes of teaching and learning science. TIMSS, PISA and PIRLS are examples of comparative studies that examine the outcomes in reading, mathematics and science. PISA as the most influential study shows that in many countries, pupils' performance in the tests and hence their knowledge and understanding of science is on a much lower level than educational officials would wish for. Even in many developed countries there are large proportions of students whose knowledge of science does not exceed general knowledge.

Interest in science education policy within the EU has been fuelled by decreasing numbers of students in the natural sciences, engineering and mathematics in Europe as evidenced by the report "Europe needs more scientists" (European Commission, 2004).[1] The decreasing uptake of careers in science and technology is seen as a threat for the economic prosperity of the EU countries and to democratic participation, thus placing recruitment to STEM studies as a top priority. At the same time the report concluded that students specializing in STEM areas of study often choose other career pathways than teacher education, making recruiting to science teacher education a particular problem in many countries. Concerning the problems of providing an adequate science education for students in order to motivate their interest in STEM subjects, the report states the following:

Doris Jorde and Justin Dillon (Eds.), Science Education Research and Practice in Europe: Retrospective and Prospective, 375–393.

> Science education suffers badly in this respect. Not only is it trying to cope with this image of 'becoming a scientist', but it is also fighting to relate to society. And yet it is being bound by an old-fashioned view that it must develop the 'fundamentals' of science which, all too often, are abstract, even microscopic, and far from the science ideas underpinning the technological advances within society which form the focus of debate and divide public opinion. It can be argued that science education in schools lives in a world of its own. It seems unsophisticated because it is unable to compete with advances within the scientific fields. It is abstract because it is trying to put forward fundamental ideas, most of which were developed in the 19th century, without sufficient experimental, observational and interpretational background, without showing sufficient understanding of their implications, and without giving students the opportunity of a cumulative development of understanding and interest. It is heavily in danger of being excessively factual because of the explosion in scientific knowledge and the 'adding-on' of topics to an already excessive content base (EC, 2004).

Conclusions from the report are many and include the need to recruit well qualified teachers, offer continuing professional development for teachers, offer innovative science curricula promoting science as a process of inquiry, and the need for bridging the gap between educational research and classroom practice.

The OECD "Global Science Forum" (2008) studied a wide perspective of countries in which quantitative trends for enrolment in science and technology as well as factors that may affect student choices were followed. Their findings reported that while absolute numbers of science and technology students have been rising in higher education, the relative share of students among the overall population has been falling. Women continue to be underrepresented in science and technology enrolments. And while young people seem to have a positive image of science and technology and its contributions to making life better, the image of science and technology as a profession is negative (OECD, 2008). The curriculum in science was found to be in need of change to promote concepts rather than facts, and the education of science teachers needs to reflect new ideas in teaching and learning.

A high level group on science education delivered a report "Science Education Now: A Renewed Pedagogy for the Future of Europe" in which a cross section of on-going initiatives were examined to try and understand ideas of good practice in European science education and to identify pre-conditions for successful change of existing practice that could be implemented across European countries (Rocard et al., 2007). Once again, the focus was on the declining interest in science and math in European countries, leading to declines in recruiting to studies and careers in STEM areas. Inquiry based methods of teaching science were recommended as a means of changing the way we teach science in order to increase interest in science. The German SINUS[2] (Improving the Efficiency of Mathematics and Science Instruction) programme was recommended along with the Pollen project[3] as good examples demonstrating potential for scaling up in Europe. Though simple in its structure, this publication placed the need to improve the teaching of science into a policy perspective at the national level as well as within the EU. Funding for projects related to the use of Inquiry Based Science Teaching (IBST) were subsequently promoted within the Science in Society funding agency for EU countries.

In 2007, the Nuffield foundation supported a project in which science educators from nine European countries were gathered to discuss concerns about the motivation of European youth to study STEM subjects. The report "Science Education in Europe: Critical Reflections" is a collection of findings that illustrate the similarities and differences between countries in Europe concerning the curriculum, pedagogy, assessment of science in schools and the preparation of science teachers. The recommendations offered by the report are meant to inspire to a new way of thinking about science education – one that has the potential to meet the needs of all students; those who will work within scientific fields and those who will not (Osborne & Dillon, 2008).

In order to change the unsatisfying state of school science towards a more positive picture, fundamental changes in teaching science need to be implemented. The science educators who worked on the Nuffield report produced seven recommendations concerning curriculum, pedagogy, assessment and teachers. "The primary goal of science education across the EU should be to educate students both about the major explanations of the material world that science offers and about the way science works" (Osborne & Dillon, 2008). Science education in schools should therefore focus on "science for all pupils" enabling pupils to deal with science related problems they may face in their everyday life, for instance climate change or food supply. Courses providing a basis for the education of future scientists should be optional.

Secondly, the report recommends "innovative curricula and ways of organising the teaching of science that address the issue of low student motivation" and a curriculum that focuses on the development of understanding. Science education before the age of 14 should emphasise "engaging students with science and scientific phenomena […] through opportunities for extended investigative work and 'hands-on' experimentation" (Osborne & Dillon, 2008).

The report recommends that "teachers of science of the highest quality are provided for students in primary and lower secondary school" (Osborne & Dillon, 2008). This recommendation is in contrast with the fact that in many countries teachers for primary schools study science to a lesser extent than secondary school teachers and tend to believe that they are not well prepared to teach science.

What is common to all of the above mentioned reports is that Europe needs to look critically at the way we teach science if we are to engage students in science both as citizens and as professionals working in science careers (science for all vs. science for careers). By changing the way we teach science, we may be able to help all students gain access to the sciences, a field of fascinating phenomena, ideas and discoveries as many scientists perceive it. In order to make this happen, students need to know why science is important in our culture, they need to be engaged in activities that allow them to experience how science works and how scientific knowledge is produced. Students need to be introduced to science courses that emphasize the "big ideas and concepts" rather than isolated facts, rules and mathematical equations to be memorized. Assessment practices need to be in accordance with good science teaching such that they too promote learning and understanding.

TEACHER PROFESSIONAL DEVELOPMENT (TPD) AS A KEY FACTOR IN IMPLEMENTING CHANGE IN SCIENCE TEACHING

Changing the way we teach science is directly connected to how we educate science teachers and how we approach teacher professional development in science. If we want to change the way science is taught (pedagogy), we must also work closely with teachers in their initial and continuing education. Hence, teachers should be strongly supported so that they are able to adapt inquiry-oriented teaching approaches, to learn about their implementation in classrooms and to experience and reflect about the effects of their own teaching practice.

At every point in a teacher's career path, teachers need to be considered professionals. As with other professions, this implies that they have formal qualifications in their education, that they have practical experience including continuous upgrading of their skills and knowledge, and that they participate in associations where their professional development is addressed through literature, courses and participatory networks.

Throughout the remainder of this chapter, we will discuss ideas of how teacher professional development plays a role in improving the way science is taught. We use the term teacher professional development (TPD) to refer to the entire spectra of a teaching career, starting with pre-service, progressing to the first years of novice teaching and finally becoming an experienced teacher. Whereas all phases of a teaching career basically have the same goals for professionalization (how learning to teach is organized and facilitated), the three phases focus on different situations for teachers regarding prior knowledge and experience in teaching and their role as a professional teacher. The pre-service teacher is experiencing an education that leads to formal qualifications, with courses connecting subject (science) to pedagogy and "didactics" and finally to classroom practice. It is almost impossible for all of these individual components to come together into a coherent understanding of practice before actually becoming a classroom teacher. The novice teacher (a professional in the making) is in need of support for implementing the theories and ideas learned in initial teacher education within the system of the school where theory meets practice. The experienced teacher has needs related to maintaining a connection to recent literature and research by attending courses introducing new research findings and by reflecting on one's own practice in a systematic way, realizing that things can always be done differently and perhaps better.

ACTIONS WITHIN THE EU TO SUPPORT SCIENCE IN SOCIETY

Science in Society is an official part of the overall funding scheme for the European Union.[4] Following the publishing of the report Science Education Now; A Renewed Pedagogy for the Future of Europe (Rocard et al., 2007) an emphasis was made on the funding of projects related to the improvement of science teaching through the use of inquiry based science teaching (IBST). The text for the funding scheme reads as follows:

> Falling interest in key science topics and mathematics has been linked to the way they are taught from the earliest age. Therefore, greater emphasis needs to be placed on the development of more effective forms of pedagogy; on the development of analytical skills; and, on techniques for stimulating intrinsic motivation for learning science, taking into account various pre-conditions and cultural differences.
>
> This topic will support actions to promote the more widespread use of problem and inquiry based science teaching techniques in primary and/or secondary schools as well as actions to bridge the gap between the science education research community, science teachers and local actors in order to facilitate the uptake of inquiry-based science teaching. The actions are intended to complement school science curricula and should particularly focus on teacher training activities and the promotion of European teachers' networks. The actions proposed should be open to the participation of entities seeking to gain experience in the area of problem- and inquiry based science education techniques.

The training of the teachers should include actions that contribute towards the following:

> securing basic knowledge, developing a task culture, learning from mistakes, cumulative learning, autonomous learning, experiencing subject boundaries and interdisciplinary approaches, differentiating between girls' and boys' interests and promoting pupils' cooperation. The actions aimed at here shall already have proven their efficiency and efficacy.

The first project funded within this scheme (Science-Teacher Education Advanced Methods (S-TEAM)[5]) is running from May 2009 until April 2012. S-TEAM was preceded by the Mind the Gap project[6] running from April 2008 until March 2010, serving as a pilot project. The Mind the Gap project included Norway, Germany, Spain, UK, France, Hungary and Denmark. The two year project began the discussion about how individual countries view the ideas of IBST in their national curriculum statements as well as in teacher professional development courses. The S-TEAM project comprises 25 institutions from 14 countries (Norway, Finland, Sweden, Denmark, Estonia, Lithuania, UK, France, Germany, Spain, Czech Republic, Turkey, Cyprus and Israel).

Both projects aim at fostering inquiry teaching and build on a definition that promotes what is considered to be a modern view of inquiry in science teaching.

> Inquiry is the intentional process of diagnosing problems, critiquing experiments, distinguishing alternatives, planning investigations, researching conjectures, searching for information, constructing models, debating with peers, and forming coherent arguments. (Linn, Davis & Bell, 2004)

There are many different ways to characterize IBST as found in the science education literature. The trends in science education are described by Duschl and Grandy (2008) as a shift:

- From a goal of providing science education for scientists, to providing science education for all.
- From an image of science education as what we know, to science education as teaching science as a way of knowing.
- From an image of science education that emphasizes content and process goals, to science education that stresses goals examining the relation between evidence and explanations.
- From an emphasis on individual science lessons that demonstrate concepts, to science lesson sequences that promote reasoning with and about concepts.
- From the study of science topics that examine current scientific thinking without regard for social context, to the study of science topics in social contexts.
- From a view of science that emphasizes observation and experimentation, to a view that stresses theory and model building and revision.
- From a view of scientific evidence principally derived from sense-perception (either direct or augmented), to a view that evidence is obtained from theory-driven observations.

In the Mind the Gap and the S-TEAM EU projects, four dimensions of inquiry are promoted that seem to characterize inquiry based science teaching in national perspectives in Europe:

- 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 activities where students' autonomy is emphasized
- Discursive argumentation and communication with peers (talking science)

All of these characteristics have been shown to have a positive influence on the learning and understanding of science and on pupils' attitudes towards science. However, in order to strengthen the role of IBST in classrooms, reforms in pre-service and in-service teacher education are crucial since teachers are responsible for setting up the classroom conditions so that inquiry may take place. As stated by Bybee (2000):

> teaching science as inquiry means providing students with diverse opportunities to develop the abilities and understandings of scientific inquiry while also learning the fundamental concepts of science. The teaching strategies that provide students those opportunities are found in varied activities, laboratory investigations, and inquiries initiated by students.

The Mind the Gap and S-TEAM projects both have concentrated on the role of the teacher for the implementation of IBST in science classrooms. As a starting point experiences from the German large scale TPD programme SINUS are used to initiate discussions about the development of a common framework for TPD that can be shared by all EU countries.

SINUS – A MODEL FOR EFFECTIVE TPD IN GERMANY

The SINUS approach (Increasing the efficiency of mathematics and science instruction) was selected as a model for the Mind the Gap and S-TEAM projects because it is one of only a few initiatives in Europe that was designed for a non-uniform education system (Germany has 16 federal states with their own laws and regulations concerning education, their own curricula and a diversity of different types of schools through its almost unique tracking system). The size of the programme and its duration was the result of a change in the promotion of innovative educational projects by the government (Prenzel & Achtenhagen, 2000). Could the success of the SINUS programme in Germany be exportable to other European countries and contexts?

The SINUS programme was initiated in 1997 as a direct result of the TIMSS findings in Germany. Germany was not pleased with what they called mediocre results compared internationally. The aim of the SINUS programme was to improve instructional quality and to then systematically disseminate this within the school system (Prenzel, Stadler, Friedrich, Knickmeier & Ostermeier, 2009).

A comprehensive approach was developed by drawing on research from education, educational psychology and science education in order to address a broad range of challenges in science instruction and to meet quality criteria for effective TPD (Garet, Porter, Desimone, Birman & Yoon, 2001; Loucks-Horsley, Hewson, Love & Stiles, 1998). The SINUS programme recognizes the professionalism of teachers, allowing them to critically reflect on their own instruction and provides support for them in finding solutions to the challenges they face in teaching. In a period of nine years, the programme has managed to reach nearly 1,800 schools throughout Germany and has allowed for the monitoring of outcomes that can be generalised despite different conditions in the federal states and in individual schools (Ostermeier, Prenzel & Duit, 2010).

There are four principles that constitute the concept of SINUS (Prenzel & Duit, 2000; Prenzel, Stadler, Friedrich, Knickmeier & Ostermeier, 2009):

- A set of eleven 'modules' describing problem areas of science education and translating them into work packages
- The introduction of quality development at the participating schools
- The collaboration of teachers in their own school and with teachers in other schools and researchers to work on teaching problems (school based TPD)
- Support of the teacher networks

SINUS provides a flexible framework of modules for working on pedagogical problems in science teaching. These challenges are derived from various sources of research (Baumert, Bos, & Lehmann, 1998; Baumert et al., 1997; Stigler & Hiebert, 1997). In each module a specific problem area of science instruction is described followed by research-based suggestions of how to overcome the difficulties illustrated by examples. The module approach serves several purposes:

1. Modules provide a shared language for challenges that many science teachers experience. This allows teachers to start discussions about their own instruction with their colleagues, to become aware of common shortcomings and to work towards changing unsatisfying teaching practices.
2. Each module introduces alternative approaches to teaching with evidenced improvements in student learning. Hence, teachers working with the modules are likely to experience positive changes in their classrooms when they introduce changes in accordance with the suggestions.
3. The modules are illustrated with examples to show alternative teaching approaches, thus helping to facilitate the modification of instructional approaches and materials by teachers.
4. The modules can be selected independently from each other so that teachers can concentrate on the aspects of instruction they find most important, thus avoiding too many changes happening at once.

The following list gives the titles of the eleven modules and a short description of the particular challenge addressed by each:

(1) Further development of the task culture
Aims at a larger variety of tasks in mathematics and science instruction (e.g. tasks that allow for different ways of solving them) both in situations where a new concept or phenomenon is introduced and elaborated, as well as when skills are practised or knowledge is applied to new cases or situations.
(2) Scientific inquiry and experiments
Focuses on more open forms of experiments that allow for active student participation, discourse among students about research questions, the planning and interpreting of experiments, and an understanding of the nature of science.

(3) Learning from mistakes
Claims that mistakes are essential for learning, but should be avoided in assessment situations; students' conceptions and mistakes are viewed as opportunities for learning.

(4) Securing basic knowledge – intelligent learning at different levels
Addresses the need for a common knowledge basis that all students are to achieve; takes into account the different pre-requisites for learning offering tasks that allow for solutions on different levels.

(5) Cumulative learning – making students aware of their increasing competency
Aims at a higher coherence by linking the actual subject matter to prior knowledge; also stresses the need for using and developing basic concepts in order to design cumulative teaching and learning sequences that make learning progress obvious for the students.

(6) Making subject boundaries visible: working in an interdisciplinary way
Aims at a better understanding of scientific phenomena by differentiating and linking the perspectives provided by the different scientific disciplines, mathematics, and other school subjects; allows for more complex and meaningful applications of science.

(7) Promoting girls' and boys' achievement and interest
Focuses on gender differences with respect to interest and achievement; addresses possibilities for support, for example, by establishing differential courses or by embedding the content to be learned in contexts that are especially interesting for girls, but also for boys.

(8) Developing tasks for student cooperation
Encourages students to verbalise what they think, to argue, and to deal with discrepant views and opinions, so that cooperative work will result in social learning as well as in cognitive gains.

(9) Strengthening students' responsibility for their learning
Supports students' readiness and ability for self-regulated learning within the context of the particular subject; supporting strategies for the self-structuring and self-monitoring of learning are to be explored.

(10) Assessment: surveying and providing feedback on competency increases
Takes into account that the type of assessment is of utmost significance for the success of instruction; aims at developing supportive feedback and assessment tasks that allow for the evaluation of students' progress beyond routine knowledge.

(11) Quality assurance within and across schools
Aims at developing standards for science and mathematics instruction that are universally valid (and not only in the participating schools).

Although the modules were developed for the German situation of science instruction at the end of the 1990s the problem analyses are still valid because of the slow pace of change processes in the educational system. Furthermore, discussions with science educators and policy makers in the field revealed that the challenges are shared in many European countries despite the cultural and organisational differences in the respective education systems.

In addition to the modules the design of the SINUS programme comprises a number of features that are regarded as crucial for effectively implementing innovation in education and achieving sustainable improvements. The whole design intends to further develop and strengthen the professionalism of science teachers. A minimum requirement for a school to participate is the commitment of the school to the principles of the programme, expressed by a decision of the department of science teachers and an approval by the school leadership.

In SINUS the central working unit is the group of science teachers of one school who meet on a regular basis working collaboratively on perceived problems of their instruction. In the beginning the teachers analyse challenges in teaching that they would like to work on, choosing one or two of the modules that are most appropriate for this purpose. Ideally, they take their own examples of instructional approaches and try to improve them in line with the modules' recommendations. After trialling the new material they reflect on their experiences and students' reactions, discussing with colleagues as a means of making further improvements in instruction.

Teachers are acknowledged as experts in teaching and learning who see it as their professional responsibility to improve their teaching and hence the learning of their students. They engage in a professional dialogue about teaching and learning with their fellow colleagues and researchers who offer ideas and advice of how to successfully improve instruction. In this dialogue teachers learn to reflect on the quality of their teaching, to diagnose their students' learning processes, to set up suitable instructional goals for all students in one class and to continuously develop, trial and evaluate new teaching approaches. The teacher groups of individual schools are connected to other groups in neighbouring schools and even in larger regions in order to allow for an exchange of material and approaches and hence benefit from work in these extended networks.

In order to make all this happen teachers need support and resources. SINUS developed a system of facilitators who introduced the teacher groups to the approach, helped them to select modules and goals, provided examples of how to start the work and gave advice whenever needed. The programme offered regular meetings at the regional and national levels where renowned researchers introduced new ideas. Additionally, it established connections to other institutions in the field of teacher professional development like universities, state institutes for teacher professional development and school authorities in order to sustain support after the funding period. There was only a small amount of compensation for the participating teachers regarding teaching duties (only at the school level and during the five years of the pilot programme) and a small budget for purchases and training sessions at individual schools.

The SINUS approach gives ownership in the development process to the teachers. They are free to choose appropriate modules, set their own goals, agree on a working scheme and adjust their workload in the programme according to specific conditions in their school. This approach serves for keeping motivation high and lets the teachers adopt new approaches that fit their personal needs. It is assumed that teachers will only continue to work on the improvement of their teaching after a termination of the programme if they perceive the work in the programme as helpful. Thus, ownership is crucial for sustained quality development.

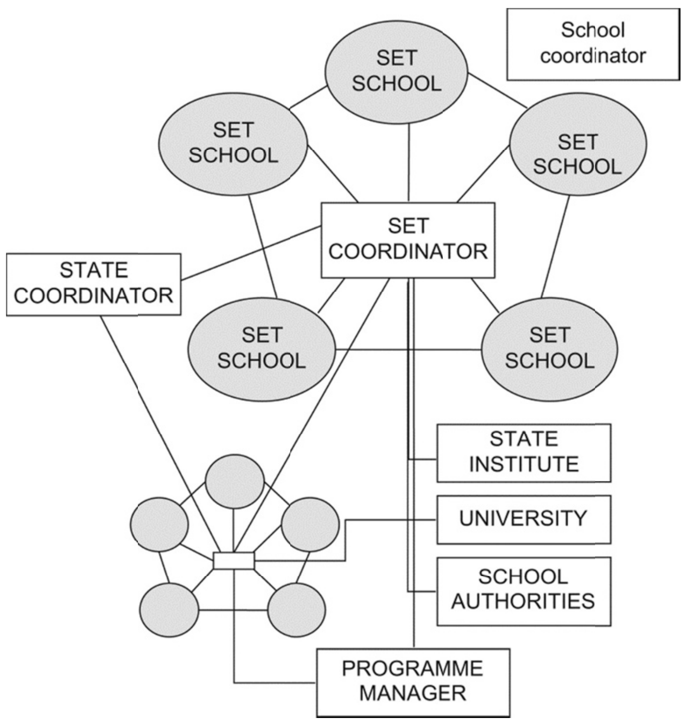


Fig 1. Organisational structure of the German SINUS programme (1998 – 2007) for the improvement of science and mathematics instruction

Evaluations carried out in the course of the nine-year programme produced evidence demonstrating an impact at different levels. At the end of the nationwide programme more than 10,000 teachers in about 1,800 secondary schools (grades 5–10) participated, representing about 15% of general secondary schools in Germany. At the teacher level results showed that teachers made use of the offered support and invested time and effort into the development of instruction. They established collaboration within their schools, evaluated the work as productive and perceived personal growth (Ostermeier, 2004; Ostermeier, Carstensen, Prenzel, & Geiser, 2004). At the classroom level students perceived changes regarding applied teaching methods and cognitive stimulation increased. At the student level motivation and self concept as well as performance improved compared to students from a representative sample of schools not participating in the programme

(Ostermeier, Prenzel, & Duit, 2010; Prenzel, Carstensen, Senkbeil, Ostermeier, & Seidel, 2005).

All in all the experiences with SINUS in Germany show that it is possible to implement innovation in schools on a broad basis and to have a positive impact on the system. They confirm findings from research on teacher professional development stating that "professional development yields the best results when it is long-term, school-based, collaborative, focused on students' learning, and linked to curricula" (Borko, 2004; Garet, Porter, Desimone, Birman, & Yoon, 2001; Hiebert, Gallimore, & Stigler, 2002; Loucks-Horsley, Hewson, Love, & Stiles, 1998).

EXPLORING CURRENT MODELS OF TPD IN EUROPE / MODELS FOR ORGANIZING TPD IN DIFFERENT COUNTRIES IN EUROPE

Within the first year of the S-TEAM project a series of national seminars was organized in the participating countries in order to initiate discussions about the state of science education, prevailing problems, needs for reform, and promising approaches to improve science education. Important stakeholders in the educational system (representatives from science and teacher education, from the ministry of education, from teacher education institutions, from teacher's and parent's associations and from industry) were invited to these seminars. Participants were asked to explain their views on strengths and weaknesses of their particular systems and what each group of stakeholders could contribute to the improvement of the educational system. In order to provide views and ideas from outside the particular country, current trends in European science education policy and experiences from the German large scale TPD programme SINUS were introduced by the authors of this chapter.

Despite large differences between the educational systems in the participating countries concerning for instance students' performance, the amount of money spent, the quality of teacher education programmes, the extent of centralisation, and the integration of IBST into curricula, there was one common opinion held by all participants: TPD was not regarded as effective and successful as far as the promotion of changes in science teaching was concerned. In all countries, the need for a sustainable model of TPD was stressed (Lipowski & Seidel, 2009; Jorde et al., 2010).

TPD in Europe is neither systematic nor sustainable. Regardless of its organization most offers do not meet the prerequisites for successful TPD (collaborative, long-term, school-based, linked to curriculum, focusing on student learning) identified by research. All educational systems try to identify the needs of teachers and appropriate forms of TPD. They seem however, to fail in offering TPD that helps teachers to improve their teaching skills. Most TPD activities are short and singular events focusing on content knowledge. Furthermore, there seem to be no effective means for measuring effects of TPD which makes it difficult or even impossible to monitor and develop the quality and impact of the activities.

In order to illustrate the diversity of the different TPD models found, we briefly describe the situation in Turkey and Denmark. Turkey has a rather centralized educational system. The Department of In-Service Training in the Ministry of National Education is responsible for organizing training activities for teachers. Every year an annual in-service training plan is prepared by the Department of In-service Training in collaboration with other ministry departments. This plan includes priorities for the training, time, place, and date of the training period, training programme, the teaching staff who will give the training and the personnel who will receive the training. The nationwide training plan is mainly put into practice within two weeks during the summer holidays.

In Denmark, choosing professional development activities is the responsibility of the individual school. Danish schools receive funding from the government and are responsible for their own internal budgets, with few restrictions. Concerning TPD, each school decides on which teachers participate and how often. Despite these fundamental differences in the organization of TPD in Turkey and Denmark both countries show similar, i.e. rather low participation rates of teachers according to the TALIS report (OECD, 2009). Whereas in the 23 participating countries on average 89% of teachers in lower secondary education engaged in professional development within the last 18 months, the numbers for Denmark and Turkey were only around 75%.

Teachers, and especially science teachers, do not seem to have a strong perception of themselves as being professionals. For other professions like medical doctors or lawyers it is self-evident that updating ones knowledge to follow developments in the discipline is a requirement for success. In the teaching profession, however, there is a breach between initial teacher education and TPD. In many educational systems there are no constraints for further development for teachers once they have received their teacher qualifications or a permanent post. In many European countries TPD is mandatory mainly for professional advancement, for instance to become a school principal or for obtaining higher salaries. But even in the latter case teachers only have to collect a certain amount of professional development hours (for instance in Spain; 120 hours within 6 years) without any restrictions regarding the content of the courses.

Another problem lies in the lack of sustainability of educational innovations. The examples of SINUS in Germany and the Science Learning Centres in the UK[7] show that even successful approaches with high quality TPD are at risk because of a fixed-term funding. This problem might be due to the fact that there are already systems in place which compete with the new initiatives for resources without appropriate quality regulations. Under such conditions competition does not lead to improvement but apparently to a resistance towards change.

The Case of Norway

Norway is an interesting country to use as a case, since they have strong traditions of TPD in terms of commitment. At the same time, Norway experiences many of the same problems other countries encounter in that TPD is short term, and in most cases, not school based; both of which do not allow for long term sustainability. TPD in Norway consisted of two types: short in-service courses without credits and longer, subject related courses providing credits. In both cases, the individual teacher was the participant and not an entire school or group of teachers from a school.

Norway participated in the Mind the Gap and the S-TEAM projects where TPD was developed using the school based SINUS model from Germany. In response to thinking about school based TPD, the government provided funding for a pilot project. The Norwegian project is called "School based development in Science (SUN)", and is running a pilot in three nodes in Norway: Oslo, Bergen and Trondheim, with three slightly different models for implementation. What is common to all nodes is that teachers from the same schools are identifying the challenges they wish to work with, together with science educators from the local universities. In Oslo, high school science teachers are looking at how inquiry based methods may improve their teaching and have chosen to use the 5E model of instruction (Bybee et.al., 2006). Participants include experienced teachers as well as novice teachers, making the dynamics of discussions and wiki exchanges important since experiences are so varied. Older teachers come into the project with lots of experience and need encouragement to think a bit differently about their established teaching practice, whereas novice teachers have more modern ideas yet lack experience in classroom management, for example. Teachers have developed networks using a common wiki for sharing ideas and experiences. Science educators from the University of Oslo meet regularly with the participants to introduce research literature, to listen to discussions promote new ideas for classroom practice. A similar network of teachers is established in Trondheim together with The Norwegian University of Science and Technology (NTNU) as well as in Bergen, together with the University of Bergen (UiB).

The project will be evaluated in 2012 with an eye towards scaling up the implementation of school based TPD. What we know already is that this type of TPD is much more appropriate and inspirational for teachers than traditional types of TPD based on courses and short events. Teachers are changing the way they teach based on just a few months of discussing pedagogical aspects of their teaching. The model will require that Norway develop similar nodes throughout the country, based on proximity to universities and colleges where teacher education takes place. In addition, teacher educators will need to become a part of the model for interacting with local schools. Finally, we will need to consider how local schools will have the possibilities for developing their own networks, both physically and through shared wikis. This model is not inexpensive. Yet, when we consider the amount of funding going into less successful models of TPD, we will argue for transferring funding towards a school based model. If we are successful, we see a long term scaling-up of the Norwegian SUN project.

WHAT CAN BE DONE TO MOVE TOWARDS MORE EFFECTIVE TPD?

The S-TEAM collaboration has provided the opportunity for many European countries to look comparatively at their educational systems and their mechanisms for TPD. We have been able to identify criteria that seem to be necessary for improving TPD and have started to look critically at inclusion into existing systems of teacher support. The sharing of experiences between countries and programmes has been an important way for us to move forward as we criticize our current practice and initiate projects to make improvements. However, there is a weakness in that most of these initiatives are small scale and rarely have a long-term perspective. We lack systemic approaches that take into account the complexity of the educational system. Instead we tend to implement simplistic solutions for isolated problems. Too often politicians believe – and researchers often support them or even share this believe – that quality will prevail in the long-run and good ideas will spread without taking any further actions. This is certainly not the case.

At the European level there is an awareness of the need for concerted actions in order to achieve an impact at the systems level. The development of a few general models incorporating the most important aspects of effective TPD (collaborative, long-term, school-based, linked to curriculum, focusing on student learning) are beginning to serve as our "cases" for implementation. Then these models will need a content framework like the modules in SINUS in order to address prevailing problems in science teaching. These frameworks will need to be flexible in order to allow for adaptations and the integration of specific topics of importance for some cultures and countries. In the individual countries there have to be discussions and negotiations with all stakeholders (policy, teachers, school authorities, teacher education, parents, pupils) in order to achieve a consensus about the aims of the reform initiatives, the contribution of every group, and the prerequisites. It has to be clear that such a reform is designed to change the respective system step by step and not once as a whole in order to allow for the development of adequate activities and routines.

APPENDIX I

The following example shows a "typical" way of presenting experiments in science classrooms, followed by ideas on how small changes may be important for challenging students' thinking.

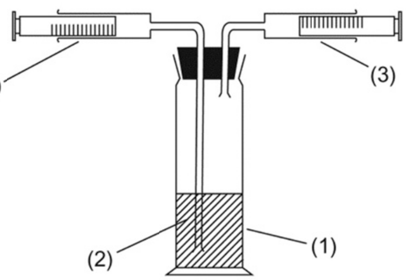
Working with Module 2 (Scientific Work)

In traditional instruction, experiments are often used as a proof for a scientific law or a concept. When students are asked to do practical work, a detailed worksheet is usually provided. The heading of the worksheet gives the topic followed by a detailed description of the procedure to be followed. An illustrating picture of the equipment or the apparatus to be used often helps students to figure out what to do. In many cases, such descriptions of experiments have an additional introduction giving a short overview of the chemical concept addressed by the experiment (which in our case would have been that carbon dioxide dissolves in water to form carbonic acid, see picture). You can also find examples giving chemical equations and results of calculations at the end. It is evident that such an experiment neither challenges students' thinking nor gives an opportunity to discover anything.

Solubility of carbon dioxide in water

Conducting the experiment:

Fill the washing bottle (1) with 250 ml of boiled water (2) and replace the air in the bottle with nitrogen. Let the apparatus cool to room temperature and measure the pH-value.



Attach a gas syringe (3) to the outlet of the washing bottle and a gas syringe filled with carbon dioxide (4) to the inlet. Let the gas pass slowly through the washing bottle (about two minutes). Calculate the volume of the carbon dioxide that was dissolved in the water by measuring the volume of the gas in the second gas syringe. Measure the pH-value again.

In order to shift away from a setting where students simply follow cook book recipes without understanding, teachers from one SINUS school designed the following experiment (Stäudel, 2004). They omitted all information that could be discovered by the students themselves and set the problem in a more familiar context. They expected that this would allow for questions to originate that were interesting for the students.

The teacher prepared a water basin with a measuring cylinder upside down filled with water. He put one effervescent tablet under a funnel fitted into the mouth of the cylinder. When the tablet dissolved students observed that small bubbles formed. The bubbles rose through the cylinder and accumulated in the upper part. After discussing the students' observations the teacher asked what would happen if another tablet was dissolved. Concerning the amount of gas formed the class agreed that the same amount would be formed as with the first tablet. After dissolving the tablet, however, students realized that the amount of gas from the second tablet was larger than from that of the first.

The teacher let students think and discuss in pairs about possible reasons for their observations. Afterwards, the ideas were shared with the whole class. Eventually, some students came up with the idea that a part of the gas from the first tablet had dissolved in the water. The teacher asked the students (in groups) to design experiments that could give evidence for this idea. The suggestions were again discussed with the whole class and those that were regarded as suitable and helpful were then conducted by the students.

This example also features aspects of some of the other modules. It places a different emphasis on the tasks given to the students (module 1 - task culture) by turning away from simply reproducing what is known in science towards inquiring into what is unknown to the students. In order to be able to provide an appropriate learning environment the teacher tries to reveal students' concepts and ideas about the topic at the beginning of the lesson (module 3 - learning from mistakes and student concepts). Through questioning and group work, the teacher takes these ideas seriously, challenges them and offers opportunities to further develop or reframe them so that they become more useful and flexible. Also modules 8 and 9 (cooperation of students and responsibility for own learning) are addressed.

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NOTES

1. For more information on statistics based on human resources in science and technology in Europe see: http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Human_resources_in_science_and_technology
2. http://sinus-transfer.uni-bayreuth.de/home.html
3. http://www.pollen-europa.net Pollen participants have become a part of the new fibonacci project funded by the Science in Society programme - http://www.fibonacci-project.eu/
4. http://cordis.europa.eu/fp7/sis/home_en.html, http://ec.europa.eu/research/science-society
5. https://www.ntnu.no/wiki/display/steam/SCIENCE-TEACHER+EDUCATION+ADVANCED+METHODS
6. http://www.uv.uio.no/english/research/projects/mindingthegap/
7. https://www.sciencelearningcentres.org.uk/

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