Strand 10

Science curriculum and educational policy

CONTENTS

INTRODUCTION

Science curriculum reform has been a topic of interest to researchers since the post-Sputnik era which began in the 1960s. The demand for more modern and more appropriate curricula emerged as a policy response to the perceived technological race between the West and the Soviet bloc. The influence of these curriculum developments spread across the globe. More recently, international studies such as TIMSS and PISA have encouraged policy-makers to judge the performance of their country's education systems against the rest of the world. Countries as diverse as South Korea, Canada and Finland have found themselves held up as beacons of excellence in terms of the way they teach science and mathematics.

In parallel to a policy-driven desire to 'do well' in international comparisons, there has been an increasing focus on giving all students the opportunity to encompass the scientific and cultural background that allows them to become responsible citizens, capable of understanding and taking action in a world where science and technology occupy a predominant role. New science curricula tend to focus on scientific problem solving with methods and skills to be acquired and attitudes such as critical thinking to be inculcated. Students and future citizens are expected to be able to distinguish and recognise science in society, and develop skills to be able to utilise scientific theories as a basis for discussion and explanations of the science and technological phenomena they meet in their everyday lives.

Research on science teaching, the science curriculum and educational policies has attracted the attention of many science educators and researchers during the last decades. The field of research presented in this strand explores numerous aspects and perspectives. The strand covers a number of topics: curriculum development; reform implementation; dissemination and evaluation; international comparison studies such as TIMSS and PISA; evaluation of schools and institutions; and, local, regional, national, or international issues of policy related to science education.

The Strand Papers

The papers submitted for consideration to this strand are diverse in terms of geographical context, subject matter, research methodology and the age of the participating students. Some involve case studies of individual institutions, some look at Mathematics, Science and Technology in a region or a country, and others present cross-national comparisons. Together they provide an insight into the key issues facing a number of stakeholders including schools, teachers and policy makers.

Focusing on learners in one particular school, Patrick Löffler and Alexander Kauertz, from Germany, report on 'Applying physics models in context-based tasks in physics education'. Their starting point is that little is known about the processes of how learners apply physics models to problems in real life situations (context-based problems). They set out to investigate which features of the context can be used to help students find physics solutions for the problems using think-aloud protocols and a video study of ten 10th grade students from a German middle school. The authors found that students tried to link elements from the context (‘real world’) and the physics model (‘model world’) with opposite effects.

Fernanda Franzolin and Nelio Bizzo from Brazil present a study entitled ‘Basic genetics content in secondary education: Comparing high school teachers’ and faculty members’ opinions with the university curriculum’. Their study aimed to identify high school teachers’ and university faculty members’ opinions with the basic genetics concepts that students finishing secondary education should know to become informed citizens capable of critical thought. The study also determined whether these concepts are being considered by higher education institutions during teacher training. The opinions of faculty members and the curricula of the areas that they teach were similar, but in one city there was a difference of opinions concerning biotechnology. Such a difference in opinions is important for stimulating critical reflection, but these topics should be taught in conjunction with other basic principles.

In ‘Essentials of science – Development, evaluation and transfer into school practice of a competence oriented science course’, Cornelia Stiller, Andreas Stockey, Stefan Hahn and Matthias Wilde from Germany describe an attempt to improve competency in scientific literacy which involved developing, testing and evaluating a competence oriented science course for grade 11, with an emphasis on self-regulation in experimentation at an experimental school in Germany. The success of the intervention depended on several factors, including characteristics of the innovation, of teachers and of the environment and supporting activities. In this paper, the authors present the main characteristics of the course concept and its didactical approach to teaching. They also identify important preconditions in the procedure of transfer that effect its successful implementation into general school education. The possibility of scaling up the innovation are discussed in the light of the research findings.

James Watters and Clare Christensen, from Australia, present a study entitled ‘Vocational education in science, technology, engineering and maths (STEM): curriculum innovation through industry school partnerships’. The authors report the preliminary findings of an attempt to develop two curricula that attempted to integrate science and mathematics with workplace knowledge and practices. The curricula were co-developed by industry and educational personnel across two industry sectors (mining and aerospace) with a view to providing knowledge appropriate for students moving from school to the workplace in the respective industries. The authors argue that these curricula provide educational opportunities for students to pursue their preferred career pathways. Their findings highlight the importance of teachers having substantial practical industry experience and the role that whole school policies play in attempts to align the range of learning experiences with the needs of industry.

Jan Petr, Iva Stuchlíková and Miroslav Papáček from the Czech Republic, present their study, ‘Biology Olympiad as a model for inquiry-based approaches’. The authors look at the possible school application of tasks which were originally produced for competitions. They found that while teachers can use competition activities there are some limits because the tasks are designed for extra-curricular use and for gifted youth.

A multi-national team from the UK comprising Kathryn Woods-Townsend, Andri Christodoulou, Jenny Byrne, Marcus Grace, Janice Griffiths and Willeke Rietdijk report on their study ‘Meet the Scientist: the value of short interactions between scientists and secondary-aged students’. Twenty scientists from eight different professional areas were asked to share their experiences of becoming and being a scientist in 20-minute sessions, with groups of 7-8, 13-15 year-old students. Pre/post-questionnaires were used to assess students’ views of scientists and their work, and scientists’ experiences of interacting with students. The face-to-face interactions allowed students to view scientists as approachable and normal people, and to begin to understand the range of scientific areas and careers that exist. The student-scientist interactions were also valuable for the scientists, who saw this opportunity as a vehicle for science communication.

Joana Torres, Sara Moutinho and Clara Vasconcelos, in their paper, ‘Questioning in natural science tests and textbooks: A look into the Portuguese curriculum’ note that the country’s Natural Science Portuguese Curriculum ‘highlights the development of conceptual, reasoning and communicative competences’. Within this approach, which ‘favors students’ active engagement and a personal construction of knowledge, questioning is considered a powerful tool in the learning process’. Using a case study approach of a school in the north of the country, the authors examine the nature of questions applied in natural science textbooks and natural science tests based on their cognitive level. Despite the ambitious curriculum, the ‘number of questions of high cognitive level is low in textbooks, as well as in tests, revealing some inconsistences between curriculum suggestions and what is really done in science classes’. The authors argue that ‘it is important to coordinate curriculum demands with teachers’ knowledge, as well as with science textbooks elaboration’. The authors argue that it is necessary to improve textbooks ‘by including material and questions consistent with an inquiry-based approach’ – an approach which has been heavily promoted in many countries in the European Union.

Although most papers in this section focus on curriculum and pedagogy, Ann Mutvei and Jan-Eric Mattsson, from Sweden, examine ‘The impact of performance assessment on science education at primary school’. Sweden’s new curriculum for primary and secondary schools contains more explicit educational targets than before. School science education now has to be linked to the students’ own experience. There is a stronger focus on developing students’ critical thinking in terms of the ability to review arguments and to argue in situations where knowledge of science is important.

Three colleagues from Spain, Carolina Pipitone, Digna Couso and Neus Sanmartí report on their study into ‘Teachers' perspectives regarding a new subject: “Science for the contemporary world”’. The authors set out to identify the differences between the Implemented Curriculum (IC) as reported by teachers, and the Potential Curriculum (PC) according to official documents and science education literature. They identified four ways of perceiving the PC, three of them in agreement with a competence-based framework while the last one, associated with standard teachers, completely distorts the proposed rationale of the subject.

Providing a study of an education system set in an economic crisis, Katerina Plakitsi, Anna Spyrtou, Katerina Klonari, Michail Kalogiannakis, George

Malandrakis, Pinelopoi Papadopoulou, Euthimios Stamoulis, John Soulios, Panagiotis Piliouras and Nikolaos Kolios, from a number of universities in Greece, focus on innovations in primary education. In ‘New Greek Science Curriculum (NGSC) for primary education: promoting educational innovation under hard conditions’ the authors argue that it is important for a country under a crisis to have a high quality science education for all students.

Anastasios Siatras and Panagiotis Koumaras, from Greece, present a paper entitled, ‘Exploring the role of the science curriculum towards social justice’. The authors present a research model developed in order to analyse: (a) science education scholarship related to poverty, social exclusion, scientific literacy for all, and pedagogy and (b) science curricula of three different countries, so as to identify features that could transform science education to become ‘community science’ for all children. The authors examine science education scholarship as well as the science curricula using five different levels: 1) Intentions, 2) Content, 3) Methodology, 4) Assessment, and 5) Support. The analysis identifies features that can be used to design a science that may promote social justice and equity.

Päivi Kinnunen, Jarkko Lampiselkä, Lauri Malmi and Veijo Meisalo, from two Finnish universities, present a study entitled ‘Identifying missing types of Nordic research in science education’. The authors report on a new way to categorise research papers in order to obtain a comprehensive picture of science education research and to identify overlooked research topics. Their novel categorisation system is based on what they term, the ‘didactic triangle’ which is ‘a theoretical model describing the elements of teaching-studying-learning processes’. The approach supports meta-level analysis of published papers and the authors argue that it can contribute to discussions about the goals and the current state of science education research.

Evidence for the value of cross-country comparisons is provided by Theresa Schulte, Yiannis Georgiou, Eleni Kyza and Claus Bolte from institutions in Germany and Cyprus. Their study, ‘Students’ and teachers’ perceptions of school-based scientific literacy priorities and practice: a cross-cultural comparison between Cyprus and Germany’ involved a Delphi approach which investigated empirically the extent of any consensus between students and teachers, in terms of their assessments of what aspects of science education should be prioritised as well as the extent to which these aspects are currently practiced. The outcome of this cross-cultural research revealed that, except for some minor differences, students and teachers in both countries perceived large discrepancies between a desired status and the status quo in science education.

Stefano Vercellati, Marisa Michelini and Lorenzo Santi from Italy and Dagmara Sokolowska and Grzegorz Brzezinka from Poland examined teachers’ and students’ views of the curriculum in mathematics, science and technology (MST). They surveyed over 8,000 students and almost 1,500 teachers. In their paper, ‘Investigating MST curriculum experienced by eleven-year-old Polish and Italian pupils’, the authors report that despite differences in the curriculum between the two countries there is much in common in terms of what happens in the classroom. Perhaps disappointingly, they found that there is still ‘more passive and traditional teaching, with not much emphasis given to practical work and use of other materials than text books’. The assessment strategies are similar ‘with huge attention paid to written and oral tests’. The authors speculate about the reasons behind these similarities but more research is needed to fully explain them.

Yun-Ping Ge, Chang-Hung Chung, Len Unsworth, Huey-Por Chang and Kuo-Hua Wang report on a study entitled ‘What can images tell us? A cross-cultural comparison of science textbooks between Australia and Taiwan’. The study was designed to compare the images in Taiwanese and Australian high school science textbooks. The authors sought to investigate the images according to three metafunctions: ideational, interpersonal, and textual. Content analysis was used to analyze the sample units of biological classification, which are shared most consistently across six textbooks: three from Taiwan and the other three from Australia. While on the surface the text-books appear to be similar, closer analysis shows that Australian versions use more overt taxonomy which can explicitly represent hierarchical relationships of classification among concepts. Taiwanese versions use more covert taxonomy which is short of such function. The comparison of textual metafunction unfolds the hidden influence of image design comes from socio-culture. The results from these three metafunctions all confirm there are differences of image design between the science textbooks of Taiwanese and Australian. The implications for images teaching are discussed.

Three papers focus on the EU-funded project SECURE (Science Education Curriculum Research). In one, Jessie Best, Meike Willeke and Gesche Pospiech describe the project’s implementation in Saxony in Germany. Their research focuses on students from 5-13 and their MST teachers and covers three different aspects of the curriculum: the intended (represented by the formal written curricular documents), the implemented (as perceived by the teachers) and the attained (learning experiences of the students as well as experiences in teaching of the teachers). The authors used questionnaires and interviews in a quasi-longitudinal study. In primary school the regular use of many different approaches (for example, group work, individual learning, out-of-school learning) is very common, whereas in secondary school the variety of approaches decreases. As in many countries, in primary education, out-of-school learning is considered to be more important. In order to reduce the gap between primary and secondary education, the authors argue for more communication between schools.

In a second study on the SECURE project, Dagmara Sokolowska and Barbara Rovsek from Poland and Job De Meyere and Wim Peeters from Belgium report on research carried out in almost 600 classes which involved around 9,000 learners and 1,500 teachers. The authors report on learners’ attitudes towards MST school subjects and teachers’ attitudes towards teaching and curriculum goals.

The third SECURE paper, ‘Perceptions of teachers and learners about the mathematics, science and technology curricula in two European countries’ looks at findings from Austria and Cyprus which have very different curricula. Veronika Rechberger, Michalis Livitziis, Judith Aldrian, Maria Hadjidemetri, Costas Constantinou and Leopold Mathelitsch found that ‘differences in systems and curricula seem to effect teachers’ and learners’ perceptions and practice’. However, there were many similarities in terms of ‘the perception of teachers and learners in relation to the implementation in class’.

Perhaps surprisingly, there are relatively few papers which look at data from the PISA studies. In 'Curriculum policy implications of the PISA scientific literacy framework', Harrie Eijkelhof from the Netherlands argues that PISA results should be interpreted with care. He also presents examples of implications for educational policy in various countries and provides recommendations for future international curriculum development.

Finally, María Isabel Hernández and Roser Pintó, from Spain, report on a study entitled 'How do funded science education projects disseminate their outcomes to target audiences? Analysis of the current status and recommendations for more effective dissemination'. The authors present an analysis of the dissemination strategies used in funded science education projects. The study identifies the difficulties and needs of several stakeholders involved in dissemination processes including project managers or researchers, science teachers, advisors of policy-makers, and science communicators. The authors devised two instruments for data collection, an online questionnaires and on-line or face-to-face discussion events. The paper concludes with an identification of some needs that should be taken into account to recommend measures to improve how dissemination is planned and carried out. These recommendations are summarised in this paper.

Final Thoughts

Taken together, these contributions indicate the widespread commitment within the ESERA community to researching curriculum and policy using a number of methodologies and, increasingly, using aspects of international and comparative education. We hope that you enjoy reading these varied papers.

Justin Dillon and Andreas Redfors

NEW GREEK SCIENCE CURRICULUM (NGSC)[1] FOR PRIMARY EDUCATION: PROMOTING EDUCATIONAL INNOVATION UNDER HARD CONDITIONS

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Abstract: The New Greek Science Curriculum for primary education aims to contribute to the current agenda about curriculum reform in Europe. It focuses on improving science education as a way of child development for a sustainable society. According to Bologna Process, we set the NGSC focusing on the Expected Learning Outcomes (ELO). Specifically, the NGSC aims to develop scientific skills, understandings and competences both inside educational institutions and in all societal "informal" settings where learning, culture and social interactions occur (i.e., museums, science centers, environmental parks, families, forest kindergarten). We argue that it is important for a country under a crisis to have a high quality of science education for all students. In this paper firstly, we describe the innovative characteristics of NGSC and afterwards we present research results concerning teacher's views about these characteristics.

Keywords: New Greek Science Curriculum, Science Education, Society.

INTRODUCTION

The NGSC tries to become a balanced open and/or closed curriculum, on comparing the best practices of the high scored countries in PISA, and giving emphasis on the relationship between formal and informal science education, on the connection of science education to society and everyday life, on effective hands on activities we really need, and, finally, on the school science textbooks and their role to improve a sustainable society (Whittle & Goel, 1999; Beyond, 2000; Science Education Now, 2007).

The New Greek Science Curriculum (NGSC) for primary school was designed by taking into account two pillars: (a) the current trends in science, technology, society, and environment curriculum development (STSE), and (b) the research and practice tradition in science education of the last decades. In respect of the first pillar, the envision of the curriculum developing group was making NGSC more consistent with the calls for scientifically literacy. In relation to the second pilar, the NGSC is based on the major pinpoints and recommendations of science education research. NGSC underpins the issue of high quality science education acting not only in formal but also in non-formal cultural settings (Plakitsi, 2013).

[1] The NGSC includes topics from Physics, Biology, Chemistry, Geography, Technology and Studies for the Environment.

THE NEW GREEK SCIENCE CURRICULUM

Basic characteristics of NGSC

In their final form, the primary NGSC is organized in two sections. In the first one, the rationale and the innovative characteristics of the curriculum are described, in addition to the poor Greek students' achievements on OECD PISA program (OECD, 2007, 2010; Anagnostopoulou et. al., 2013). The second section is divided into thematic topics and subsections for each one of the six Grade levels of primary school (Grade 1 to Grade 6). Each of these thematic topics is organized in four-column tables[2], in which the core issues and the ELOs for every topic under study are described, accompanied by a number of suggested activities and instructional material. The latter, following the guidelines of the Greek Institute of Educational Policy (IEP), mainly includes digital material, facilitating their use and dissemination into school practice. The core issues and the respective ELO are mandatory in nature, meaning that these at least have to be covered by teaching. On the other hand, the suggested activities and instructional material are indicative, in the sense that they only provide ideas and give examples to teachers for more effective teaching of the proposed issues, but they are not obligated to follow the particular ones.

Table 1 illustrates an example of the NGSC, from Grade 5, on the topic of energy.

Table 1

Example of NGSC from Grade 5, on the topic of energy.

Section 3.3: The energy wealth of our country now and in the future

Indicative time: 2 teaching hours.

Expected Learning Outcomes (ELO)	**Core issues**	**Activities**	**Instructional Material**
Students to be capable to collect, process and analyze information related to the energy wealth of the our country	The energy wealth of our country now and in the future: - Lignite - Oil - Sun - Wind - Waterfalls - Waves - Geothermic - Biomass	They fill the energy map of Greece They locate in the map the areas in Greece where lignite and oil deposits are available They collect information and discuss about the advantages of Greece regarding the renewable energy sources (sun, wind, waves, biomass, geothermic)	http://digitalschool.minedu.gov.gr/modules/document/file.php/DSGL101/Διδακτικό%20Πακέτο/Βιβλίο%20Μαθητή/Kefalaio_1.pdf In pages 18, 28 and 35 you can find information about the deposits of oil, lignite, and renewable energy sources in Greece http://www.youtube.com/watch?v=coWQ1R2r5MY Educational film titled: *«The journey of electric energy»*.

[2] It should be noted that the particular organization within sections (the tables) was among the guidelines of the Greek Institute of Educational Policy (IEP).

In addition to the NGSC, a teacher's guide was also developed constituted by:

(i) further elaboration of the innovative characteristics of each thematic section,

(ii) outlines about the new teacher's role and profile, and

(iii) nine indicative teaching scenarios, which implement in detail the principles and methods of specific NGSC topics.

Innovative characteristics of NGSC

We realize six innovative characteristics of NGSC (Figure 1). More specifically, it advocates the mutual and fertile relationship between Science and Technology, putting emphasis on the development of technical and inquiry skills *(School Science & Technology)*. For instance, 'students are encouraged to describe the problem or needs, to formulate hypothesis or ideas, to choose a hypothesis or idea and to test it, to experiment or construct a technological apparatus' (NGSC, p. 8).

Moreover the NGSC promotes the opening to learning communities beyond the traditional boundaries of the typical school environment, which provide multiple learning contexts necessary for the development of students' scientific and technological literacy *(Linking School with Society)*.

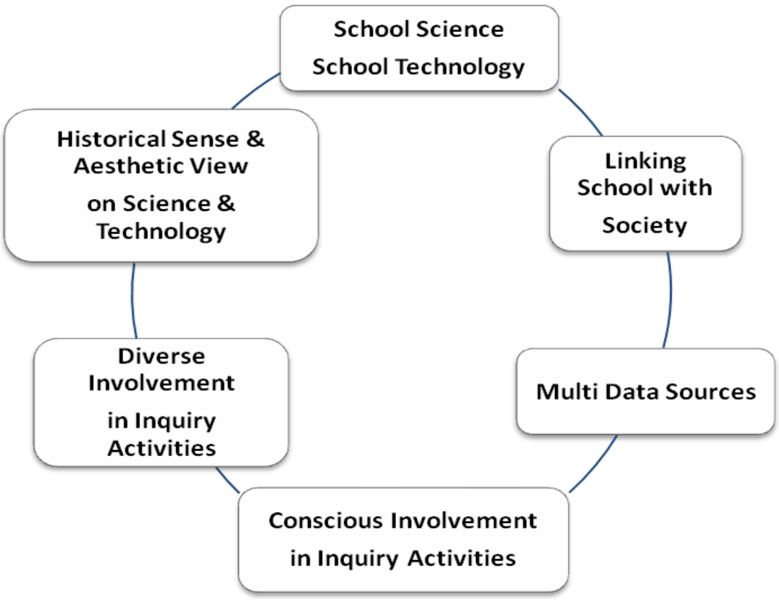

Figure 1. *Six Innovative Characteristics of NGSC*

METHODOLOGY

Research question

Based on the above, the basic research question that guided our study is the following:
- Which are teachers' views about the innovative characteristics of NGSC?

Procedure

The NGSC was implemented for pilot-testing during the 2011-12 school year into 99 schools with approximately 1200 teachers throughout Greece. Although, on a personal level, teachers' participation to the pilot testing of NGSC was on a voluntary basis, the central planning and organization of teachers' education and NGSC pilot testing was run by Institute of Education Policy (IEP) and Ministry of Education. However, this central coordination was characterized by severe omissions. For instance, at the beginning of the school year, the teachers of pilot schools had no clear idea of what they have to do.

A curriculum advisor visited each pilot school, supporting teachers in multiple levels and assessed the progress of NGSC implementation. All authors, who were also members of the curriculum development group, were acting, along with others, as curriculum advisors of schools, of school advisors and of teachers. Furthermore, a report was prepared by the advisors for every school about the actual level of NGSC implementation, mainly based on teachers' semi-structured interviews. These reports are the main data set for testing our first research question.

Data sources

Data used in the particular study retrieved from 28 reports –corresponding to 28 schools and 78 primary teachers- of curriculum advisors who visited pilot schools at the end of year-1 pilot implementation (spring 2012). These reports were based on one-to-one semi-structured interviews with teachers implementing NGSC. The interview questions were pre-defined by IEP and were in accordance with the goals and objectives of the NGSC. They were organized in four categories, each one containing 2-4 questions. An example from each of these groups of interview questions is presented in Table 2.

Table 2

Examples of semi-structure interview questions exploring teachers' views about the characteristics of NGSC during its pilot implementation

Category 1: Content of NGSC
In which extent teachers think that there is coherence and correspondence among the ELOs and the activities and teaching material suggested by NGSC and teacher's guide?
Category 2: Implementation of Multiple Teaching Methods
In which extent teachers believe that the implementation of multiple teaching methods is necessary for the achievement of ELOs?
Category 3: Use of ICTs and Other Teaching Materials
In which extent teacher believe that there is a need for multiple educational materials and ICT use for the achievement of ELOs?
Category 4: Students' Evaluation
In which extent the NGSC helped teachers to adopt an alternative students' evaluation model which will be integral part of the learning process

Data analysis

Curriculum advisors' reports were analyzed according to the process of qualitative content analysis (Cohen, Manion & Morrison, 2007). As a unit of analysis was defined each sentence or phrase in the reports referring to teachers' considerations about the NGSC characteristics. In a first step, the following dichotomous coding scheme was used to characterize each of these considerations:

(a) Positive consideration: when it was linked with a positive view on a NGSC characteristic, for example, "*NGSC really enhances students' involvement in inquiry activities"*.

(b) Critical consideration: when phrases exhibited reservations/difficulties or described prerequisites needed for the successful implementation of the particular characteristic. For example, "*Parents are unprepared to support the use of multiple sources*", "*More time should be allocated for implementing inquiry activities*".

RESULTS

Teachers' views

Teachers' views on the six innovative characteristics of NGSC concerning the application of primary Physics, Chemistry, Biology, Environment and Geography are summarized in Table 3. Clearly, three of the NGSC characteristics, seem to be most appreciated most by teachers, as gained the majority of their positive comments (i-iii).

Table 3
Teachers' views about the six innovative characteristics of NGSC

Characteristics of NGSC	Positive considerations	Critical considerations
i. Multi-data sources	74	30
ii. Conscious involvement in inquiry activities	44	8
iii. Linking school with society	39	10
iv. Diverse involvement in inquiry activities	16	13
v. Historical sense & aesthetic view on science & technology	2	
vi. School science & technology	2	4

A critical outcome is that multi-data sources got the largest number of positive as well as of critical considerations. A potential explanation for this, seemingly contradictive finding, could be that although Greek teachers are willing to further enrich their teaching methods with multiple data sources, they still have a strong reservation about the way it could be achieved, mainly due to the severe economic crises that the country faces. As a result, encouraging comments like '*[using other data sources]... lesson becomes more interesting, attractive, and innovative, so more productive for students*" strengthen the need to abandon the one, nationwide school textbook, are often followed by hints like "*...multiple data sources require adequate equipment e.g., computers, labs, libraries'*.

Concerning the second as well as the third NGSC characteristic, we realized that primary teachers seem willing to adopt them in their teaching, ascribing to them adjectives such as 'useful', 'interesting', 'unprecedented' etc. For instance, in the core issue of the reproductive system, a teacher enthusiastically notes: *'I found it fine [Linking School with Society]. Thus, in order to teach the human reproductive system I brought in the classroom a specialized doctor and a pregnant mother. They discussed with students issues like the health of the pregnant and the twin pregnancy. It was an innovative and interesting experience'.*

The fourth characteristic (Diverse Involvement in Inquiry Activities), either gains contradictive comments or lacks these at all. Some primary teachers claim that they already implement varied methods of teaching into their daily practice, taking into account their students' diversity, while others underpin the special difficulty for implementing it, e.g., *'It is very difficult to implement it. More time and effort is needed, so I prefer the use of the school textbook'.*

The lack of comments regarding the last two characteristics could be possibly perceived as a lack of awareness or interest on behalf of the teachers on these issues. However, such unfamiliarity is a common finding; teachers' professional development for teaching aspects of history and nature of technology and science is a complex and difficult process (Jones & Moreland, 2004; Akerson et al., 2011).

DISCUSSION

In this study we focus on a special education event in Greece: the introduction of NGSC during the period of financial crisis. We see this curriculum reform as a deep political action, trying to develop next generations' literacy in science for a sustainable society. In the first part of paper, we mapped the initial impressions of primary teachers about NGSC. It was ascertained that despite the severe organizational and structural problems at the beginning of the pilot implementation, teachers finally managed to engaged in their daily practice, even though in variant degree, the characteristics of NGSC.

Multi-data sources seem to be the most prominent among the innovative characteristics of NGSC. This is in line with the related literature where "*the issue of resources may be considered as a subset of curriculum, but it assumes such importance for elementary school teachers in science that special consideration is necessary"* (Appleton 2005, p.43). Nonetheless, this characteristic seems to be considered as the most associated with the financial crisis.

Furthermore, it was ascertained that beyond the tough financial situation, two main parameters of STSE education, the historical sense and aesthetic view on science and technology as well as the interrelation of science with technology are unfamiliar for primary teachers. This finding is in the heart of the related research on teachers' development of science pedagogical content knowledge (Park et al., 2011). We think that these two characteristics need more attention and discussion concerning their educational importance in teacher training programs. Nowadays, the ultimate goal of science education in Greece is to instill into teachers the appreciation for science and technology as an important cultural and intellectual process, embedded in complex and financially indebted societies; an achievement that may increase the number of new Greek scientists and technologists, contributing, in a long-term perspective, to the recovery of the Greek economy and society.

According to the general statistics provided by the IEP, the NGSC was very well receipted and often in an enthusiastic way by schools. More reliable conclusions could be provided from a possible expansion of the pilot implementation to more schools and for more time, given that training seminars and support to teachers would be continued. In any case, changes in education succeed, when we focus on people, both students and teachers, and giving them space for initiatives.

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EXPLORING THE ROLE OF THE SCIENCE CURRICULUM TOWARDS SOCIAL JUSTICE

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Abstract: In this paper we present a research model we have developed in order to analyze: (a) science education scholarship related to poverty, social exclusion, scientific literacy for all, and pedagogy and (b) science curricula of three different countries, so as to identify features that could transform science education to ‘community science’ for all children. Both science education scholarship as well as the science curricula will be analyzed using five different levels: 1) Intentions, 2) Content, 3) Methodology, 4) Assessment, and 5) Support. The analysis aims to identify features that can be used to design a science curriculum towards the development of science education that promotes social justice and equity. In this paper we present the preliminary results only for *Level 2: Content* which includes an analysis of teaching objectives related to the science content, the Nature of Science (NOS), scientific methodology as well as the socio-scientific issues.

Keywords: Science curriculum; science education; social exclusion; social justice

INTRODUCTION

Many scientists support the idea that science reflects an objective and indisputable knowledge without the implication of any sociopolitical values (see Poincaré 1920/1958, p.12, MacIntyre 1981, p.80). From this perspective, science teaching may often be based on teaching children amassed science concepts. With this view of science, it could be argued that the success or failure of students in learning science would depend entirely on their mental abilities regardless of the features of the science curriculum which are related to the social and cultural milieu of children (Brickhouse 1994, p.401). However, following the discourse in 1860s and 1890s about the content that should be included in science curricula in the United Kingdom and the United States of America respectively (see Layton 1968, Lord Wrottesley 1860, Spencer 1891), the importance of science curriculum in (de)constructing social exclusion through science education has increasingly captured the interest of science educators and curriculum scholars. Hodson and Prophet (1994) describe how teaching the ‘science of everyday life’ was rejected by the educational leaders of the late nineteenth century because of its success in the education of working-class children. Indeed, Lord Wrottesley (1860) notes in his book *Thoughts on Government and Legislation* an incident that took place in a classroom where the science teaching was focused on teaching ‘science of everyday things’:

> At a recent examination of the children of one of these schools the question was asked, whether there was any one present who could explain the principle of a pump? Several hands of both male and female pupils were immediately raised in token of assent, and a pupil was selected to answer: presently was heard the sound of crutches of the paved floor, and a poor boy hobbled forth to give a reply; he was lame and humpbacked, and his wan emaciated face told only too clearly the tale of poverty and its consequences, unwholesome and scanty diet in early years; but he gave forthwith so lucid and intelligent a reply to the question put to him, that there arose a

> feeling of admiration for the child's talents combined with a sense of shame that more information should be sometimes found in some of the lowest of our lower classes on matters of general interest than in those far above them in worldly station (p.192).

Successful science teaching but to the wrong student population, according to Hodson and Prophet (1994), led to the development of teaching of *pure science* which promoted science curricula based on teaching an abstract conceptual content that excluded working-class children from learning science. Science curricula became more compatible to the expectations of upper-class education which could afford – literally moneywise and metaphorically timewise – to acquire the knowledge of *'pure science'*. As a result teaching and learning science within the school environment became an important cultural aspect only for a few who could actually afford their own education. In other words, schooling and scientific knowledge – which was communicated through education – were structured based more on the notion of upper/lower social classes (Hodson 1987). The goal was to ensure the superiority of upper-class groups in order to protect the *national happiness* of the society (see Lord Wrottesley 1857 cited in Layton 1968, p.241; Lord Wrottesley 1860, p.28). Lord Wrottesley (1860) acknowledged and was intimidated by the fact that, unless science education was not focused on teaching abstract content, then all children would be able to acquire science knowledge and thus disturbing the 'natural order' of the society. In his own words: "it would be an unwholesome and vicious state of society in which [the working-class children] should be generally superior in intellectual attainments to those above them in station" (pp.204-205).

THEORETICAL BACKGROUND

Research in the field of science education has shown that science learning is related to the social, economic, and cultural status of children. In other words, students who face inequalities in their daily life such as social exclusion or poverty have less opportunities to learn science (see Aikenhead, 2006; Avalos, 1992; Bencze, 2000; Bencze and Carter, 2011; Brickhouse and Kittleson, 2006; Calabrese-Barton, 1998a; 1998b; Tsiakalos, 2003).

The 2006 Programme for International Student Assessment (PISA) researched the relation of the economic, social and cultural status (from now on ESCS index) of students with regard to their performance in science (OECD, 2007). **Figure 1** shows the relation between the performance in science (vertical axis) and the ESCS index (horizontal axis) of students from countries that participated in the 2006 PISA research.

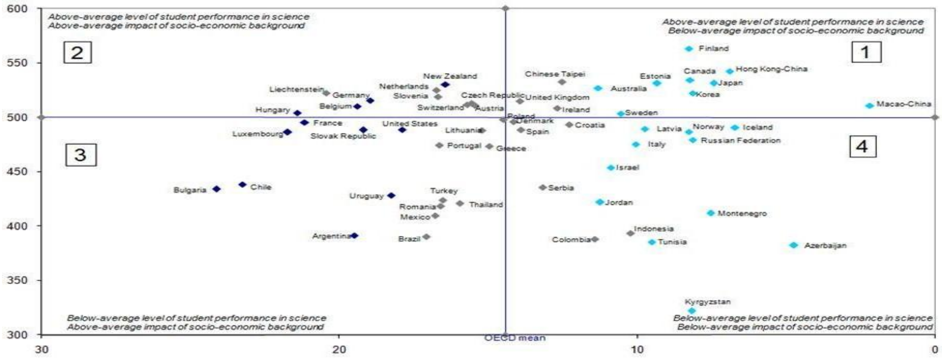

Figure 1: Relation between the performance in science and the ESCS index

The countries located in the first quadrant of **Figure 1** achieve high performance in science independently of students' ESCS index (e.g. Finland, Hong-Kong, Japan). Thus, the argument that high performance of most students is associated with low curriculum requirements (e.g. teaching less science content to students) takes a significant hit. Students in countries which are in the second quadrant have high performance in science as well. However, in this quadrant performance depends on students' ESCS index (e.g. New Zealand, Germany, Belgium). The more advantageous the socio-economic background of students is, the better they perform in science. On the other hand, students from countries which belong to the third quadrant get low performance in science while at the same time performance is related to their socio-economic background (e.g. France, Greece, Bulgaria). In the fourth quadrant, students perform in science below the overall average, but students' failure in science isn't related to their socio-economic background (e.g. Iceland, Norway, Italy).

In this paper we try to answer the following research questions:

1. Which are the features that are proposed by the scholarship in science education related to poverty, social exclusion, scientific literacy for all, and pedagogy for the development of a science curriculum that addresses all children equally, attempts to mitigate the problems of socio-economic inequity and propels social justice?

2. Can features of science curricula be traced – and if yes, which are these? – in countries that: a) accomplished high performance in the 2006 PISA regardless of the ESCS index, b) marked high performance attributed to the ESCS index, and c) displayed low performance which again was linked to the socio-economic milieu of students? In other words, the research zooms in finding evidence in the science curricula that explains the correlation between the ESCS index and the success or/and failure in science in the 2006 PISA.

3. Combining the findings from the analysis of science curricula (research question 2) and the scholarship (research question 1), can we propose features that should be included in the science curriculum in order to combat social exclusion in/through/by science education?

METHOD

To answer the previous three research questions, we have developed a research model called SCAN (Scholarship and Curriculum ANalysis) which is presented in **Figure 2**.

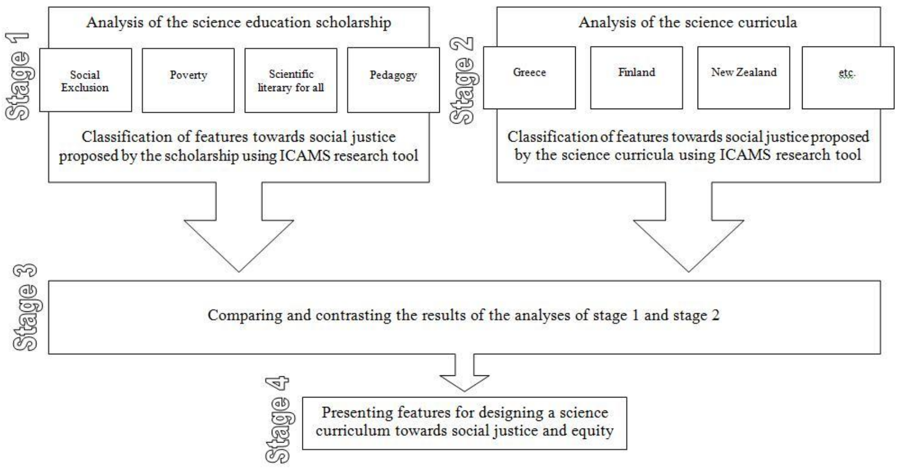

Figure 2: Scholarship & Curriculum Analysis

The SCAN model includes four stages.

- *Stage 1*: We classify science education scholarship in order to highlight features proposed by researchers internationally that contribute to improving teaching and learning science for all students. The classification of features ensued from using the ICMAS (Intentions, Content, Methodology, Assessment, and Support) research tool which was developed by our research group (see Karidas and Koumaras, 2001). We focus our research on the broader context of science education scholarship related to poverty, social exclusion, scientific literacy for all, and pedagogy.
- *Stage 2*: We use the ICMAS research tool to analyze science curricula of different countries which are taken from the three quadrants of **Figure 1**. In this stage we aim to find out: (1) whether there are any particular features in the science curricula under analysis from the first quadrant of **Figure 1** which validate the dismantling of social exclusion. And secondly (2) we are interested in any particular features of the analyzed curricula of countries in the second and third quadrants of **Figure 1** that reproduces social exclusion in learning science. In other words, we try to outline features that should be included or not in the development of the science curriculum.
- *Stage 3*: We compare and contrast the findings of the analyses of the previous two stages. Particularly, we compare and contrast the findings from analyzing the scholarship (research question 1) with the findings of the analysis of three different national curricula (research question 2). Through this path, we could either contribute to the science education scholarship (by highlighting features from the curriculum analysis that the scholarship hasn't brought to attention thus far) or verify partially/totally the features which are proposed by it.
- *Stage 4*: In stage four we present the features that can be used to design a science curriculum towards the development of science education that promotes social justice and equity.

The ICMAS, which is part of the SCAN model, is a research tool for analyzing science curricula (see **Figure 3**).

Levels of the science curriculum		Sub-levels of the science curriculum	
Level 1	**Intentions** (Pedagogical intentions)	**I.1**	General principals
		I.2	General aims
Level 2	**Content** (Science teaching objectives)	**C.1**	Science content
		C.2	Nature of Science
		C.3	Scientific methodology
		C.4	Socio-scientific issues
Level 3	**Methodology of Teaching** (Science teaching)	**M.1**	Context of science content
		M.2	Teaching practices
Level 4	**Assessment** (Assessment in science curricula)	**A.1**	Assessment goals of science education
		A.2	Assessment techniques of science education
Level 5	**Support** (Supporting science learning)	**S.1**	Science education towards social justice and equity
		S.2	Guaranteeing equal access to all students in a high quality science education

Figure 3: ICMAS research tool

The ICMAS research tool focuses on five different levels in analyzing the science curriculum.

Level 1: We examine the pedagogical intentions of science curricula. In other words, we analyze the general principals and aims of science education that are stated within the science curricula.

Level 2: We focus on the teaching objectives which are included in the science curriculum. The teaching objectives are classified and analyzed in four different sub-levels: a) science content, b) Nature of Science (NOS), c) scientific methodology, and d) socio-scientific issues.

Level 3: We analyze the organisational matters of science teaching such as the context in which science content is extended as well as the teaching practices which are proposed in science curricula.

Level 4: We focus on the assessment proposed within science curricula by analyzing the goals of the assessment in science and the assessment techniques.

Level 5: Finally, we try to locate features in science curricula that support science teaching and learning for all students. The focal point is to identify features that are related to social justice and equity by guaranteeing equal access to all students as part of their high quality science education.

PRELIMINARY RESULTS

Due to the limited space in this paper, we decided to present some preliminary results of our study in order to clarify the function of the SCAN research model.[1] Here, we present the analysis of the scholarship in science education as well as the analysis of three national science curricula for primary education (grades 5 and 6) only for *Level 2: Content – science teaching objectives* of the ICMAS research tool (see **Figure 3**). We chose to focus our analysis on science curricula for grades 5 and 6 due to our work experience which comes from primary education as well as define a detailed starting point for a broader research in that field. We support the idea that the results of our research can be associated to the PISA data despite the fact that the PISA testing takes place at the end of the compulsory education because of a consistent and coherent development and linkage of science curricula that begins in primary education and continues till early secondary. The three countries chosen for curriculum analysis were taken from the three groups (quadrants 1, 2, 3) of the 2006 PISA research (see **Figure 1**).

Analyzing science education scholarship (Level 2: Content)

By analyzing our fields of interest of the science education scholarship related to poverty, social exclusion, scientific literacy for all, and pedagogy, we highlighted four pillars on which a science curriculum should be elevated (in this level) in order to guarantee children's equal absorption of the public and social wealth offered by science education. The first pillar is about providing students with an adequate and coherent science content which takes into account the broader context of democratic and humanitarian purposes of education and is fully linked to their daily life (e.g. Aikenhead, 2006; Brickhouse, 1994; Brickhouse and Kittleson, 2006; Calabrese-Barton, 1998; DeBoer, 2000; Dewey, 1910; Feynman, Leighton, and Hutchings, 1986; Hodson, 2011; Quicke, 2001; Reid and Hodson, 1987; Tate, 2001). The second pillar supports teaching the Nature of Science (NOS). Science curricula should highlight the social construction of scientific knowledge as science is a social outcome of the continuing changes of our society and so knowledge can change over time in the light of new evidence. In light of this, students should regard themselves not only as consumers of scientific knowledge, but also as generators of knowledge in order to bring structural changes towards a democratic and humanist society based on their socio-cultural background (Abd-El-Khalick, Bell and Lederman, 1998; Abd-El-Khalick and Lederman, 2000; Bell, 2009; Calabrese-Barton, 1998; Costa, 1995; Harding, 1986; Longino, 1990; Osbrne, Collins, Ratcliffe, Millar and Duschl, 2003). The third pillar sustains the teaching of scientific methodology through which students will be able not only to follow given instructions to solve science problems, but collect and evaluate information or data, develop scientific attitude and respond critically to familiar or unfamiliar situations in their everyday life as well (Bell, Toti, McNall and Tai, 2004; Dewey, 1910; Harlen, 2001; Harlen and Elstgeest, 1992). The fourth pillar maintains the engagement of students in sociopolitical action. On one hand, the science curriculum should include characteristics that guarantee the acquisition of scientific knowledge and competencies by *all* children in order that they be able to make informed decisions about socio-scientific issues. On the other hand, the science curriculum should ensure opportunities to all students to intervene in the structure of society by assuring that social rights such as the equal absorption of the public and social wealth, collective activism and democratic and humanist structure of society will be accessed by all students and not tuned to the needs of the dominant social or economic groups (Bazzul, 2012; Bencze, 2010; Bencze and Carter, 2011; Chen and Novick, 1984; Freire, 2005; Hodson, 2011; Tate 2001; Tsiakalos 2003).

Analysis of science curricula (Level 2: Content)

The Finnish science curriculum[2] *(first quadrant)*

Sub-level: Science content (C_1)

The Finnish science curriculum notes that the teaching of science content should not be limited to simply providing information concerning abstract science concepts, but linking scientific knowledge with students' everyday life-worlds. For example, students should acquire essential knowledge about the human body and its function. However, that kind of knowledge is not to be narrowed down to teaching the way particular human organs function or describing in detail the human anatomy of parts of the heart, eye, and tooth. On the contrary, knowledge about the human body is expanded towards protection of, and respect for the human body, outlining factors that either help or hinder growth and development, and exploring individual differences in sexuality, etc. In other words, science teaching objectives must form a bridge between scientific knowledge and broader socio-scientific issues as well as everyday life.

Sub-level: Nature of Science (C_2)

NOS teaching objectives provide opportunities for students to understand science as a result of human creativity and imagination. The Finnish science curriculum includes objectives which focus on highlighting the relationship between science and the social and cultural identity of the students. For example, the science curriculum includes objectives related to how the human activity has caused changes in society as well as to know how to recognize features of their own and foreign cultures that define the human life in different environments. This way, students have the opportunity to identify science as part of their everyday life-world.

Sub-level: Scientific methodology (C_3)

The Finnish science curriculum provides science teaching objectives which refer to how students will develop competencies such as observing, measuring and searching for information or data on science-related issues and evaluating the reliability of that information and data. Moreover, the science curriculum includes objectives which provide students with the opportunity to apply those scientific practices in their daily life.

Sub-level: Engaging students in socio-political action (C_4)

The science curriculum includes objectives which focus on motivating students to become responsible, participatory and justice-oriented citizens who act collectively to confront socio-scientific issues. For instance, students are expected to recognize factors that threaten safety in their immediate environment and act towards the protection of that environment. In other words, objectives focus on encouraging students to act in the direction of the construction of a social and natural environment that fosters the wellbeing of the community.

The New Zealand science curriculum[3] (second quadrant)

Sub-level: Science content (C_1)

Analysis shows that teaching objectives here highlight the meaning of a science content which refers primarily to students' needs within the school context and secondarily to students' everyday life outside the school environment. To a great extend the science content focuses on the so-called 'academic context' of science and only in few cases does it bridge the science content with students' everyday life. For example, students are expected to know how to investigate and classify the living world at a microscopic level (e.g. protists, plant, and animal cells) or to acquire knowledge of how carbon is transferred through an ecosystem, when they draw labeled diagram showing the components of the carbon cycle. It should be noted that the science content is primarily linked to students' everyday life concerning environmental issues as one part of the socio-scientific issues (e.g. nature protection) and not to other social aspects of socio-scientific issues that students deal with in their daily life.

Sub-level: Nature of Science (C_2)

The New Zealand science curriculum brings forth a multicultural awareness about scientific issues by focusing on the importance of indigenous knowledge concerning nature, plants and the environment. Objectives provide students the opportunity to perceive scientific knowledge as an outcome of the relationship of science with technology and everyday life. The science curriculum includes objectives that motivate students to investigate and describe the diversity of scientific thought based on many social, ethical, and moral considerations. Thus, teaching objectives about NOS aims to emphasize how science knowledge is intertwined with technology and society.

Sub-level: Scientific methodology (C_3)

Objectives in this sub-level refer to students acquiring competencies in using tools to make observations and qualitative and quantitative measurements, record their observations systematically and identify information using Information and Communication Technologies (ICT), collect and analyze data and communicate the results of their research to other students. However, analysis shows that the scientific methodology is focused on addressing science curriculum requirements and is not valued outside the school context.

Sub-level: Engaging students in socio-political action (C_4)

The New Zealand science curriculum includes objectives that refer to the preparation of future citizens who are sensitive to environmental issues. Objectives focus on motivating students concerning environmental aspects of socio-scientific issues such as the protection of the natural environment and the human interaction with nature. On one hand, students are expected to apply their knowledge of chemical and physical properties of substances to investigate their safe and appropriate use in the home and the community (e.g. swimming pool chemicals, cleaners, fuels). On the other hand, the science curriculum does not provide opportunities to students to act on the basis of socio-scientific issues in order to protect their own society.

Greek science curriculum[4] (third quadrant)

Sub-level: Science content (C_1)

The Greek science curriculum includes science content which focuses on teaching students the microcosm (structure of matter) and abstract science concepts; that kind of science knowledge is not only difficult to acquire for students in primary education, but also it is not related to the students' daily life. Even in the case of everyday phenomena, the science curriculum provides academic definitions which students ought to memorize. For example, students in grade 5 (eleven-year-olds) should be able to describe the molecular motion in the three states of matter and based on that description they should interpret the different behavior of solids, liquids, and gases. Moreover, students are taught in detail the human anatomy; which means that they should able to name all the parts of the heart, eye, ear, and tooth, however they are not taught issues of hygiene, or issues related to the prevention of diseases, etc.

Sub-level: Nature of Science (C_2)

The Greek science curriculum does not provide explicit objectives related to NOS issues.

Sub-level: Scientific methodology (C_3)

The science curriculum includes teaching objectives concerning scientific methodology in a theoretical content. Students are expected to learn how scientists find, collect, organize, analyze, transform and communicate information and data, but are not taught how to apply these competencies in their own research. In particular, students learn to follow given instructions in order to solve problems assigned in the science courses. The science curriculum does not provide objectives in this sub-level which could make students able to use scientific competencies in every aspect of their daily life.

Sub-level: Engaging students in socio-political action (C_4)

Analysis of the objectives in this sub-level shows that the science curriculum draws attention to abstract science content. For example, in the unit 'Infectious Diseases' the sixth-grade science curriculum, instead of placing emphasis on the protection against infectious diseases (e.g. regular hand-washing to reduce chances of bacteria transportation, etc), describes concepts such as microorganisms, the content of vaccines or components of drugs, presenting wider social issues in terms of absolute and specific 'academic knowledge' – a 'non-real' world for students. Moreover, in the unit ‘Environmental Education’ objectives focus on teaching specific matter-of-fact knowledge concerning the description of the carbon dioxide (e.g. students should be aweare of the chemical formulas) and not on motivating students to take action to protect the environment (e.g. by recycling, using public transport, etc).

COMPARING/CONTRASTING SCHOLARSHIP & CURRICULA

The analysis of science education scholarship shows that fostering equal participation of all students in science courses presupposes a curriculum which values the socio-cultural background that students bring to school. The analysis of the Finnish science curriculum shows that the curriculum places importance in relating science education to students’ everyday life, building a good and safe social and natural environment. The New Zealand science curriculum attempts to prepare students to understand science and its relation to technology and acquire scientific competencies in order to make sense of the way the natural and material world functions. However, that knowledge seems to address the needs of students who come from a privileged socio-economic background. It should be noted that science teaching objectives are aligned with the pedagogical intentions[5] stated in the science curriculum which support the idea of designing science education for talented students and thus ensuring the existence of a future scientific community. The Greek science curriculum focuses on teaching a science content which prepares students to address the requirements of science courses and not students’ needs outside the school context. In other words, the Greek science curriculum mostly prepares students for the next school year, but not for the real deal of everyday-life issues. Science teaching objectives refer to the so-called ‘academic world’ of science which means science knowledge which is ‘decontextualized’ from the broader social and cultural context of students.

Features for designing a science curriculum towards social justice

The comparative analysis of the science education scholarship and the science curricula highlights some features for *Level 2: Content – science teaching objectives* which can be used in designing a science curriculum to guarantee students’ equal absorption of the social wealth given through science education. Hindering that equal absorption of the social wealth in the field of science education deprives students of accessing the social decision-making structures related to socio-scientific issues (Hodson, 2011; Tsiakalos, 2003). *Hindering*, also means promoting passive participation of students in science courses due to the great gap between the ‘academic world’ of science and students’ everyday life. It can also mean a science curriculum which reproduces specific knowledge that is not important outside the school context and appeals only to a small group of students coming from a privileged socio-economic background who can acquire it through a supportive surrounding network (e.g. family that can afford afterschool private lessons, etc). Moreover, hindering means an exclusive orientation of science education toward teaching science content without paying attention to other aspects of science education such as the Nature of Science, scientific methodology and the socio-scientific issues. In other words, we support the idea that blocking the equal absorption of social wealth of science education means *incomplete* science education and failing to prepare students to deal with problems that they will encounter in their lives. Therefore, if we are to guarantee equal absorption of the social wealth offered by science education to all students, we must design a science curriculum that values their socio-cultural background in science teaching. The inclusion of the socio-cultural background in the science curriculum is likely the factor that will help students challenge the traditional image of science in which science teaching focuses solely on memorization of data, concepts, principles and abstract applications of science. It is not enough to simply teach the same scientific concepts to all students, rather the science curriculum has to bridge effectively science and students' everyday life.

CONCLUSION

In this paper we presented a research model we have developed in order to analyze science education scholarship as well as three different national science curricula. We aimed to identify features that could aid in the fight against social exclusion through science education. Due to the limited space in the paper, we presented preliminary results of our research only for *Level 2: Content – science teaching objectives* of the ICMAS research tool and tried to clarify the function of the SCAN research model. Results of our research show that through SCAN we can identify features for designing a science curriculum towards social justice and equity.

NOTES

1. The main goal of the paper is to present the SCAN research model. In our next paper we will thoroughly present the results of the scholarship and curriculum analysis.

2. Finnish National Board of Education (2004). *Core Curriculum for Basic Education 2004*. Vammala: Vammalan Kirjapaino Oy.

3. Ministry of Education (1993). *Science in the New Zealand Curriculum*. Learning Media Wellington. This science curriculum was in place during the 2006 PISA testing.

4. Ministry of National Education and Religious Affairs. (2003). *Science curriculum for the fifth and sixth grade of elementary school*. Retrieved August 29, 2008 from http://www.pi-schools.gr [in Greek]

5. Due to the limited space, we have not included in this paper the analysis of the pedagogical intentions of the science curricula. The analysis of the pedagogical intentions will be presented in our next paper.

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CURRICULUM POLICY IMPLICATIONS OF THE PISA SCIENTIFIC LITERACY FRAMEWORK

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Abstract: Since 2000 the PISA-programme of the OECD assesses knowledge, skills and attitudes in the areas of reading, mathematics and science, areas which are seen as very important for the development of knowledge societies. Youngsters of age 15 in more than sixty countries are involved. The test items are based on three frameworks, not based on common curriculum standards but on knowledge requirements for future life. The PISA Scientific Literacy Framework deals with three competencies which are based on attitudes, contexts and knowledge, not only on science but also about science, i.e. procedural and epistemic aspects on which the work of scientists is based. The PISA-results are taken increasingly serious by media, ministers and members of parliament, resulting in visits to high ranking countries and quick measures, not always appreciated by teachers. In this paper it is argued that results should be interpreted with care and comments on interpretation of the results are given. Examples of implications for educational policy in various countries are shown. In view of the revised SL Framework (2015) recommendations are given for future international curriculum development.

Keywords: curriculum, PISA, scientific literacy, educational policy

INTRODUCTION

In 1997 the OECD took the initiative to develop PISA, the Programme for International Student Assessment, which monitors the outcomes of education systems regularly and provides a basis for international collaboration in defining and implementing educational policies. PISA focuses on students age 15 in the fields of reading, mathematics and science literacy and the tests are administered every three years since 2000, each time with emphasis on one field. In 2012 Mathematics was the main topic and the results will be published in December 2013. Preparations are in progress for PISA 2015, when Science for the second time will be the main field.

The frameworks are not based on common curriculum elements across the world (such as in TIMSS) but on skills and knowledge which students need in further life in the 21st century. The Science Literacy Framework (SLF) forms the foundation for construction of the assessment items. The core of the SLF has been based so far (OECD, 2009) on three scientific competencies: (1) identify scientific issues, (2) explain phenomena scientifically, and (3) use scientific evidence. These competences include both scientific knowledge and attitudes towards science, and should be applied to personal, social and global contexts. Scientific knowledge is split into knowledge of science and knowledge about science. The former contains the usual concepts in the fields of life, physical and earth science. The latter could be characterized as insight into the nature of science.
In the 2015 Scientific Literacy Framework more emphasis will be given to knowledge about science as this knowledge area will be split into procedural and epistemic aspects (OECD, 2013).

INTERPRETING RESULTS: TAKE CARE

The results of the PISA tests differ greatly between the participating 65 countries (OECD, 2010). For instance, in 2009 for Science the overall results per country varied between 575 (Shanghai-China) and 330 (Kyrgyzstan). Even within the group of OECD countries the differences are fairly large, with Finland (554) at the top and Mexico (413) at the bottom. Originally it was not the intention of the OECD to attribute high value to league tables. It was considered much more important to develop a common standard to identify bottlenecks and to monitor progress within countries. However, in media and politics the leagues tables have got more attention than intended.

In interpreting the results care should be taken, as has been stated by a number of authors:

a. PISA is not assessing all aims of science education in the participating countries as it is not based on current curricula (Mortimore, 2009); for instance students' laboratory performance is not assessed (Dolin & Krogh, 2010);
b. in the participating countries common test items and textbooks might be different from the PISA test items (Dolin & Krogh, 2010; Figazzolo, 2009; Mortimore, 2009; Hatzinikita, Dimopoulos & Christidou, 2008);
c. PISA results might partly be explained by scientific culture in society, for instance reflected in attention for science in the media, in science centres and in the nature of topics discussed at home and with friends (Lau, 2009);
d. the league tables should not be interpreted as precise ranking order; for instance in PISA 2006 the differences between Taipei (score 532, place 4) were not significantly different from Korea (score 522, place 11) and all countries in between;
e. it is not always clear with what motivation students participate in the PISA-study; this might be different between highly collective or individualistic cultures (Tan, 2013).

This is not to argue that the results have no value, only that they should be handled with care to make optimal benefit from them.

POLICY IMPLICATIONS

In many countries the PISA results have got public attention. In the United Kingdom alarming articles were seen in the media (Mortimore, 2008; Gardner, 2010). Journal articles have been devoted to the implications in for instance Germany (Kauertz et al., 2010; Knodel et al., 2013), England (Knodel et al., 2013), Denmark (Dolin & Krogh, 2010), Japan (Takayama, 2008; Knipprath, 2010), Shanghai (Tan, 2012; Sellar & Lingard, 2013), France (Dobbins & Martins, 2012), Israel (Feniger et al., 2012), Turkey (Gür et al., 2012), New Zealand (Baker & Jones, (2005), Europe (Grek, 20009) and the USA (Anderson et al., 2010) .

A general trend is to look across the border and some countries with positive PISA results came into the position of 'reference societies' (Schriewer & Martinez, 2004). For example, Finland and Shanghai have received many visitors from abroad to learn from the educational systems of these countries (Sahlberg, 2011; Tan, 2013). One may call this a PISA syndrome but unfortunately this term has already been used to refer to a neurological disorder which occurs due to a prolonged exposure to antipsychotic drugs[i].
Although benchmarking with other countries might be beneficial one should realize that problems in some countries could not always be solved with solutions from other countries. A striking example can be found in a publication of the Learning Curve Programme (Pearson,

2012) reporting on the top ranking of Korea and Finland according to educational output while their educational culture and tradition is in many aspects very different, such as the role of exams, teaching culture, class time, class size and salaries of teachers. What they have in common is not easily transferred: high status of teachers and teacher training, and high value of education in society.

In the Netherlands the Government has set some precise performance objectives related to PISA results: the Dutch scores should each three years increase with 5 points for mathematics, 4 points for reading and 2 points for science. One may wonder if such precise objectives are realistic. More effective might be that schools in the Netherlands have received additional funds to pay more attention to high achievers as both in TIMSS and PISA Dutch students score relatively low at the higher levels.

WHAT IS NEW IN THE PISA 2015 SCIENCE FRAMEWORK?

In the new framework (OECD, 2013) Scientific Literacy is defined as the ability to engage with science-related issues and with the ideas of science, as a reflective citizen. A scientifically literate person should be willing to engage in reasoned discourse about science and technology which requires the competencies to:

1. Explain phenomena scientifically:
    - Recognise, offer and evaluate explanations for a range of natural and technological phenomena.
2. Evaluate and design scientific enquiry:
    - Describe and appraise scientific investigations and propose ways of addressing questions scientifically.
3. Interpret data and evidence scientifically:
    - Analyse and evaluate data, claims and arguments in a variety of representations and draw appropriate scientific conclusions.

These competencies will only be tested using the knowledge that 15-year-old students can reasonably be expected to have of the concepts and ideas of science (content knowledge), the procedures and strategies used in all forms of scientific enquiry (procedural knowledge), and the manner in which ideas are justified and warranted in science (epistemic knowledge). See Figure 1.

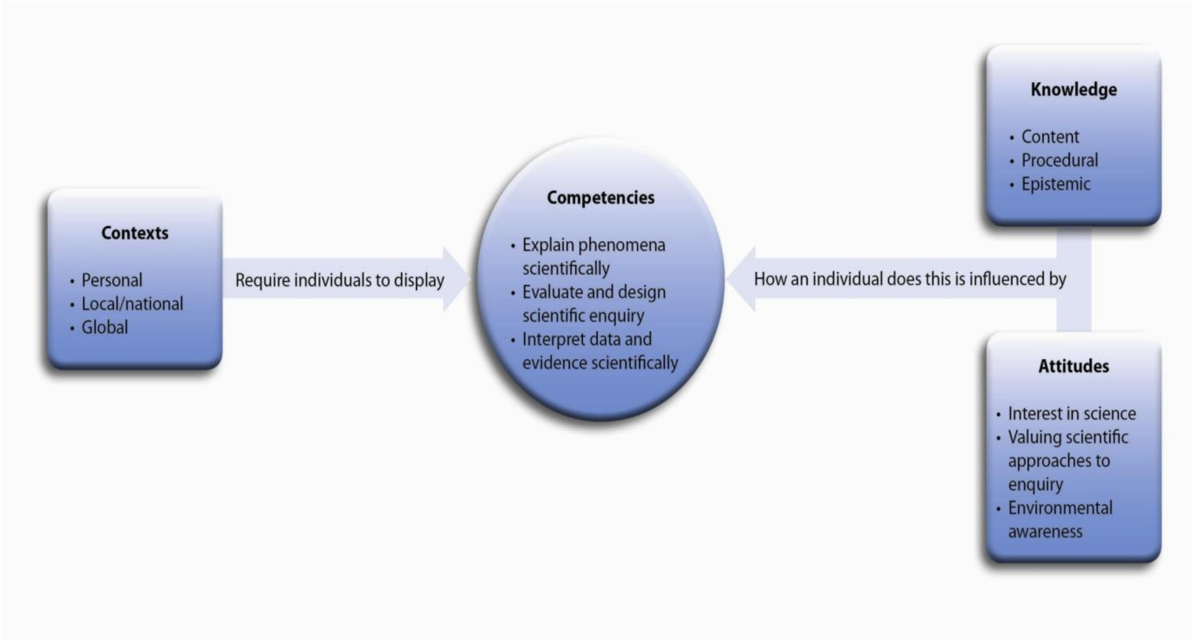

Figure 1. Components of the PISA 2015 Science Literacy Framework (OECD, 2013)

The *content knowledge* in the framework (physical, life and earth science) is likely to be fairly common to what is taught all over the world, although not described in detail. The *contexts* in the framework (at personal, local/regional and global levels) are almost similar to those in previous PISA SL frameworks. What is most innovative are the categories *procedural* and *epistemic knowledge*.

Procedural Knowledge

- The concept of variables including dependent, independent and control variables;
- Concepts of measurement e.g., quantitative [measurements], qualitative [observations], the use of a scale, categorical and continuous variables;
- Ways of assessing and minimising uncertainty such as repeating and averaging measurements;
- Mechanisms to ensure the replicability (closeness of agreement between repeated measures of the same quantity) and accuracy of data (the closeness of agreement between a measured quantity and a true value of the measure);
- Common ways of abstracting and representing data using tables, graphs and charts and their appropriate use;
- The control of variables strategy and its role in experimental design or the use of randomised controlled trials to avoid confounded findings and identify possible causal mechanisms;
- The nature of an appropriate design for a given scientific question e.g., experimental, field based or pattern seeking.

Figure 2. PISA 2015 Procedural Knowledge (OECD, 2013)

Epistemic Knowledge

1. The constructs and defining features of science. That is:
   - The nature of scientific observations, facts, hypotheses, models and theories;
   - The purpose and goals of science (to produce explanations of the natural world) as distinguished from technology (to produce an optimal solution to human need), what constitutes a scientific or technological question and appropriate data;
   - The values of science e.g., a commitment to publication, objectivity and the elimination of bias;
   - The nature of reasoning used in science e.g., deductive, inductive, inference to the best explanation (abductive), analogical, and model-based.
2. The role of these constructs and features in justifying the knowledge produced by science. That is:
   - How scientific claims are supported by data and reasoning in science;
   - The function of different forms of empirical enquiry in establishing knowledge, their goal (to test explanatory hypotheses or identify patterns) and their design (observation, controlled experiments, correlational studies);
   - How measurement error affects the degree of confidence in scientific knowledge;
   - The use and role of physical, system and abstract models and their limits;
   - The role of collaboration and critique and how peer review helps to establish confidence in scientific claims;
   - The role of scientific knowledge, along with other forms of knowledge, in identifying and addressing societal and technological issues.

Figure 3. PISA 2015 Epistemic Knowledge (OECD, 2013)

In my view procedural and epistemic knowledge are very important for interpreting claims from researchers, for instance in media reports. Just content knowledge is not sufficient to understand how science works. However, the description of knowledge is fairly theoretical and might be read as a syllabus for a course on the philosophy of science. I am convinced that this is not the intention, so the main challenge for PISA 2015 is to write test items which are feasible for 15 year olds at various ability levels.

RECOMMENDATION

If governments find it important that their students rank high in the PISA league tables one might hope that this is not just for ranking purposes but for the benefit of the future of their citizens. As all participating countries agree on the frameworks it is surprising that so little has been done to identify common ground in curricula and practices of teaching in view of the SL Framework.
In the Netherlands we have made efforts to interpret the PISA 2006 science results in view of the Dutch curricula (Eijkelhof, Kordes & Savelsbergh, 2013). The relatively high scores on real context-based PISA questions (Nentwig et al., 2009) might, for instance, be explained by the focus on contexts in Dutch science curricula.
An interesting development in this respect in the USA is the development of the Next Generation Science Standards (NRC, 2012) which seem related to the new SL Framework in several ways, such as the focus on scientific practices.

As European countries tend to score far below East Asian participating communities and as it is neither easy nor advisable to blindly copy educational systems, I recommend that a European initiative is taken to:

- Identify differences and similarities between the PISA Science Literacy Framework and educational practice at junior secondary level.
- To develop, trial and evaluate curriculum materials which might bridge the gap, for instance as regards procedural and epistemic knowledge.
- To give recommendations to educational authorities in the participating countries.

To avoid misunderstanding, I do respect the variety in education in European countries and I am not in favour of a European science curriculum. But I expect that we could more cooperate in developing science education which is beneficial for the future of our citizens. No better platform than the ESERA community could be found to take an initiative in this field.

NOTE

[1] http://en.wikipedia.org/wiki/Pleurothotonus

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THE IMPACT OF PERFORMANCE ASSESSMENT ON SCIENCE EDUCATION AT PRIMARY SCHOOL

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Abstract: The new curriculum in Sweden for primary and secondary school contains more distinct educational targets. Science education at school now has to be linked to the students own experience and shall develop critical thinking of the student. This is supposed to the ability to review arguments and to develop their ability to argue in situations where knowledge of science is of big importance. To achieve the required knowledge, students have to train abilities or skills before the assessment. In order to assess the required knowledge and to view the development of a student, the teacher has to accomplish several practical assessments and training occasions. The new curriculum expects the teacher to design learning situations where the students get the possibility to have relevant training before the performance assessment. The earlier Swedish curricula had a stronger emphasis on theoretical knowledge whereas the new curriculum highlights the ability to use knowledge.

Keywords: teaching evolution, tacit knowledge, science teaching

INTRODUCTION

The new curriculum in Sweden for the primary and secondary school contains more distinct educational targets. The political background was among other things, the poor Swedish results in PISA and TIMMS. There had also developed a strong opinion against what was regarded as a modern school without any demands on the students and a wish to return to a school focused on knowledge. Also the ROSE project, focused on the interest in science education, showed that a very low number of Swedish students were interested in this field. Important parts in the political agenda was the improvement of teacher training programs focused on subject knowledge, better evaluation programs, teacher certificates, inspections of schools and new curricula. The new curriculum for the primary school contains three important parts concerning the studies of the different subjects. These three were; the aim of the subject in the school context and in society, the core content of the subject and the knowledge requirements to reach a specific level at the assessment performance. Further, the assessments are linked to the usage of knowledge both in a specific subject context according to the assessment criteria, but also in other contexts outside school rather than remembering facts.

BACKGROUND

Science education at school now, according to the curriculum, has to be linked to the students own experience and development of critical thinking of the student. This aim is supposed to enhance the ability to review arguments and also to develop the student’s ability to argue in situations where knowledge in science is of great importance. The performance assessment according to the curriculum shall be used to evaluate if the student have achieved the capacity to use knowledge in discussions within scientific contexts.

The student's practical investigations and documentation of these are important parts in science education. To achieve this required skill, students have to train before the assessment. In order to assess the required knowledge and to view the development of a student, the teacher has to accomplish several practical assessments and training occasions. This is an important change compared to earlier curricula. The teacher was earlier supposed to concentrate on teaching but the content of the lessons was not described in the curriculum. The new curriculum expects the teacher to design learning situations where the students get the possibility to have relevant training before the performance assessment. Thus, the role of the teacher has changed from being a performer in the classroom to becoming a designer of learning situations. This includes also the situation when the performance assessments are made, they shall not only assess the abilities of the student but also stimulate to further studies. The earlier Swedish curricula had a stronger emphasis on theoretical knowledge whereas the new curriculum highlights the ability to use knowledge.

In our positions as lecturers at teacher training programs we have observed several obstacles of different nature, diminishing the learning outcome in science teaching. We identified some of these as important and relevant to deal with in the pre-service training as we thought this would help our students in their coming profession.

In a recent quality report from Skolinspektionen (Swedish Schools Inspectorate 2012), concerning teaching in years 1–3, similar problems have been identified. Almost all students regard science as interesting subject, they feel satisfied with the classroom climate and the visited lessons where described as peaceful with supportive teachers. More negative is that some parts of the core content are absent and that there is a focus on biology at the expense of chemistry and physics. This does not mean a higher quality in biology; the teaching is mainly concentrated on observations and learning of concepts without deeper understanding. Further, the students rarely practice scientific methods, they need help to understand the content and the quality varies between schools and also within schools.

We were also interested in how teachers did when they had to explain things they didn't know so much about. Teachers often claim a lack of knowledge as the reason why they don't teach science properly or even try to teach. On the other hand we had a feeling, out of what we had seen visiting schools and when we met teachers at in-service courses, that many of them expressed tacit knowledge used in informal or spontaneous learning situations.

We had also discovered poor knowledge in the main principles of evolutionary theory. Although many students know words or concepts like random variation, natural selection, adaptation etc. they do not use them in appropriate ways.

In the pre-service training it is important to know how science could be taught at school and to give opportunities for the becoming teacher to practice in similar ways as they are supposed to design learning situations with their students in the future.

THEORETICAL FRAMEWORK

Biology is often “taught” outdoors but this activity is often delimited to observations often transformed to numerical values. Why is biology, which always has an evolutionary foundation, almost always about facts and not about processes? If processes occur they are usually taught as concepts that should be memorized not as dynamic models with several interacting forces (Alters & Nelson 2002, Skolinspektionen 2012).

Out of our experiences presented in Background, three questions surfaced covering the main parts of our concern: 1) How is science in general taught in the classroom, 2) is there a structure of the tacit knowledge among teachers and is there a strategy for expressing it by them (Parker & Heywood, 2000) and 3) how do we get teacher students to be more evolutionary in their thoughts? These were questions not primarily to establish thorough research on, rather ideas that could be investigated in order to find the core of the problems.

Like Alters & Nelson (2002) our general experiences from teaching, in different fields of science like biology and chemistry but also in behavioral and educational sciences, was that the main obstacle almost always were the students’ prior conceptions regardless how well-founded they were. This problem arises in all learning situations, not only of evolutionary theory.

METHODS

Classroom study

In the first case the learning situations in a class of 23 students in year one were recorded by Iphone simultaneously as notations of the activities were made. The time in minutes spent on different types of activities was summarized. These observations were used to evaluate the actual leadership of the teacher in the classroom and outdoors.

Tacit knowledge

During a course for teachers in primary school the participants wrote reflections about problems of knowledge of concepts, processes, relations etc. and problem solving when students posed questions they were uncertain about. These reflections were analyzed in order to reveal how they in practical situations expressed tacit knowledge.

Evolution

In order to create a better understanding of the basic principles of evolution we tried to use TED-talks from the internet in a course in chronological perspectives for primary school teacher students. If the students first watched a lecture on scientific method related to evolution followed by another strict evolutionary lecture we thought they would achieve tools for analyzing other talks. The ambition was to make the students aware of the fact that also prominent researchers may slip into a more entertaining costume when talking to non-specialists. In order to make it possible to compare different talks we divided the student in ten groups of about five in each. All groups were instructed to watch same two TED-talks, first Lotto & O’Toole: Science is for everyone, kids included (2012), followed by Elaine Morgan says we evolved from aquatic apes (2009).

After this the groups was given one talk each to critically watch and discuss. We chose a packet of talks called *Ancient clues*, containing 5 different talks by Enriques (2012), Goodall, (2002), Leakey (2008), Pääbo, (2011) and Zeresenay (2007).

After having watched the lectures the students had discussions on the course web which was followed by the teachers and later studied. The occurrence of concepts from the evolutionary theory and the manner of writing in the lines of the students were analyzed

RESULTS AND DISCUSSION

Classroom study

In total 585 minutes of science teaching were observed. The numbers of registered minutes were larger as many activities occurred simultaneously. For example, if the teachers were talking when the students were making drawings both activities were registered. In total 972 minutes were registered in the classroom and 156 minutes outdoors.

In the classroom a minor part of the activity performed by the teacher alone and almost all activities is performed by the students (Figure 1).

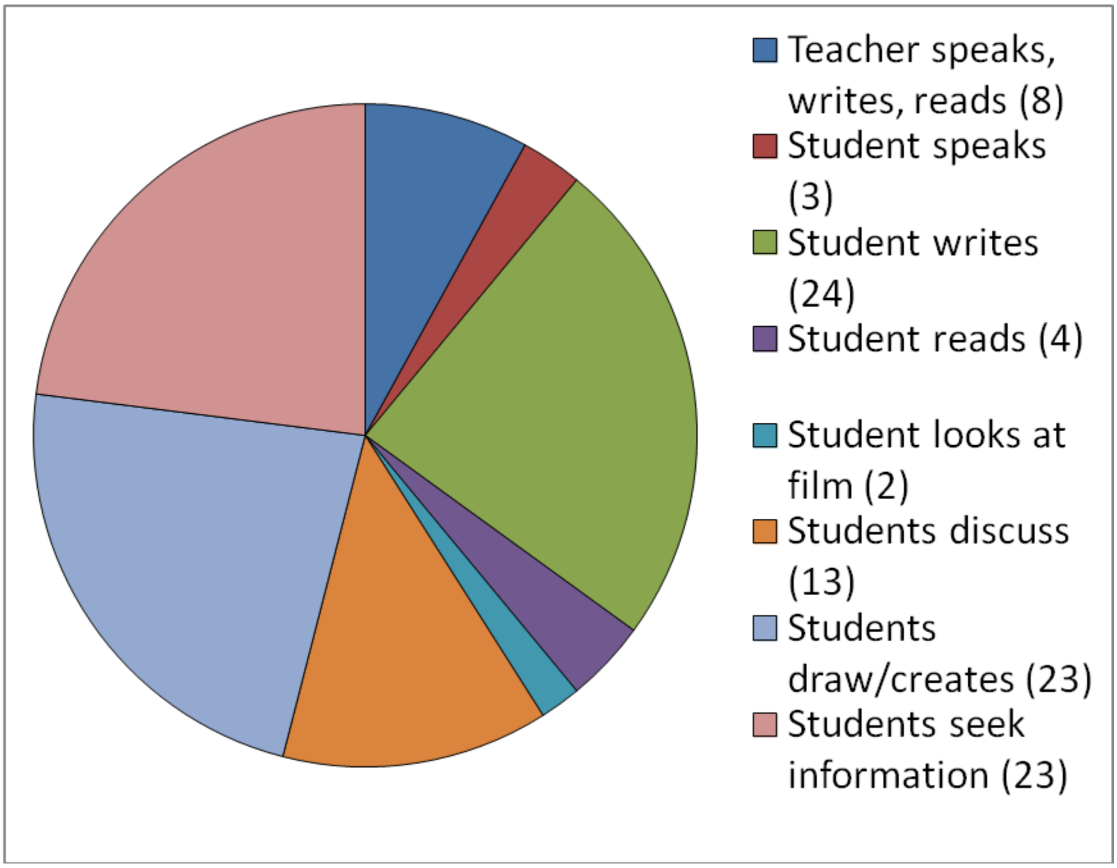

Figure 1. Percentage of time used for different activities in science teaching in the classroom

One third of the time is used for strict individual activities of the students and only 13 % to collective activities. Most of the time (46 %) is used for a mix of individual and collective activities (Figure 2).

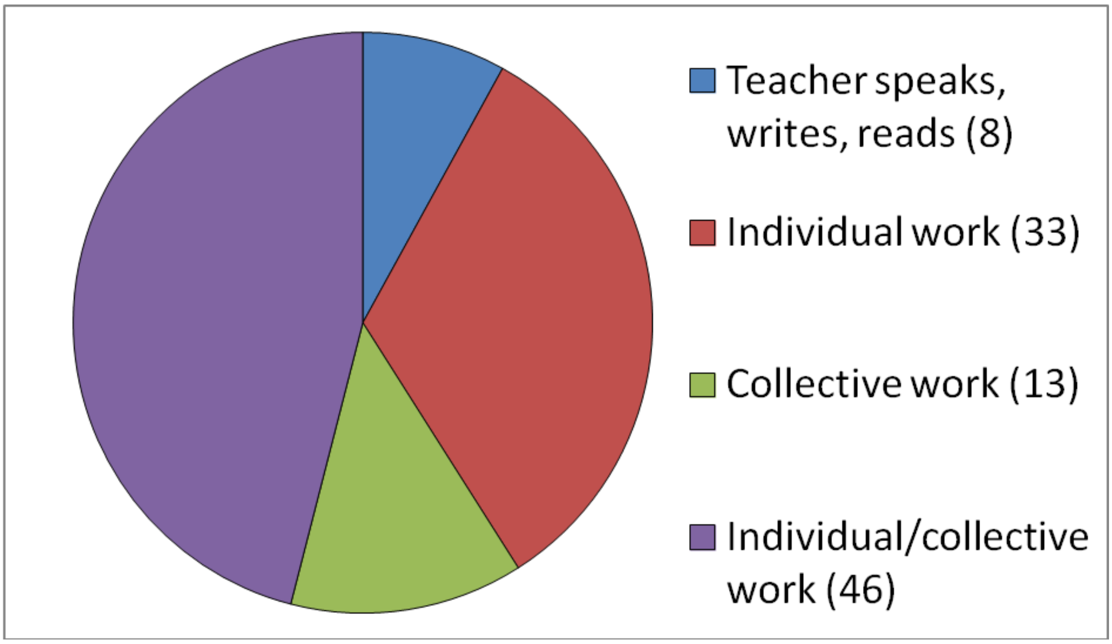

Figure 2. Percentage of time used for teacher, individual and collective activities in science teaching in the classroom

The outdoor activities were of much shorter duration but the pattern was similar (Figure 3). The teacher uses a small part of the time and the students activities seem to be of a fairly free character.

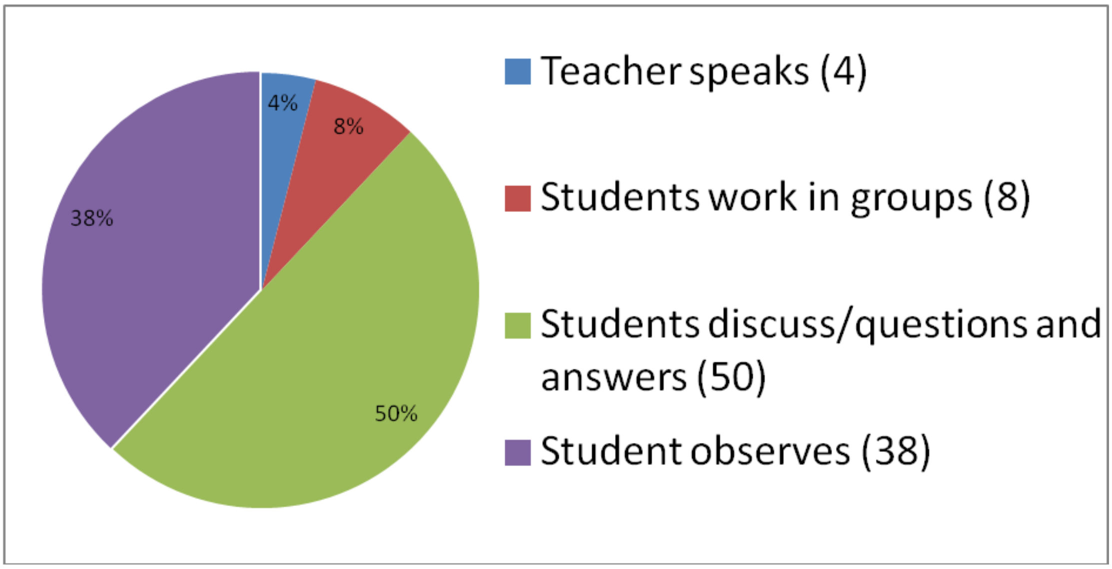

Figure 3. Outdoor activities

The result supports the view of Skolinspektionen (2012). The outdoor education is not directly related to theory but is concentrated on observations and questions. Also in the classroom the leadership of the activities probably is weak as the time of teacher dominance is limited.

This supports the opinion that the design of science learning situation has to be developed.

Tacit knowledge

The reflections contained a large number of ideas how to do when you initially thought you didn't know how to explain when you got impossible questions. In Table 1 the most common problems and their suggested solution are listed.

Table 1

Problems identified by teachers in primary school

Problems	*Solutions*
To use concepts correctly	Relate to the students own explanations and experiences in different situations
To see other than simple relations	Discuss the relations in different situations. Don't read, work practically!
To understand processes	Use activities (e.g. cooking and baking) as examples of transforming processes.
To put knowledge in a larger context	Expand the world of the student by new experiences.

The results show how many, a majority of the reflections of 14 teachers have strategies for answering scientific questions although the regard themselves as more or less ignorant. This support what we often find in our courses; students claiming ignorance although they can prove practical (tacit) knowledge. To some extent we think this is a defense; their self esteem in science is often very poor regardless their skills.

Evolution

Primarily, we found that students do not follow instructions. Many of the groups started to listen uncritically to the talk of their own and tried to analyze the first two out of this. Secondary many argued against criticism with arguments like; why should our teachers provide us with poor talks, of course they must be good if they are included in the course. Finally almost no students used evolutionary concepts and most of them showed poor understanding of evolutionary principles. Almost no one referred to the textbook (Guttman 2005).

Teaching evolution is more problematic than we thought. Here we have a dilemma in the trust of the students. They hesitate in being critical against their teachers. It is hard for them to imagine why the teachers should give them poor material even to practice critical thinking?

Another problem was that the student didn't follow instructions. They preferred to start with their own material directly instead of first develop critical thinking. This shows how curiosity may lead to poor learning when not properly guided.

We have to create distinct learning situations, otherwise we get nowhere.

Acknowledgements

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BASIC GENETICS CONTENT IN SECONDARY EDUCATION: COMPARING HIGH SCHOOL TEACHERS' AND FACULTY MEMBERS' OPINIONS WITH THE UNIVERSITY CURRICULUM

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Abstract: A recent debate about teaching genetics concerns the importance of teaching concepts of biotechnology. The present study aimed to identify high school teachers' and university faculty members' opinions with the basic genetics concepts that students finishing secondary education should know to become informed citizens capable of critical thought. The study also determined whether these concepts are being considered by higher education institutions during teacher training. Data were collected through interviews and by analysing the programmes and syllabi of university courses in São Paulo (Brazil) and Kalamazoo (USA). The content areas that were most often mentioned by the interviewees in São Paulo were *inheritance patterns (Mendel's laws and gene interaction), cell division and molecular genetics (gene expression and biotechnology).* In Kalamazoo, the most common responses were *inheritance patterns (Mendel's laws and codominance), molecular genetics (gene expression, DNA structure, mutation, biotechnology and DNA replication)* and *cell division.* These topics are covered in the programmes and syllabi of graduate courses that focus on teacher training. The opinions of faculty members and the curricula of the areas that they teach were similar, but in the São Paulo context, there was a difference of opinions concerning biotechnology. Such a difference in opinions is important for stimulating critical reflection, but these topics should be taught in conjunction with other basic principles.

Keywords: Genetics education, curriculum, secondary education level, teacher training

INTRODUCTION

Among the knowledge produced by science, knowledge of genetics has great importance, both for its relevance to the various areas of biological sciences and for its connection with various aspects of the daily life of individuals (Griffiths et al., 2006). In Brazil, one of the goals of basic education, which has even been provided for by law (LDB 9394 /96 Art. 2), is the preparation of students for citizenship. This concern is not restricted to the Brazilian context. Among the driving forces for reform of science education worldwide are the advances in science and technology, with a growing concern for the importance of such knowledge for the development of societies and the education of well-prepared citizens to act and make decisions about such issues (Guo, 2007).

Regarding the knowledge of genetics specifically, recent studies have been concerned with the difficulties related to these concepts and with the development of attitudes displayed by students both with respect to more traditional topics in the area (Lewis & Wood-Robinson, 2000) as well as with respect to the most current issues related to biotechnology (Usak et al., 2009; Pedrancini et al., 2007; Pedrancini et al., 2008; Dawson & Soames, 2006).

However, it is not only students' understanding of genetics topics that concerns researchers. If we look at the development of this area of study, we can see that it has been undergoing constant development (Flodin, 2009; Shapiro, 2010; Bizzo, 1998; Dougherty, 2009), raising reflections on topics that are relevant for teaching in the school setting (Bizzo, 1998; Dougherty, 2009; Ayuso & Banet, 2002; Camargo & Infante-Malaquias, 2007; Bridgforth, 1993).

A developing field of genetics refers to technologies developed as a result of its application. In recent years, researchers in the area of biology education have been concerned with the teaching of biotechnology-related topics linked to genetics. One of the more recent discussion topics is centred on the teaching of biotechnology. For example, Xavier, Freire and Moraes (2006), Nascimento (2005), Ayuso and Banet (2002) have addressed this topic. When seeking to determine how knowledge regarding the application of genetics is presented in textbooks, Xavier, Freire and Moraes (2006) have demonstrated their concern for the absence of such content in textbooks. In addition, other researchers have also expressed concern about the need for such content to be addressed in a high-quality manner in these educational materials (Dawson & Soames, 2006; Martínez-Gracia & Gil-Quílez, 2003; Pedrancini et al., 2007; Pedrancini et al., 2008; Usak et al., 2009). Bonzanini and Bastos (2005) and Ayuso and Banet (2002) state that these topics are often discussed in the media and thus should be taught in parallel with other topics. The authors argue that students develop their values by debating these subjects (Ayuso & Banet, 2002). Issues related to cloning and genetic programming of organisms bring up controversial issues such as eugenics (Bizzo, 1995, 1998).

Therefore, because genetics is an area of study whose contents are constantly expanding and because researchers have demonstrated the difficulties exhibited by students in understanding this field, it is important to think about what to teach in this area. Thus, many questions may arise in this framework: Can you teach all of the knowledge already included in the topic to secondary education students? If it is necessary to make choices, what should be selected? Will the classically taught knowledge be too basic for students? Would the selected knowledge facilitate or hinder the students' understanding of concepts in genetics?

Arguments in favor of quality over quantity can also be found. Authors assert that *time* is a necessary element for students to really learn about biological inheritance and achieve substantial changes in their intellectual abilities. Therefore, they consider that the contents should be selected in a more critical and reasoned manner, taking into account their educational usefulness and focusing on learning quality rather than quantity as the greatest concern (Banet & Ayuso, 2002).

In this context, the present study aimed to identify high school teachers’ and university faculty members’ opinions about the basic genetics concepts that students finishing secondary education should know to become critical citizens. The study also determined whether these concepts are being considering by higher education institutions during teacher training.

METHODS

Interviews were conducted in two different contexts with a sample of 24 participants. In the first context, six genetics and molecular biology professors at São Paulo University

(Universidade de São Paulo - USP) and six biology teachers at the secondary education level in the city of São Paulo (Brazil) were interviewed.

In the second context, six faculty members at Western Michigan University (WMU) and six teachers from the city where the main WMU campus is located (Kalamazoo, USA) were interviewed. The aim was to assess whether the obtained results were only applicable in a specific context or could be applied in different contexts.

The interviews were conducted between the years 2008 and 2010. The sample was designed using the maximum variation criterion (Patton, 1990), i.e., it focused on a few cases but was as diverse as possible, thus trying to avoid biases. For this purpose, results of institutional evaluations [Brazil: ENEM 2007 (National High School Exam - Exame Nacional do Ensino Médio); USA: ACT spring tests 2009 (American College Testing) and MME (Michigan Merit Examination)] were used to select teachers from schools with different performance results for their students and to interview both professors who teach genetics classes as well as molecular biology classes to avoid a possible trend in valuing classical genetics.

Interviews began with an open question about what genetics topics the interviewees considered to be necessary for secondary education level students to become informed citizens capable of critical thought. In light of a difference in opinion about the teaching of biotechnology, we also determined interviewees' opinions about including biotechnology topics in the curriculum.

With the permission of the interviewees, the interviews were recorded with a digital voice recorder. After transcribing and organizing the data, the process of data immersion began in an attempt to develop familiarity with them, seeking alternatives of analysis and more specifically of categorization, which in this case corresponded to the development of content categories.

As some topics were considered to be fundamental by the majority of the interviewees, this study also determined whether these topics were being addressed by the higher education institutions during teacher training. The syllabi were reviewed for the following training courses for biology teachers: in São Paulo, *BIO0203 (Genetics), BIO0205 (Molecular Biology), BIO0509 (Practical Genetics for Elementary and Secondary Education)* and *BIO0441 (Graduate Degree Programme in Molecular Biology)* were reviewed, and in Kalamazoo, *BIOS1500 (Molecular and Cellular Biology), BIOS2500 (Genetics) and SCI4040 (Teaching of Secondary Science)* were reviewed.

RESULTS

In São Paulo, the topics that were most often mentioned as basic content included *inheritance patterns* (100%), *cell division* (83.3%) and *molecular genetics* (75%).

Under *inheritance patterns, Mendel's laws* (83.3%) was the most cited topic, followed by *gene interaction* (41.1%). Within the category *molecular genetics*, the most commonly cited topics were *gene expression* (66.7%) and *genetic applications (biotechnology)* (58.3%).

In comparing the two sites, two topics stood out as being considered to be basic concepts: *inheritance patterns (83.3%)* and *molecular genetics (91.7%). Mendel's laws* (58.25%) and *codominance* (41.7%) were mentioned under *inheritance patterns.* There were also several topics associated with *molecular genetics*: *gene expression* (66.7%), *DNA structure* (66.7%), *mutation* (50%), *genetic applications (biotechnology)* (50%) and *DNA replication* (50%). *Cell division* was also commonly mentioned but with a much lower frequency in Kalamazoo (41.7%) than in São Paulo (83.3%).

When asked specifically about the teaching of the topic of genetic applications (biotechnology) as a basic content in secondary education, there was a difference in opinions between the interviewees regarding the teaching of biotechnology. The majority of interviewees (Table 1) thought that biotechnology is an important subject to teach so that students could understand information that they receive in their daily lives.

However, some interviewees said that these topics should only be addressed if students had already consolidated other basic knowledge. For them, these subjects would thus be secondary and were not indispensable for students on this level.

Half of the faculty members in São Paulo thought that including biotechnology topics would create an excess of content, resulting a superficial treatment of both biotechnology topics as well as more basic genetic concepts. The interviewees believed that these are difficult topics for students and that students who learn these topics may do so at the expense of other basic concepts. Several other authors have also identified this difficulty for students (e.g., Ayuso & Banet, 2002; Usak *et al*., 2009; Infante-Malachias *et al*., 2010).

Table 1

Summary of views by teachers and professors from São Paulo (SP) and Kalamazoo (MI) on the teaching of genetic applications (biotechnology) content as a basic for secondary education students. The circles highlight the group of teachers from São Paulo, of whom half of the interviewees indicated that the teaching of this topic was secondary, which differed from the majority opinion of the interviewees, and Group 1 of the teachers from Kalamazoo, which also stood out as deserving a more in-depth qualitative analysis of its situation.

Content category	Interviewees from São Paulo												Interviewees from Kalamazoo											
	Teachers						Professors						Teachers						Professors					
	Group1			Group 2			Genetics			Molecular Genetics			Group1			Group 2			Genetics			Molecular Genetics		
	TS1	TS3	TS4	TS2	TS5	TS6	PS1	PS2	PS3	PS4	PS5	PS6	TK1	TK3	TK6	TK2	TK4	TK5	PK1	PK5	PK6	PK2	PK3	PK4
Biotechnology	+	+	+	+	+	+	+	-	-	+	+	-	+		-	+	+	+	+	+	+	+	+	+

Legend			
Group 1	From schools with the highest results	+	Mentioned as basic (without intervention)
Group 2	From schools with the lowest results	+	Mentioned as basic (with intervention)
T	Teacher	-	Mentioned as not basic (without prompting)
P	Professor	-	Mentioned as not basic (with prompting)
S	From São Paulo (SP)		Not mentioned
K	From Kalamazoo (MI)		

Qualitative data relating to Group 1, which comprised teachers from schools with the lowest performance on exams in Kalamazoo, also showed the presence of a different opinion in this group. Half of the teachers interviewed in Kalamazoo showed they do not give the same importance to these and other topics.

TK6 considered such content secondary despite presenting a lower intensity in defense of this view with respect to the professors from São Paulo. TK3, in turn, did not directly express an opinion on the teaching of biotechnology in general. However, in addition to topics in this area not appearing among the content considered basic for her, the interviewee also said that one of the topics of the Michigan curriculum that she was reluctant to address was recombinant DNA technology. When analyzing the TK1 interview, it was noticed that the single reference regarding genetic applications from her interview was on the topic *how the karyotype can be used to identify genetic abnormalities* present in the list of curriculum subjects of the district of Kalamazoo, which she thought was basic to teach, and, in turn, was based on the curriculum of the State of Michigan.

Therefore, it can be noticed that the teachers in Group 1 in Kalamazoo, although they did not consider the biotechnology-related content to be secondary as strongly as the professors from São Paulo did, they certainly did not consider such content as basic in the same way as did other interviewees.

Some evidence of factors that may explain this divergence can be found both in the programs used by professors from São Paulo in their classes as well as in discussions about the curriculum used by the Michigan public education system. In this article we will focus our observations on the programs of different academic disciplines.

At the University of São Paulo, teachers that will teach biology in secondary education attend the undergraduate Biological Sciences program. Regarding the specific knowledge areas discussed in this study, these students have the following compulsory classes: BIO0203 Genetics and BIO0205 Molecular Biology. By analyzing the topics to be developed on these undergraduate programs (available in www.sistemas.usp.br, accessed on 05/05/2011) and in programs from 2010/2011 of these classes (provided by the professors themselves), it was noticeable that there was an interesting aspect of the BIO0203 class. In the class document, the professors explain that they follow the *Science as a Way of Knowing* project guidelines. The professors emphasise that the crisis in science teaching is the result of an excessive emphasis on teaching advances in biology rather than focusing on the conceptual framework. These ideas are consistent with the opinions of several of the interviewed faculty members, who thought that biotechnology teaching should not be a priority at the secondary education level.

However, several applications of molecular genetics, such as transgenics and molecular cloning, are covered in the *BIO0205* and *BIO0441* classes. *BIO0441* even discusses current topics that are often covered by the “lay media”. These objectives coincide with the concerns that were expressed by other half of faculty members in São Paulo. These interviewees suggested that teaching these topics helps students understand what is occurring in their daily lives and in the media.

There was consistency between the opinions of the professors and the curriculum documents in their respective fields. This is especially demonstrated by the differing opinions about teaching biotechnology topics. The documents reflect the opinions of the professors, either by defending the exclusion of biotechnology concepts because they impede the learning of more basic concepts or by defending the importance of teaching biotechnology so that students can understand topics that arise in their daily lives.

CONCLUSIONS

The majority of the topics that teachers and faculty professors consider to be basic are covered in the programmes and syllabi of graduate courses for teacher training.

There was consistency between the opinions of the professors and the curriculum documents in their respective fields. This is especially demonstrated by the differing opinions about teaching biotechnology topics. The documents reflect the opinions of the professors, either by defending the exclusion of biotechnology concepts because they impede the learning of more basic concepts or by defending the importance of teaching biotechnology so that students can understand topics that arise in their daily lives.

The opinions of both teaching groups are extremely valuable, as they provide important ideas. However, we suggest one possible alternative. In textbooks, Nascimento (2005) showed that topics related to genetics have gradually appeared without any connection to other concepts. Therefore, we not only agree with Ayuso and Banet's (2002) argument that it is important to address these topics in parallel with more basic concepts, but we also agree with one of the interviewed faculty members that we must integrate new genetics topics with basic concepts.

Thus, we concluded that certain questions should be raised about the methodology in use today. Is this content considered as supplementary but not elementary for understanding the basics? Would it not make more sense for students to understand what a gene is by understanding how it is linked to a facet of everyday life? Thus, this subject is considered to be important for students to understand issues in their daily lives. Therefore, it is believed that it is be necessary to determine if the form by which they are taught (decoupled from other basic subjects) is not influencing the results of the teaching of genetics before letting students out of the classroom.

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BIOLOGY OLYMPIAD AS A MODEL FOR INQUIRY-BASED APPROACHES

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Abstract: This article deals with the discussion about possible school application of tasks which are originally produced for the purpose in subject competition such as the Biology Olympiad and analyses some related benefits or difficulties with the use of tasks in the inquiry based science education.
Three fundamental questions are being discussed:
1) Is the transfer of the tasks from competition into the biology instruction possible in general? What are the necessary or limiting conditions?
2) What are the Features of the Tasks Especially Suitable for IBSTE?
3) What typical students' mistakes say about the process of learning and inquiry?
Often repeated mistakes of competitors are mentioned because they are useful source of valuable information about knowledge and competencies of students – competitors and they are transferable to the regular science education.
Results have showed that teachers can use a selected competition task, but there are some limits because the tasks are designed for extracurricular use and gifted youth. Data from last competition year show significantly higher success rate of students in the solution of theoretical tasks more than practical laboratory tasks or identification of plant and animal species.

Keywords: the Biological Olympiad, inquiry based education, science education, school tasks, biology education

INTRODUCTION

Science olympiads are a self-improvement type of competition, in which students carefully solve prepared, complex tasks demanding well-integrated knowledge, inquiring mind, creativity and science skills. The Biology Olympiad (the BiO) is a nationwide competition, organised under auspices of the Ministry of Education as an extracurricular activity. The BiO is in fact guided inquiry, where the learner must „sharpen or clarify a question provided by the material“. The remainder is a highly self-directed activity of the student, i.e. to determine what constitutes evidence and collect it, to formulate an explanation based on evidence, to examine other resources and relate them to the explanation, and to formulate a reasonable and logical argument to communicate the authored solution. Thus, the BiO fulfils the function of the Inquiry-based science education, as it engages students in authentic, open-ended problem-based learning activities; in experimental procedures, experiments and "hands on" activities, including the search for information; in self-regulated sequences of knowledge and skills application and in argumentation and communication of the solution.

The competition has hard-and-fast rules. It is held on three national (in the Czech Republic) and one international level (IBO – The International Biology Olympiad) and competing students are categorized into the four age brackets (Farkac & Bozkova, 2006; MEYS, 2007). The tasks are developed for the school, regional and national level and have usually extraordinary inquiry provoking potential.

The common engagement of biology teachers with the BiO is to prepare the school level of this competition and to prepare gifted students for the participation at the highest levels. In the past, about 10 years ago, teachers were helping students with the choice of a subject or a domain of interest and were preparing the way for collaboration between students and scientists or scientific institutions. Currently the BiO is realized without individual scientific projects of competitors. For this event different competition (called The Students Scientific Activity) is organized in the Czech Republic and it is oriented directly on students’ scientific projects (cf. e.g. with the EUSO on the international level).

There is another mission of teachers. Teachers can motivate and inspire all students not only towards the competition but towards interest or towards science education by solving selected attractive and innovative tasks which are slightly different from common school tasks. The BiO has potential to motivate students and to develop interest in biology. For example Stazinski (1988) summarized some aspects of the BiO in the formation of students' interest in biology and stated three positive impacts on biology education:
(i) further development and stability of students´ interest in biology,
(ii) most competitors have better achievement in school results and are more active in biology lessons,
(iii) competitors undertake further biological or medical studies.

The role of subject competition in science education is discussed from point of view of the motivation and other aspects (cf. eg. Verhoeff, 1997, Wilson, 1981, Petr, 2010).

Science olympiad can be a useful tool for the preparation of teachers as well. After conclusions published by Breyfogle (2003) work with the competition tasks is an evident benefit in teacher education. Breyfogle (2003) has studied opinions of pre-service teachers. The use of competition tasks, their preparation, demonstration, solution and their analysis during laboratory course in the chemistry teacher education were conceived as a good idea. In this course students have obtained a deeper insight into problems of the using authentic activities to implement constructivist or inquiry based approach in the laboratory instruction.

Similar experience was acquired during a teacher training course at the University of South Bohemia with pre-service biology teachers (Stuchlikova, Petr & Papacek, 2013). Students stated analogous benefits of participation at lessons. They were analysed and solved selected competition tasks and discussed the educational and motivational potential of the tasks and they positively evaluated the experience gained by working on the competition committee.

The competition tasks served as a dominant material for the work in the seminar. As the tasks have an extraordinary inquiry provoking potential, it would be valuable to transform the ideas of the BiO into the regular instruction and use them also in teacher education.

We can discuss three fundamental questions:

1) Is the transfer of the tasks from competition into biology instruction possible in general? What are the necessary or limiting conditions?

2) What are the Features of the Tasks Especially Suitable for IBSTE?

3) What typical students’ mistakes say about the process of learning and inquiry?

METHODS

For the illustration of a long-term observation and longtime empirical experiences, a set of 34 protocols of competitors at regional level of last competition year (2013) was analysed. During the competition results of competitors were assessed by a regional committee comprised of 7 people (scientists, teachers, pre-service biology teachers). Protocols were compared with an author's solution published by the organizer and this was accompanied by an observation of the competitors´ work during the process of solving competition tasks. The observation was necessary for a correct evaluation of the sketches drawn during the microscopic task and a correct assessment of working procedures and skills of competitors. The sketches were compared with real microscopic slides. Results of the competitors were evaluated by the ANOVA with the Tukey post-hoc multiple comparison ($F(6, 198) = 22.11$; $p<10^{-6}$).

Possibilities and limits of the implementation of competition tasks were discussed with students - participants of the seminar oriented on the school experiments, observation and other practical methods in the biology teaching.

RESULTS

Through the analysis of students' results and protocols, it was found that students have problems with solving laboratory tasks rather than theoretical task (Figures 1 and 2). There is a significant difference among theoretical and practical tasks. A very large dispersion was found in the knowledge, or better to say identification, of animal and plant species and taxa, where the recognition of animals is significantly better than in the recognition of plants.

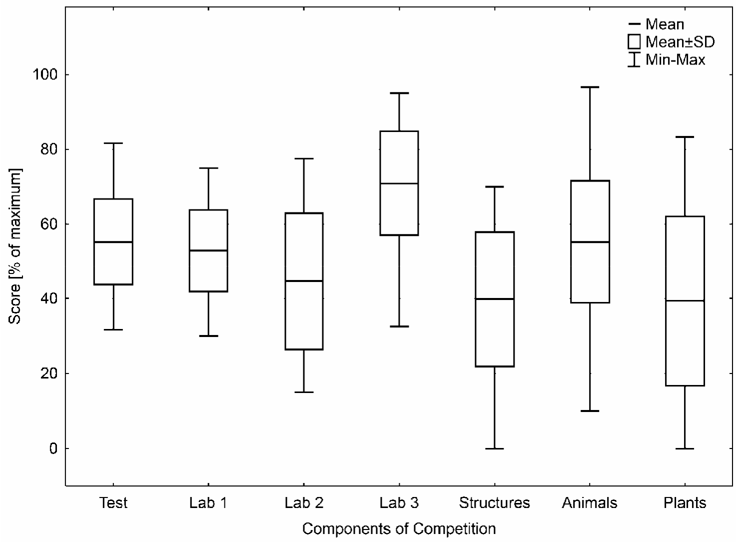

Figure 1. Results of competitors at the regional level of the BiO 2013. Legend: *Test* – theoretical test with closed questions; *Lab1, Lab 2* - laboratory tasks; *Lab 3* – the task without demands on equipment (de facto theoretical task); *Structures* - identification of some biological structures and phenomena; *Animals/Plants* - identification of the animal/plant species

	Test	Lab 1	Lab 2	Lab 3	Structures	Animals	Plants
Test		-	+	+	+	-	+
Lab 1	-		-	+	+	-	+
Lab 2	+	-		+	-	+	-
Lab 3	+	+	+		+	+	+
Structures	+	+	-	+		+	-
Animals	-	-	+	+	+		+
Plants	+	+	-	+	-	+	

Figure 2. Outcome of the one-way repeated measures ANOVA ($F(6,198) = 22.11$; $p < 10^{-6}$ Tukey post-hoc multiple comparison). Legend: + significant difference between variables.

Success rate of task Lab 3 (but this task is more than lab task rather theoretical) is significantly higher than in laboratory tasks.

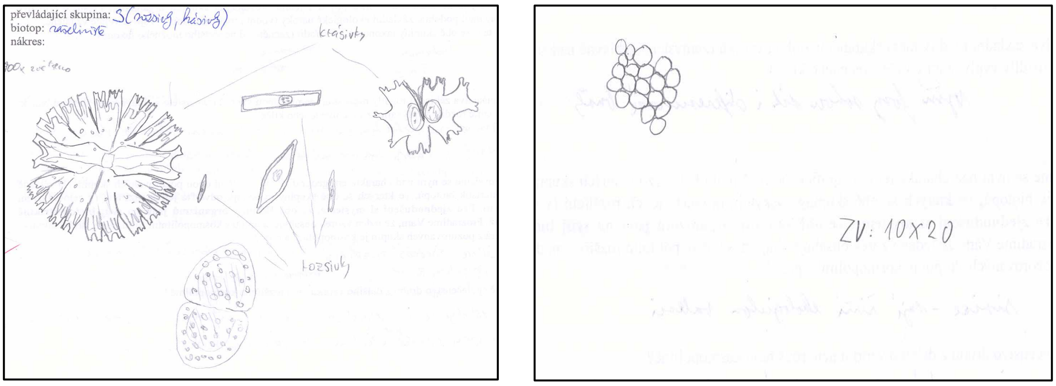

Figure 3. Examples of two sketches, correct (left) and incorrect (right), of microscopic objects.

DISCUSSION

The first question - Is the transfer of the tasks from competition into the biology instruction possible in general? What are the necessary or limiting conditions?

The portfolio of tasks produced for the BiO is relatively broad. Some tasks are very similar to common school tasks (primarily at the school competition level). Therefore the use of these tasks is possible but it provides only a small additional educational benefit. This kind of tasks is assigned for further training of some skills and knowledge at the school level.

New designed inquiry oriented competition tasks are the main source of enrichment for the biology instruction. They can bring new alternatives and challenge therefore routine instructional methods because they are new and extend teachers' portfolio of tasks, methods or forms of instruction.

Motives for the use of the competition tasks in the biology education:

1) Tasks are produced by teams of specialists from different biological branches with participation of teachers and biology students. Therefore, both factual and didactic correctness is guaranteed. Detailing of the tasks runs continually so the final manual and instructions for teachers and jury are published last of all. Teachers can obtain a good source of new and elaborated tasks for their practice in this way. Approximately 14 – 15

new tasks are developed for one year of competition. Therefore, lots of new tasks are arising for the potential use in school.

2) Teachers obtain well-elaborated methodical instructions and elaborated author's solution for every task. The solution of the BiO is a tool for the evaluation of the tasks on one hand and for the evaluation of educational processes on the other hand. The evaluation of the tasks from the point of view of the success rate is a good indicator for the implementation of the selected task into the regular classroom settings.

There are some limits for the implementation of the tasks into the regular education as well:

1) Extracurricular character of the competition (i.e., the possible different thematic scope in comparison with the curriculum).

2) Some tasks require extracurricular knowledge because they are designed for gifted youth. Teachers should try to adapt and critically evaluate the tasks before their use in education.

3) Some tasks require special equipment or material (usually it is provided only for the relevant level of competition by the central competition committee) and obtaining it may not be very easy for all teachers

4) Adaptation of some tasks from higher levels of competitions by teachers is necessary. Some of the tasks are transferable without any modification, but the most tasks require a lesser or larger adjustment for the inquiry-based teaching. Some examples include matching with relevant curriculum, specification of a hypothesis, a way of the presentation of results etc.

The Second Question - What are the features of the tasks especially suitable for IBSTE?

There are two main different kinds of the competition tasks suitable for transfer into the regular classroom:

1) Theoretical tasks without requirements of any special laboratory equipment. Nonetheless, these tasks do not lead only to identification of bare facts; they are complex and sophisticated and they are not solvable without complex problem solving operations and proper work with data. Also, the verification of the inferred solution is realized through different ways (filling in of missing information, content analysis of a text, the work with pictures, tables, diagrams etc.)

2) Laboratory tasks: only basic laboratory or field equipment is required for the solution of these tasks. Complicated tasks or tasks from higher levels can be simplified for younger pupils. On the other hand it is possible to refine or to extend relatively simple tasks depending on the curricular content.

The Third Question - What typical students' mistakes say about the process of learning and inquiry?

In view of the fact that the BiO is designed as an extracurricular competition oriented primarily on youth with broader interest in biology, we can expect appropriate, better-than-average, knowledge and competencies. During the analysis of students´ protocols it was found, that competitors had similar problems with some issues as the common students. We can generalize the most frequent issues:

1) Low understanding of written text. The dealing with tasks by competitors under pressure of the competition environment plays a certain role but this issue corresponds with poor results of Czech pupils in international comparative researches (PISA).

2) Better vs. worse laboratory skills. Laboratory skills are necessary for correct solving of many practical tasks. Very different results of competitors chiefly at lower levels were found. This fact can indicate a lack of practical laboratory lessons during biology education and a decrease of chances of some teaching methods (e.g. inquiry) to be implemented in science education. This is a typical problem of many Czech teachers – laboratory lessons are considered as time consuming, a bit expensive or complicated. Therefore, many teachers prefer verbal teaching without developing of practical skills of pupils.

3) Better vs. worse sketch drawing skills. Ability to draw correct sketches and other documentation skills are necessary for all biology students, as the way of the documentation and presentation of their own findings. About 60 % of competitors´ sketches (in one year of competition) were incorrect. There are broad differences in drawing skills among competitors. Some sketches record false objects, some are indecipherable. On the other hand, some competitors make very accurate sketches. These pictures illustrate well different skills of some competitors (Figure 3).

4) Uneven biological background. Study booklets oriented on a relevant topic in a competition year of the BiO are prepared by a national committee and are available for all competitors. It is evident that some students do not work with this text in an analytic and synthetic way. Thus, they cannot correct solve complicated and complex tasks.

5) Higher success rate in theoretical parts of the competition than in practical parts. While theoretical tasks require the use of theoretical knowledge, laboratory tasks require a synergy of theoretical knowledge and practical skills. Once again, this lack of practical skills acquired at school is a weak point of biology education.

6) Large dispersion of the ability to identify selected species of animals and plants. The identification of common animal or plant species is a traditional part of the BiO. Some teachers prepare their students in this domain (for example during thematic excursions, by collecting samples, didactic tests etc.) many results of the competitors show very different levels of knowledge. Only a part of the competitors have ideal knowledge. Poor results of some competitors (but in fact of the best students in biology) indicate broader problem in biology education (see fig. 1). Some students are not able to concretize their theoretical knowledge in biology by real taxa.

CONCLUSION

The BiO fulfils the function of the Inquiry-based science education, as it engages students in authentic, open-ended problem-based learning activities; in experimental procedures, experiments and "hands on" activities, including search for information; in self-regulated sequences of knowledge and skills application and in argumentation and communication of the solution. Although there are some limits in the use of the competition tasks in the regular school education, which follows from extracurricular character of the BiO. Teachers can use the BiO as an inspiring and rich source of well prepared tasks and experiments in regular biology education. The BiO is a good instrument for verification of the effectiveness of biology education and can show some problems concerning biology education.

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WHAT CAN IMAGES TELL US? -A CROSS-CULTURAL COMPARISON OF IMAGES ON SCIENCE TEXTBOOKS BETWEEN AUSTRALIA AND TAIWAN

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Abstract: Social semiotics proposes that image design is influenced by socio-culture. The purpose of this study intends to compare the images on Taiwanese and Australian high school science textbooks. Drawing on the theoretical framework from grammar of visual design (Kress & van Leeuwen, 2006), we seek to investigate the images according to three metafunctions: ideational, interpersonal, and textual. Content analysis is used to analyze the sample units of biological classification, which are shared most consistently across six textbooks: three from Taiwan and the other three from Australia. According to our coding scheme, 266 original image complexes can be analyzed into 755 basic image units. All of them are coded qualitatively and compared quantitatively. The comparison of ideational metafunction indicates that the image structures between countries in the first and second level analysis are similar. The majority are represented by conceptual structure. Only a few are represented by narrative structure. The structures of analytical process and classificational process are used to represent the features of living things and their taxonomy. The difference is not revealed until the third level analysis. It is found that Australian versions use more overt taxonomy which can explicitly represent hierarchical relationships of classification among concepts. Instead, Taiwanese versions use more covert taxonomy which is short of such function. The comparison of interpersonal metafunction reveals that Australian versions skillfully use the functions of image act, involvement, and social distance to construct a closer relationship between the images and readers. The comparison of textual metafunction unfolds the hidden influence of image design comes from socio-culture. The results from these three metafunctions all confirm there are differences of image design between the science textbooks of Taiwanese and Australian. The implications for images teaching are discussed. Also, suggestions for publication of science textbooks and further research are made.

Keywords: biological classification, science textbook, grammar of visual design, cross-country comparison, image

INTRODUCTION

Visual images in science textbooks play an important role for leaning. Images can display objects or events visually which are difficult to see with unaided eyes. Moreover, those abstract images, such as graphics or concept map, can organize complex information into scientific formats which can represent large amount of messages efficiently in limited space (Kozma, 2003). The roles mentioned above focus more on the benefits of representational meanings in facilitating leaning. The topic how images make meanings is seldom discussed (Han & Roth, 2005; Lemoni, Lefkaditou, Stamou, Schizas, & Stamou, 2011).

As a social semiotics, Kress and van Leeuwen (2006) proposes that meaning-making in images displays cultural regularities which can be described formally like verbal grammar. There are three dimensions of visual meanings. The first dimension, ideational meanings, can be realized through the examination of image structure which visually constructs events, objects and participants involved, and relevant circumstances as well (Unsworth, 2001). The second dimension, interpersonal meanings, is realized by visual resources which build the relations between readers/sign-maker, or images/readers. The third dimension, textual meanings, is realized by the compositional arrangement of images.

The purpose of this study is to compare three dimensions of meanings by examining the images in the science textbooks of Australia and Taiwan. The benefits of cross-country study, first of all, will generate greater variations in the variables of interest drawn from two countries than those from only one country. Secondly, the taken-for-granted beliefs and motivations in one culture can be exposed and questioned in comparison (Aldridge, Fraser, & Huang, 1999). Last, the results can also be a resource for publishers to get rid of some images which could restrict reading comprehension (Cook, 2006).

THEORECTICAL FRAMEWORK

The grammar of visual design (Kress & van Leeuwen, 2006) proposes that meaning-making of images implicitly follows some culturally regular rules. Therefore, all these three dimensions of meanings can be realized in terms of semiotic resources (shown as Figure 1). Representational meanings can be realized by representational structures which are subdivided into narrative and conceptual structure. Narrative structure represents “unfolding actions and events, processes of change, transitory spatial arrangements” (p.77); in contrast, conceptual structure represents the participants “in terms of their generalized and more or less stable and timeless essences, in terms of their class, structure or meanings” (p.77). Interactive meanings are generated by image acts, long /medium/close shot, horizontal angle, and vertical angle as well. Textual meanings can be analyzed by how visual elements are organized together. A triptych, originated from medieval religious paintings, is to arrange images and words by top-middle-bottom or left-middle-right. In contrast, a center-margin composition is strongly influenced by Buddhist paintings.

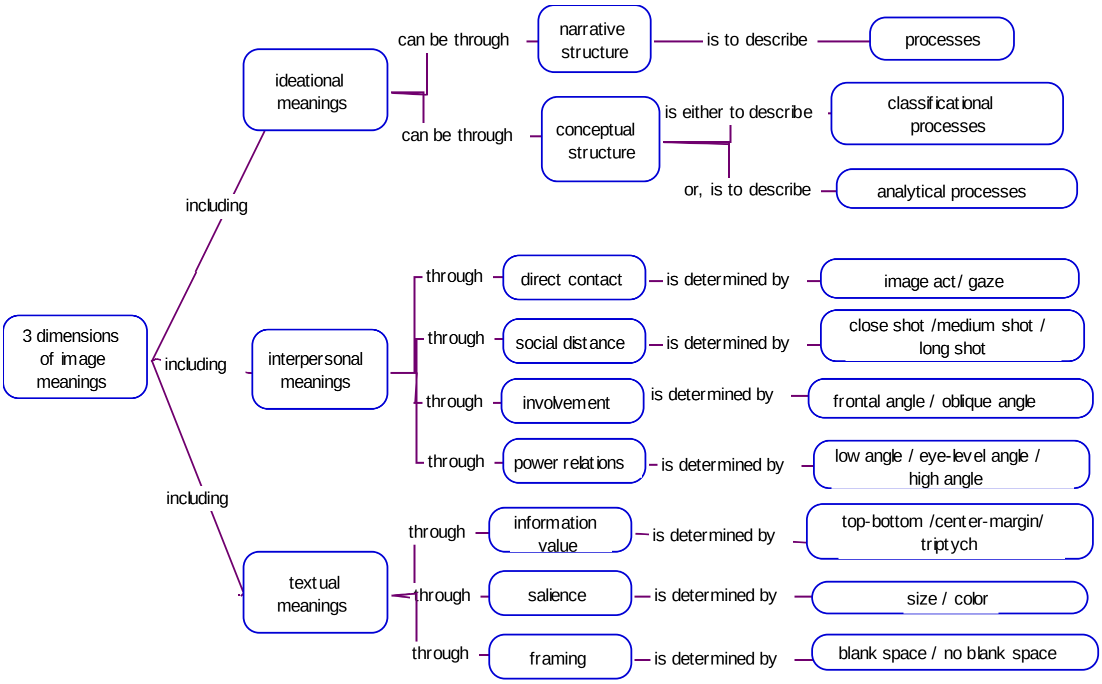

Figure1. Semiotic resources used to analyze three dimensions of meanings

METHODOLOGY

The method of content analysis is adopted to deal with the images from the chapter of biological classification in 6 textbooks from Australia and Taiwan. The overview of the samples is shown on Table 1. The majority of the original data are either image complexes or multiple representations. The unit of analysis is defined as an autonomous sign with border and participants which is not able to be analyzed. For example, figure 2 is an image complex with 6 units. The frog, shark, snake, owl, and lion are 5 units. All these five units together constitute another unit.

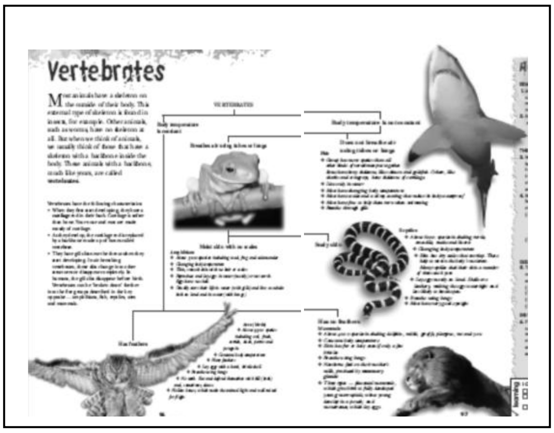

Figure 2. An image complex of overt classification (cite from Wiley 1, 2005, p.177-178)

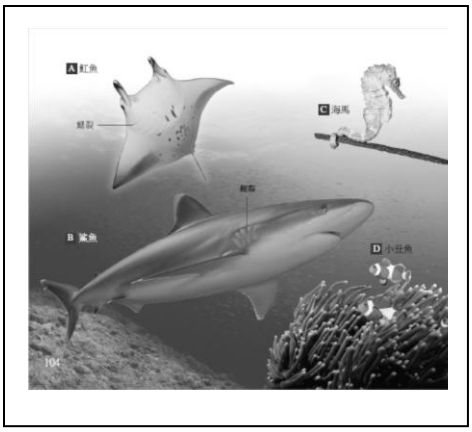

Figure 3. An image complex of covert classification (cite from Kan-Shen 2, 2010, p.104, F4-35)

According to the semiotic resources shown on Figure 1, a modified coding scheme is set up. In order to deal with the main ideas revealed by our data, biological classification, the code of 'classification processes' (under 'ideational meanings' and 'conceptual structure') is further subdivided into 'covert classification' and 'overt classification'. An image with covert classification is not easy to tell the hierarchical relation between contents (Figure 3). In contrast, an image with overt classification, such as a concept map in a tree structure, the ordering between taxonomies is explicit to tell (Figure 2).

Table 1

Overview of selected chapters and textbooks

	Australian textbooks			Taiwanese textbooks		
publisher	Oxford	Pearson	Wiley	Kan-Shen	Han-Lin	Nan-I
Copyright	2008	2006	2005	2010	2010	2010
Title of the chapter	Life on earth	Classifi-cation	Classifi-cation	Life on earth	Diversified living things	Diversified living things
Analyzed pages	21	32	24	39	31	39
Images-complex	45	57	37	40	49	48
Image unit	94	97	75	181	174	134
%image/page	4.48	3.03	3.13	4.76	4.58	4.47

Inter-coder reliability is assessed by the first author, second author, and an outsider. The outsider is an experienced high school teacher who majored in science education with PhD degree. A random sample of about 15% of images is coded by these three coders. The averaged value of agreement is 90.9%.

FINDINGS

The comparison of ideational meanings between Australia and Taiwan

According to the ordering of coding scheme, ideational meanings are analyzed in three-layer depth. The results of analysis in the first two layers are similar between countries (Table 2 and Figure 4). That is, both Australian and Taiwanese chapters use more conceptual structure to represent the concepts related to biological classification.

Table 2

The distribution of main image structures in the six samples

	Oxford	Pearson	Wiley	Kan-Shen	Han-Lin	Nan-I
Narrative structure	1.0%	4.0%	7.7%	7.7%	4.6%	7.4%
Conceptual structure	99.0%	92.3%	95.4%	92.3%	97.8%	95.4%

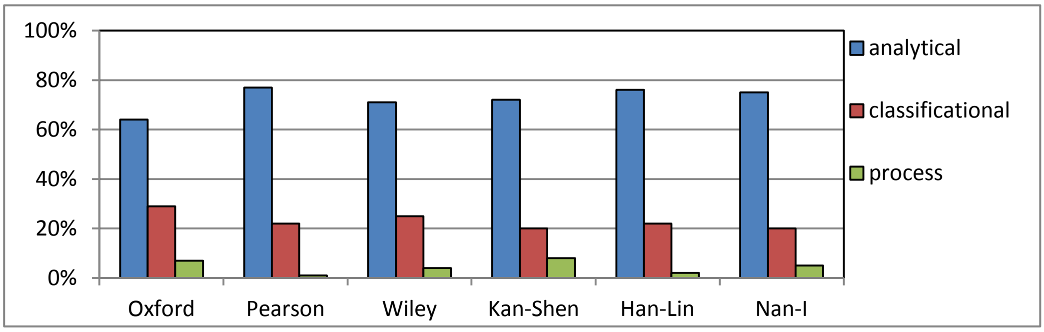

Figure 4. The frequencies of subtypes of image structure in six samples

The ideational meanings are not distinguished until the analysis of the third layer which reveals Australian chapters use more overt classification (Table 3). Instead, Taiwanese chapters use more covert classification.

Table 3

The distribution of two types of classificational structures in six samples

	Australian textbooks			Taiwanese textbooks		
	Oxford	Pearson	Wiley	Kan-Shen	Han-Lin	Nan-I
covert classification	46.2%	31.6%	42.1%	80.6%	74.2%	88.2%
overt classification	53.8%	68.4%	57.9%	19.4%	25.8%	11.8%

The comparison of interactive meanings between Australia and Taiwan

The images in Australian chapters are more skillful at generating intimate relations with viewers. The results on Table 4 indicate that Australian images can more easily attract viewers' attention to enter the imagery world. Moreover, Australian images often represent the participants in frontal angle and close shot which can facilitate more involvement and social affinity. Last, more eye-level angle is taken in Australian images which can create more close interaction by equal power relations between reviewers and images. All these results agree that the image design in Australian chapters can build better interpersonal relations with students than Taiwanese counterparts.

Table 4

The distribution of variant interactive meanings in six samples

Index \	publisher	Oxford	Pearson	Wiley	Kan-Shen	Han-Lin	Nan-I
Image act	offer	88.3%	72.0%	88.7%	**100.0%**	**93.1%**	**95.4%**
	demand*	**11.7%**	**28.0%**	**11.3%**	0.0%	6.9%	4.6%
Involvement	frontal*	**51.8%**	**60.0%**	**47.2%**	37.8%	22.6%	28.2%
	upper	19.6%	12.0%	18.9%	**40.2%**	**50.0%**	**38.2%**
	oblique	**28.6%**	**28.0%**	**34.0%**	22.1%	27.5%	33.6%
Social distance	long shot	20.0%	16.0%	1.9%	**28.7%**	**48.0%**	**37.4%**
	medium shot	33.3%	33.3%	69.8%	42.6%	46.1%	55.0%
	close shot*	**46.7%**	**50.7%**	28.3%	**28.7%**	5.9%	7.6%
Power relations	low angle	40.0%	37.0%	56.6%	**58.1%**	**77.5%**	**66.9%**
	eye level*	**51.7%**	**57.5%**	37.7%	**38.0%**	20.6%	32.2%
	high angle	8.3%	5.5%	5.7%	3.9%	2.0%	0.8%

xx* indicate the semiotic resource can create close interpersonal relations with readers

The comparison of textual meanings between Australia and Taiwan

Textual meanings can be revealed by compositional arrangements and blank space which can separate information. Table 5 indicates that triptych only appears in Australian chapters. The distribution of center-margin composition is higher in Taiwan. Triptych is unique in Australian chapters; in contrast, Taiwanese seems prefer center-margin. Both arrangements have cultural or historical origins. These serve as evidences that science images in textbooks are socio-cultural embedded.

Table 5

The distribution of variant compositional arrangements in six samples

	Oxford	Pearson	Wiley	Kan-Shen	Han-Lin	Nan-I
triptych	**69.6%**	**3.0%**	**23.8%**	0.0%	0.0%	0.0%
top-bottom	26.1%	**87.9%**	19.0%	**54.1%**	48.5%	**63.2%**
center-margin	4.3%	9.1%	**57.1%**	**37.8%**	**51.5%**	26.3%
others	0.0%	0.0%	0.0%	8.1%	0.0%	10.5%

Furthermore, to purposely leave large blank space is another evidence to prove that Australian textual meaning is different from Taiwanese counterparts (Table 6). According to the interviews with the textbook editors, Taiwanese chapters leave large blank spaces for students to take notes. This kind of arrangement is definitely not possible in Australian chapters since science textbooks there are school property on which any marking is illegal.

Table 6

The distribution of purposeful blank space in six samples

	Oxford	Pearson	Wiley	Kan-Shen	Han-Lin	Nan-I
Blank space	0.0%	0.0%	0.0%	29.7%	18.2%	34.2%

CONCLUSION AND SUGGESTIONS

Drawing on the grammar of visual design, three dimensions of image meanings serve as rich resources for the comparison of science textbooks between Australia and Taiwan. The difference of ideational meanings lies on the image structure of covert and over classification. Taiwanese prefers to use covert classification; whereas Australian prefers overt classification. The difference of interpersonal meanings results in the fact that Australian versions can skillfully construct closer relations with readers. The difference of textual meanings unfolds that image design is culturally embedded. Therefore, images from science textbooks can tell the cultural difference.

The results imply that images with covert classification might be less efficient to help students distinguish hierarchical relations among biological classes. A further empirical study is suggested to examine whether this implication is true or not. Also, we suggest teachers pay attention to image structures which might be difficult for students to comprehend. Last, the results function as a good resource for textbook publishers, especially Taiwanese publishers, to revise their images.

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HOW DO FUNDED SCIENCE EDUCATION PROJECTS DISSEMINATE THEIR OUTCOMES TO TARGET AUDIENCES? ANALYSIS OF THE CURRENT STATUS AND RECOMMENDATIONS FOR MORE EFFECTIVE DISSEMINATION

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Abstract: This paper presents an analysis of the dissemination strategies used in funded science education projects. Dissemination is considered here as the process by which, using certain strategies, projects' outcomes are made available, comprehensible and usable to be adopted by potential users. That is to say, we do not consider dissemination as merely making results available but making them potentially exploitable. This study aims to identify difficulties and needs of several stakeholders involved in dissemination processes: project managers or researchers, science teachers, advisors of policy-makers, and science communicators. With this purpose, two instruments of data collection were designed: online questionnaires and on-line or face-to-face discussion events. The collected data allowed us to characterise the types of outcomes produced by a number of selected funded projects in science education, the target audiences for the dissemination purposes of these funded projects, the dissemination strategies used by these projects and their procedures for evaluating the quality of dissemination actions. This study allowed gaining an insight into the dissemination strategies used in funded international and national projects and their impact as perceived by different target groups. Furthermore, this study identified some needs that should be taken into account to recommend measures to improve how dissemination is planned and carried out. These recommendations are summarised in this paper.

Keywords: Science Communication, Science Education Policy, Training and Development, Science Education projects, Dissemination and Exploitation

RATIONALE AND PURPOSE

There are multiple funded projects in science education around Europe each year. Most of them have the potential to change existing teaching and learning practices but their impact is sometimes poor and their outcomes are often not used in the way they could be. As stated by Hammersley (2000), the dissemination of research findings has been given increasing emphasis in recent years, particularly in the wake of critiques of educational research for failing to have an impact on policy-making and practice. Thus, educational policy-making continues placing emphasis on the dissemination of project outcomes as a mechanism for quality improvement in education.

This is also the focus of the DESIRE project, which is intended to analyze possible obstacles and facilitators to promote a more effective model of dissemination of science education projects' outcomes, preventing them becoming 'sticky' to the origin context or rapidly lost. In this paper we present an analysis of the dissemination strategies used in funded science education projects in order to identify the needs of the agents involved in dissemination actions in order to suggest recommendations to improve current models of dissemination.

Therefore, this study is intended to answer the following research questions:

1. How are the outcomes from science education projects disseminated to target audiences?
2. What recommendations do different target groups suggest to improve the dissemination strategies used in science education projects?

THEORETICAL FRAMEWORK

According to Rogers (2003), the diffusion of innovations, envisaged as the process by which an innovation is communicated through certain channels over time among the members of a social system, undergoes different phases, such as awareness, understanding, persuading, adopting (or rejecting), and re-inventing. This implies that any dissemination strategy should guarantee the availability of outcomes and it also should facilitate potential users' understanding of these outcomes to promote their adoption and adaptation.

There are those who seek to discriminate between the processes of dissemination and diffusion by asserting that dissemination is a systematic process and diffusion is more haphazard (Hughes, 2003). That is why we refer to dissemination of project outcomes instead of diffusion.

Harmsworth et al. (2001) also express their idea of dissemination on educational development projects, from three different perspectives:

- *Dissemination for Awareness*: It can be assumed that one wishes people to be aware of the work of the project since they might be trying to solve similar problems.
- *Dissemination for Understanding*: There will be a number of groups that one will need to target directly since they might potentially benefit from what the project has to offer and so they would need a deeper understanding of the project results.
- *Dissemination for Action* (i.e. changing practices by adopting project's outcomes): The groups that are in a position to 'influence' and 'bring about change' within their organisations and that can benefit from the results of the project need to be equipped with appropriate resources in order to achieve real change.

Taking into account the different perspectives, we consider dissemination as the process by which, using certain strategies, projects' outcomes are made available, comprehensible and usable to be adopted by potential users. That is to say, we do not consider dissemination as merely referring to making results available but making them potentially exploitable.

With the purpose of characterizing dissemination strategies that science education projects currently carry out, we take into account Hughes' (2003) description of models of dissemination to bridge the so-called academic – practitioner gap. Figure 1 presents a synthesis diagram that includes four dissemination models, discussed by Hughes (2003), and the reference authors who first characterised these models (in blue colour).

The author refers to *traditional models* (e.g. diffusion model, cascade model) as those conceiving knowledge transfer as a rational and linear process, from basic to applied research and development, and then on to mass dissemination. These models assume that individuals will recognize and take up 'good' knowledge in a progressive and enlightened way. The main criticism to these traditional models is that they are top-down, expert-driven and they portray the end user as passive and rational. It tends to portray knowledge as a parcel that can be easily passed from one individual to another, remaining intact in the process of transfer.

Social constructivist models assume that information is communicated, or otherwise picked up and it becomes usable knowledge only when cognitively processed by the user. Moreover, these models conceive that knowledge will only be taken up if it appears relevant and useful to a potential recipient. It is, therefore, the job of the disseminator to make the relevance explicit. The criticism, though, is that, according to these models, disseminators seek to manipulate recipients' perceptions of new knowledge by identifying and gaining support of influential groups, and individuals, and by using strategies that worked with other innovations. Therefore, a lack of focus on development of local or context-based practice is associated to these models.

The so-called *sustained interactivity model* enhances collaboration and partnership, interpersonal links, spread throughout a project to promote the use of outcomes. This model assumes that intermediaries are necessary because they provide linkage mechanisms that enhance the potential usefulness of research findings. However, this model is usually applied in small-scale projects that are time-consuming, and although the researcher is clearly given a service role, the power relations between academics and teachers confine the practitioner to the role of client rather than full partner, let alone the producer or initiator of research.

Finally, the *Model 2 knowledge model* assumes that practising teachers are at the heart of creation of quality knowledge about effective teaching applicable in classrooms, and researchers are closer to them working in networks of practitioners and academics. Knowledge is applied, problem-focused, and demand-driven. This model seeks to take account of context factors influencing knowledge disseminated.

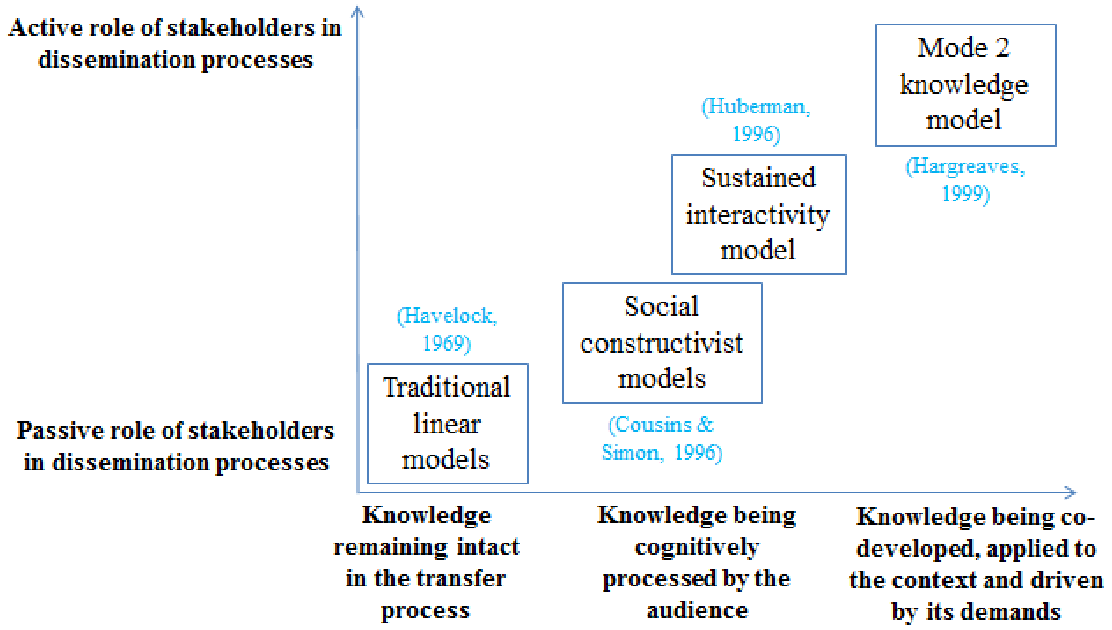

Figure 1. Models of dissemination as described in the literature.

METHODS

Data collection

Two types of instruments of data collection were designed:

- *On-line questionnaire*

Drawing upon the study on dissemination strategies carried out by Saywell, Cotton and Woodfield (1999), we designed and pilot-tested three different on-line questionnaires on dissemination strategies used in projects to reach different stakeholders. Later, these questionnaires were administered to: science education projects' managers and researchers (Q1), science teachers (Q2), and advisors of policy-makers (Q3). The sample was selected after elaborating a list of 46 research and/or innovation projects in science education funded by the European Commission under different programmes, by national public institutions or by other organisations. The managers of these projects were contacted to send them the link to Q1 and to request their collaboration in sending Q2 to teachers who had been involved in the projects they had managed. Finally, several advisors of policy-makers were asked to complete Q3.

The three questionnaires included closed-ended questions (multiple choice, matrix of choices, 5-points Likert scale) and open-ended questions.

From these questionnaires, the following data were collected: responses from 26 project managers about 26 different projects, responses from 105 science teachers about 21 different projects, and responses from 15advisors of policy-makers about 10 different projects.

In sum, data were collected from stakeholders involved in 31 national and European science education projects represented in Figure 2.

Figure 2. Projects from which data were collected using the questionnaires designed in the DESIRE project.

- *On-line or face-to-face discussion events*

Several discussion events were held during the DESIRE project, most of them took place on-line through forum in the project's website. The discussion events on the topic of dissemination were organised and addressed to different target groups: science education project managers or researchers, science teachers, advisors of policy-makers, and science communicators (i.e. science centre / museum professionals, and science event organisers). These events allowed collecting opinions, reflections, experiences and needs of dissemination from several agents involved in the dissemination of project outcomes.

Data analysis

In order to answer the aforementioned research questions, we performed a qualitative analysis intended:

- To interpret connections among dissemination strategies and outcomes to be disseminated or among dissemination strategies and target audience.
- To identify possible differences among projects funded by different funding sources.
- To identify target audiences' needs regarding dissemination.

RESULTS

On current dissemination practices

As shown in Figure 3, one of the results of the analysis of the questionnaires is that a significant number of project managers, science teachers and policy-makers consider that they do not receive too much information from funded projects in science education. This result supports the need for finding new ways to disseminate projects' outcomes in order to contribute to bridge the research-practice gap.

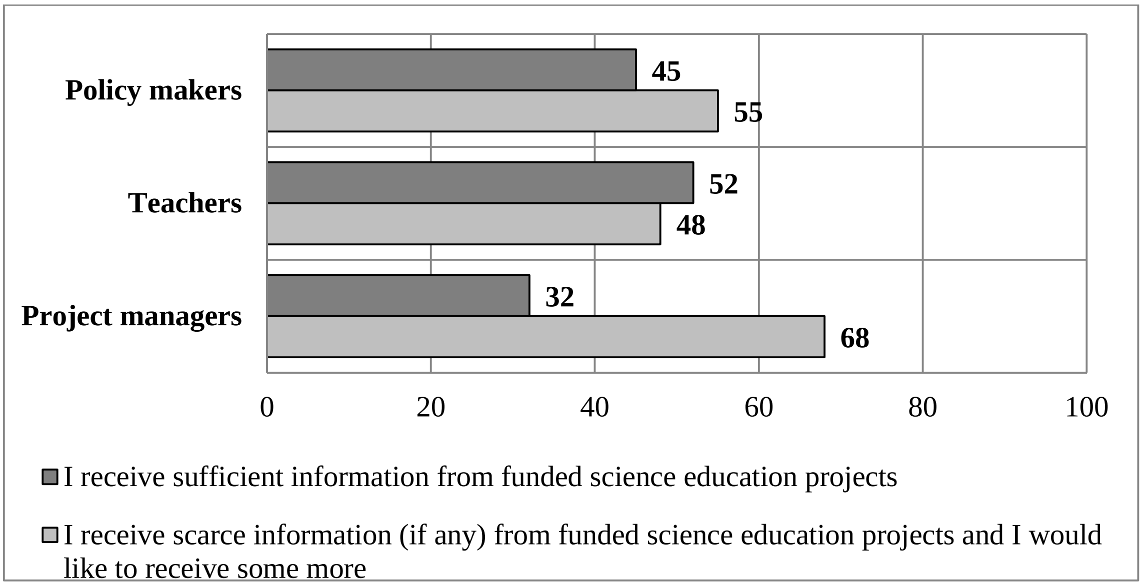

Figure 3. Different target audiences' appraisal of the amount of information received from funded projects (expressed in %).

As shown in Figure 4, the results of this study also provide evidence that almost all science education projects (96%) are intended to reach teachers and professors. This is the common target audience that most of science education projects share. About 75% of funded science education projects also intend to reach other target audiences such as teacher trainers, policy-makers and other project managers. Less than a third of the analysed projects intend to reach science events' organisers, science centres' managers, editorials or other society agents like parents or industries. The most noticeable difference when comparing projects funded by different institutions is that projects funded by the 7^{th} Framework Programme (FP) of the European Commission seem much more devoted to disseminate their outcomes among a wider range of society agents such as parents or industries (46%) than projects funded by the Lifelong Learning Programme (LLP) (14%) or national or academic projects (0%).

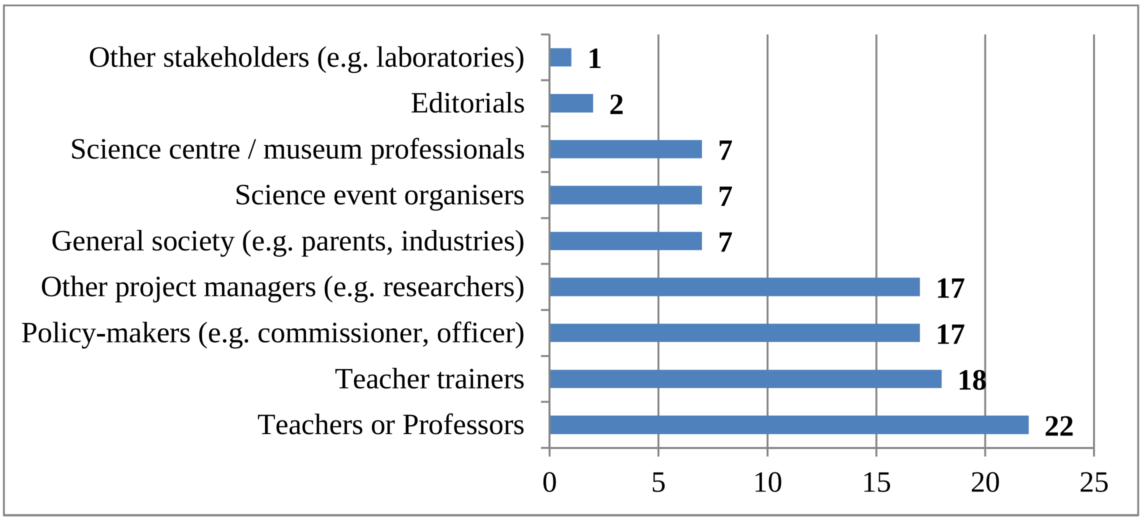

Figure 4. Target audience of science education projects (N = 23 project managers)

As shown in Figure 5, the previous results are consistent with the fact that most of the analysed projects (81%) disseminate teaching/learning materials as main outcomes. Other types of outcomes that are also frequently disseminated (more than 50%) consist of guidelines of good practices, networks of people and teacher training materials. On the contrary, literature reviews, empirical findings and theoretical contributions are not common outcomes to be disseminated.

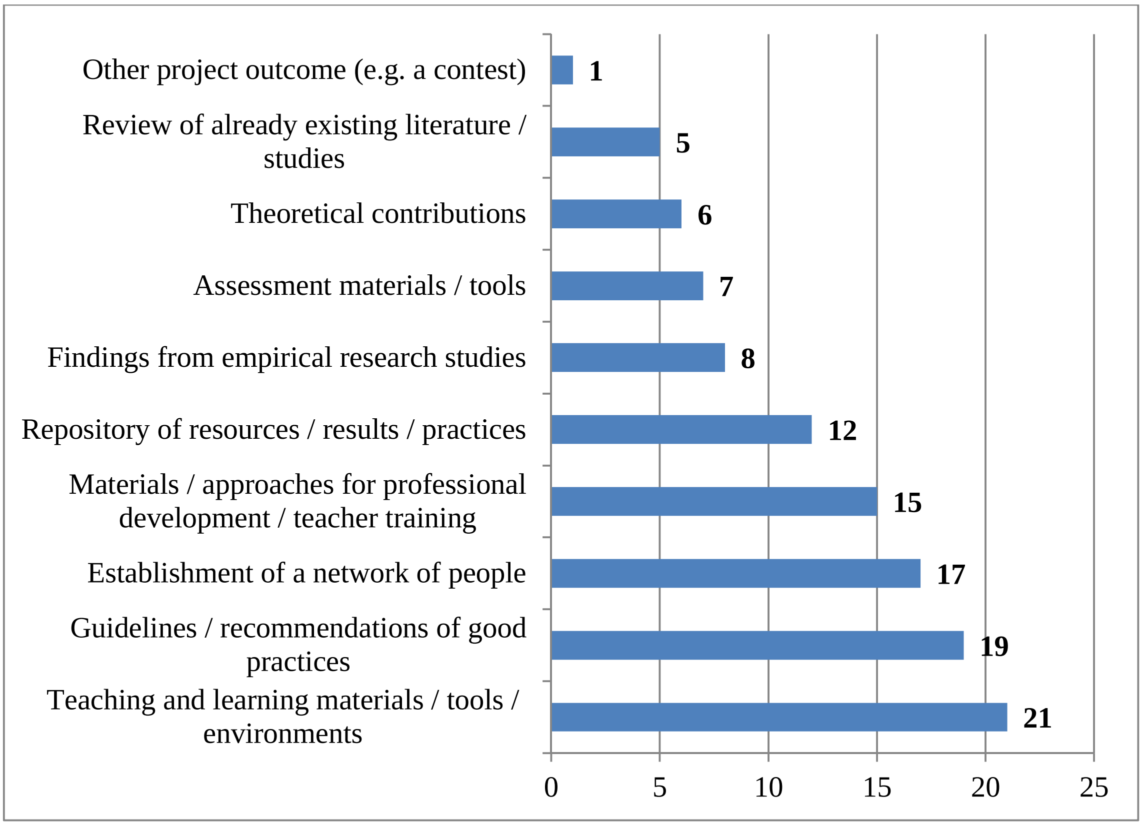

Figure 5. Types of projects' outcomes disseminated by funded projects (N = 26 project managers).

The only type of project outcome that presents significant differences depending on the funding source seems to be the repositories of resources. 71% of science education projects funded by the LLP produced and disseminated such type of outcome whereas only 47% of projects funded by the 7th FP did it. Any academic or national project did not produce and disseminate this kind of outcome. This result might be related to the priorities of certain calls and funding institutions. For example, the 7th FP tends to fund research and development projects and coordination actions much more than the LLP.

From the stakeholders' perspective, the types of outcomes that have lower impact among teachers and advisors of policy-makers are: reviews of already existing literature or studies, theoretical contributions and findings from empirical research studies. Surprisingly or not, teachers expressed that they do not frequently reach assessment materials, which could be considered problematic taking into account that assessment is a key aspect which should accompany any innovation process intended to change educational practice. It is also noticeable that just one third of teachers recognised that they had reached teacher training materials. This might be interpreted as a lack of teacher training of some funded projects.

Regarding the dissemination strategies that are used in the analysed funded projects to reach their target audience, Table 1 summarizes the main types and also the frequency of use of these strategies in the projects that have been analysed.

Table 1

Strategies used by project managers to disseminate project outcomes

Types of dissemination strategies	**Specific dissemination strategies**	**# of projects (*)**	
Text-based strategies	**Public project documents / reports**	**14**	**24**
	Articles in academic, refereed journal	5	
	Articles in professional journals / magazines	3	
	Brief documents (e.g. brochures, leaflets)	6	
	More than one text-based strategy	11	
Media-based strategies	E-mail lists (e.g. newsletters)	5	**24**
	Internet (e.g. portals, websites, videos)	**17**	
	Popularization / Mass media (e.g. TV)	0	
	Online social networking (e.g. blogs, forum)	0	
	More than one media-based strategy	16	
Face-to-face strategies	**Traditional events (e.g. conference, seminar)**	**13**	**23**
	Participatory techniques (e.g. community of practice, workshop)	9	
	More than one face-to-face strategy	15	

(*) 24/26 project managers provided this information

These results show that funded projects intend to reach teachers and teacher trainers using multiple strategies: (i) text-based (e.g. reports, papers), (ii) web-based (e.g. project websites), and (iii) face-to-face (e.g. conferences, workshops). The combination of dissemination strategies is considered (NCDDR, 2001) a factor that facilitates dissemination. In fact, the findings show that teachers and teacher trainers are the only target audiences that are involved in face-to-face participatory techniques, such as workshops and communities of practice, whereas other target audiences like policy-makers and other projects managers, are usually reached by a fewer number of dissemination strategies such as public reports, articles, websites and traditional face-to-face events.

Similarly, the findings from this study show that project outcomes such as teaching and learning materials or teacher training materials are mainly disseminated combining reports, brief documents, websites and participatory techniques among other face-to-face events. Outcomes like empirical research findings, theoretical contributions or reviews are mainly disseminated using text-based strategies such as reports, and academic or professional journals, as well as websites and face-to-face traditional events such as conferences. Finally, networks of people and repositories of resources are usually disseminated through public reports, brief documents, websites, and face-to-face events.

In sum, the project managers' choices of dissemination strategies depend on the type of project outcome intended to be disseminated and are adapted for different stakeholders. However, all stakeholders recognise that other channels through which they usually get informed are e-mails, brief documents and social media, although project managers do not seem to prioritize these channels.

Finally, although most project managers who participated in our study recognized to feel satisfied about the dissemination plan and actions they had carried out, it is also the case that many of them claim that it is difficult to appraise the quality of dissemination actions since they lack of criteria and tools to evaluate it. The most common criterion of evaluation is the number of people who are reached using a certain dissemination strategy implemented in the project. This quantitative indicator seems necessary to evaluate whether dissemination actions make project outcomes available to the target audiences. However, this criterion does not seem to evaluate dissemination actions thoroughly considering that dissemination also means making project outcomes understandable and usable in order to facilitate their use or exploitation. Other qualitative indicator used in projects refers to target audiences' perception of the quality of the project. This criterion might allow evaluating whether target audiences consider that dissemination channels are usable and the outcomes are clear, useful and ready to be used in practice. However, this criterion is not so used to measure the quality of a dissemination plan since it would require surveys or interviews to participants or elaboration of case studies. Therefore, there seems to be a need for developing instruments and/or indicators that allow appraising the quality of dissemination actions.

On specific needs for dissemination of science education projects' outcomes

The analysis of the data collected from the questionnaires allowed identifying specific needs or difficulties either to disseminate or to reach projects' outcomes that all involved stakeholders emphasized. Table 2 summarises the types of needs for dissemination stressed by each target group and the percentage of people from each of these target groups who mentioned these needs.

Table 2

Specific needs for dissemination of project outcomes

Specific needs for dissemination	Project managers	Teachers	Policy makers
Time constraints	25%	34%	40%
Resource constraints (e.g. funding, technology, human)	11%	22%	20%
Lack of active involvement of the target audience	35%	38%	36%
Underuse of already existing resources or networks	34%	50%	18%
Low outreach of the target audience (i.e. number or variety)	14%	25%	30%
Language barriers	-	26%	50%
Barriers related to the style of dissemination channels	-	26%	20%
Lack of support from partners in the project	-	18%	-
Lack of support from colleagues in one's own context	-	44%	-

Data from questionnaires and from discussion events also allowed collecting experiences and suggestions on how to improve the dissemination strategies that are currently used in funded science education projects. Table 3 presents some of the recommendations derived from the aforementioned needs or difficulties.

Table 3

Recommendations from stakeholders on how to improve dissemination strategies

Specific needs for dissemination	Recommendations
Time constraints	Projects devoted to produce outcomes might be followed by projects specifically addressed to disseminate and exploit those results
Resource constraints (e.g. funding, technology, human)	Incentives (e.g. remuneration, recognition, training, equipment for school) should be provided to teachers and other stakeholders so that they engage in reaching and using projects' outcomes
Lack of active involvement of the target audience	Stakeholders should be involved as intermediaries, ambassadors or members of an steering committee from the beginning of a project to act as multipliers at a regional / national level
Underuse of already existing resources or networks	Strong contact and cooperation should be established with local teacher training institutions and programmes, reference centres, databases (e.g. Scientix), and networks addressed to

	similar topics (e.g. ProCoNet). New teachers' networks should be potentiated after the end of a project for scaling up
Low outreach of the target audience (i.e. number or variety)	Mass media (e.g. newspapers) and social networks (e.g. local and international) should be used more often in order to have a larger impact among teachers. Conferences, seminars and workshops are one of the best ways to gain new knowledge and inform teachers and policy-makers about projects.
Language barriers	Dissemination materials should be provided in other languages than English and more dissemination initiatives (e.g. conferences) should be organised at a local or regional level
Barriers related to the style of dissemination channels	Projects should document experiences and present them in a flexible way (e.g. case studies, scripts for teachers, movies of educational activities, evidence-based books for teachers) in order to spread good practice and generate adaptive processes so that stakeholders can learn from past experiences. Brief and concise messages may facilitate the communication between researchers and other stakeholders. The usability of some dissemination channels (e.g. websites) should be improved so that people do not get lost
Lack of support from partners in the project	Guidelines and support should be provided to stakeholders so that they can use what has been disseminated. These guidelines should take account of the curriculum, school organization, teachers' current practices, etc.
Lack of support from colleagues in one's own context	Local consulting commissions should be developed involving teachers, researchers, students' families, school principals and administrators, and other relevant actors

CONCLUSIONS

The diverse data collected through the three questionnaires administered to different agents (i.e. project managers, teachers, and policy-makers), who are involved in the management and execution of STEM education projects, have allowed us to analyse and understand how managers of funded projects plan and carry out dissemination actions, which obstacles are perceived by different stakeholders to reach projects' outcomes and what needs they have. Furthermore, the discussions that took place in the (online or face-to-face) discussion events have enriched our understanding on the needs that different target audiences may have regarding dissemination, giving them a voice to make suggestions about how to improve the dissemination models that are usually applied within funded projects.

Our results show that a significant number of project managers, very active teachers and policy-makers consider that they do not receive too much information from science education projects. Given this situation, it seems necessary to look for improved ways to carry out the dissemination of projects' outcomes in order to overcome the gap between different stakeholders.

Comparing projects' managers intentions with regards to dissemination and the impact of specific actions perceived by different stakeholders, some needs have been identified that should be taken into account in order to improve how dissemination is carried out. As evidenced in the discussion events, some project managers have some reservations about using participatory techniques as dissemination strategies since they are considered very demanding and time-consuming, they require a lot of involvement of all parts, and they do not tend to have impact at a large scale. There seems to be also some pressure for scaling up innovations so that research-based practices are more widely spread among teachers. Given this appraisal, we can interpret that project managers decide to invest time and effort to use participatory techniques in case they intend to reach and have a deep impact on the main target audiences and potential users: teachers and teacher trainers.

While teachers seem to be keener to use dissemination strategies that support them in their teaching practise and that allow them to interact and network with other teachers and researchers (e.g. face-to-face strategies, social media, etc), other target audiences such as policy-makers and science museum organisers stress the need for more media-based dissemination strategies such as online portals that are considered by practitioners a reference contact point that may facilitate the search for projects' outcomes. All of them agree on the need for involving target audiences throughout the lifetime of projects as intermediate stakeholders in order to have a higher impact in practice, playing and active role in the dissemination plans and actions.

Concerning the characteristics of the dissemination strategies, our results evidence that teachers and policy-makers recognize that main dissemination strategies through which they reach projects' outcomes (i.e. project reports, websites and traditional events) usually use English as a preferential language and take a considerable amount of time. This does not facilitate to overcome the gap between research and practice or research and educational policy. For instance, according to different reports (Anastopoulou, 2010; CIHI, 2004), researchers and policy-makers are driven by different incentives and reward structures, and they have different timeframes for action. Moreover, policy-makers recognize that they often do not have the time to pay attention to project results published in the style and media typically used by researchers. Some teachers also emphasize the need for including dissemination materials in other languages than English and the need for organizing more dissemination initiatives (e.g. conferences) at a local or regional level.

As it is also supported in this study, one of the facilitators of dissemination that should be considered consists of providing incentives or rewarding systems (e.g. equipment for the school, training, human mediation and support) provided to teachers.

According to the models of dissemination described by Hughes (2003), most of the projects on science education currently funded seem to combine dissemination channels and strategies characteristic of *traditional linear models* and *social constructivist models* (e.g. wide use of reports, websites and conferences as dissemination channels, face to face participatory techniques to interact with stakeholders).

However, recommendations from stakeholders tend to advocate for dissemination models which assume wider involvement of stakeholders and already existing institutions and networks as intermediaries with an active role in dissemination actions, which is characteristic of the *sustained interactivity model*. At the same time, stakeholders recommend to take account of contextual factors influencing dissemination, stressing the need for overcoming language barriers, aligning the outcomes with curriculum, school organization, and teachers' current practices, organising local consulting commissions, etc. These recommendations are also consistent with the *Mode 2 knowledge model*.

In sum, the results of the Desire project point out some measures that might be carried out in order to improve how dissemination of science education projects' outcomes is usually planned and carried out (Debry et al., 2013).

ACKNOWLEDGEMENTS

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MEET THE SCIENTIST: THE VALUE OF SHORT INTERACTIONS BETWEEN SCIENTISTS AND SECONDARY-AGED STUDENTS

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Abstract: Secondary aged students' understanding of the nature of scientific knowledge and practices varies, and is often characterised as 'unsophisticated'. What is more, widely held stereotypes of scientists as middle-aged white men in lab coats are also reported to dominate students' views of scientists and their work. Even though currently there is extensive research evidence on students' understanding about science and ways to improve it, these are restricted to 'school science' and do not provide students with any insight of scientists and 'science-in-the-making'. We argue that a way to provide students with a more informed view of scientists and their work is to provide them with the opportunity to learn about science in an authentic science environment from practicing scientists. Thus, the purpose of this study was to explore the value of such student-scientist interactions. For that reason, 20 scientists from 8 different professional areas were asked to each share their experiences of becoming and being a scientist in short 20-minute sessions, with groups of 7-8 students. The student sample consisted of 180 Year 9 students (14-15 years old) and 43 Year 8 students (13-14 years old). Student and scientist questionnaires were used before and after the 'Meet the Scientist' sessions to assess students' views of scientists and their work, and scientists' experiences of interacting with students. The pre-session questionnaires revealed that students considered scientists as 'boring' and 'nerdy' whereas after their 'Meet the Scientist' sessions they focused extensively on how 'normal' the scientists appeared to be. The face-to-face interactions with scientists, allowed students to view scientists as approachable and normal people, and to begin to understand the range of scientific areas and careers that exist. The student-scientist interactions were also valuable for the scientists, who saw this opportunity as a vehicle for science communication.

Keywords: student-scientist interactions; secondary education; views of science; science communication

INTRODUCTION

Science – both as a practice and a product – is an integral part of everyday life and therefore, the ability to understand and evaluate scientific findings critically is a requirement of contemporary societies (Giere, 1991). Yet, it is now well documented that secondary school students' understanding of the nature of scientific knowledge and practices varies, and is often characterised as 'unsophisticated' (Lederman, 2006). What is more, widely held stereotypes of scientists as middle-aged white men in lab coats are also reported to dominate students' views (Barman, 1999; Chambers, 1983; Finson, 2002). These stereotypes, often reinforced by the way that scientists are portrayed in the popular media offer a partial and misguided view of scientists and their work (Reis & Galvao, 2007). As a result, students distance themselves from science and begin to consider it as 'not for me' (Archer, 2013; Archer, DeWitt, Osborne, Dillon, Willis & Wong, 2010), and this has consequences in their decision to follow a science career. Attempts to improve students' views of the nature of science (NOS) and of scientists often focus on incorporating explicit teaching of aspects of the NOS in science instruction (e.g. Khishfe & Abd-El-Khalick, 2002), or through the history of science (e.g. Abd-El-

Khalick & Lederman, 2000). Even though these attempts have been found to be effective at times, they are restricted to ‘school science’ and do not provide students with any insight of scientists and ‘science-in-the-making’. We argue that a way to provide students with a more informed view of these aspects is to provide them with the opportunity to learn about science in an authentic science environment from practicing scientists. Yet, there are only a few studies that provide an insight into the effects and value of scientist-student interactions (e.g. France & Bay, 2010; McCombs, Ufnar & Shepherd, 2007). Thus, the two research questions guiding this study were:

RQ1: What is the value of interactions between scientists and students for the development of students’ views of scientists and their work?

RQ2: How can interactions between scientists and students help facilitate effective engagement of scientists with young people?

THEORETICAL FRAMEWORK

Students’ views of scientists and their work

Students’ views of scientists and their work has been the subject of various studies for a number of years (e.g. Chambers, 1983; Barman, 1999; Finson, 2002; Hubert & Burton, 1995; Ruiz-Mallén & Escalas, 2012). Chambers (1983) first used the ‘draw-a-scientist’ test (DAST) to determine students’ views of scientists and their work and to establish at what stage of children’s lives these views develop. Using seven common indicators identified in the literature (lab coat, eyeglass, facial growth of hair, symbols of research such as instruments and equipment, symbols of knowledge such as books, technology, and science-related captions such as symbols and equations) he analysed the drawings of almost 5000 primary school children. He found that stereotypical images of scientists started developing in the second year of schooling and that these became stronger and more prevalent as children got older. Chambers (1983) also found that some children attributed negative images to scientists such as portraying them as monsters and ‘mad scientists’. More recent studies such as that conducted by Newton and Newton (1998) in the UK context, and Buldu (2006) in Turkey, have yielded results similar to that of Chambers (1983). Further, Hubert and Burton (1995) found that middle school boys hold more stereotypical images of scientists than girls. Fung (2002) compared primary to secondary students’ images of scientists using the DAST and found similar trends with older students having more stereotypical images of scientists that younger students and with scientists portrayed as predominantly male.

A different approach to the traditional ‘draw-a-scientist’ tests is reported by Dagher and Ford (2005), who studied students’ images of science and scientists through written science biographies and found that the students’ written accounts focused more on the final product of the scientists’ work and less on the processes they went through in developing their scientific explanations. They found that students focused predominantly on the experimental nature of science and the ways in which scientists reached their conclusions. Personal characteristics were ascribed to scientists, such as hobbies and interests, but this was as a result of the students researching and reading about their chosen scientist before writing their biographies, and not the way in which students viewed scientists and their work in general.

These views are persistent, even after a number of years of research into ways of improving students’ views of scientists (Finston, 2002). One reason might be the way in which scientists are still portrayed in social media, and how the stereotypical images of scientists are maintained through the social media. Reis and Galvao (2007) report two cases of students that also provided narratives of scientists. The analysis of the students' narratives and interviews showed that these two students' stereotypical and negative perceptions of scientific activity were influenced by the way scientists' work was portrayed in the media. Thus, they suggest that explicit discussions of such images should be taking place in science classrooms in order to elicit and address such conceptions. The ASPIRES project, which investigates students' science aspirations in the UK at ages 10-14, reports that although 10/11 and 12/13 year-old students find science enjoyable and believe that scientists do valuable work that can make a difference in world, only a handful of them aspire to be a scientist at this age (Archer, 2013). Archer and her colleagues (Archer, 2013; Archer et al., 2010) attribute this discrepancy between science interest and science aspirations to factors such as the lack of career advise at this stage of the students' schooling. For instance, they report that in the UK, most students at ages 10-14, and many parents, believe that science qualifications can lead to careers such as becoming a doctor or teacher, but are not aware of the wide range of post-16 opportunities provided by gaining science qualifications. Archer et al. also point out the fact that schools often fail to convey to students how studying a science-related degree post-16 might be valuable in gaining access to a wide range of careers. Consequently, there is a need to address students' views of scientists and their work within formal education to allow students to develop an inclusive view of science and its practices. One way to do so, is to create opportunities for students to interact and learn with, and from, practicing scientists.

Scientist-student interactions

The literature on scientist-student interactions is drawn mainly from summer school programmes and apprenticeship evaluations (e.g. Bell, Blair, Crawford & Lederman 2003; Bleicher, 1996; Hsu, Eijck & Roth, 2010; Knox, Moynihan & Markowitz; 2003; Rahm, 2007) and focus on how these programmes have influenced students' attitudes towards science and students' conceptual and epistemological understanding. For instance, Knox, Moynihan and Markowitz (2003) investigated the impact of a summer school program that took part in a at a university research facility over a number of years on students interest in science and their perceived skills in laboratory work. They have found that students' interactions with scientists and opportunities to engage in hands-on science in authentic science microbiology labs had a positive influence on these students' attitudes towards science and their enthusiasm about science careers. Similarly, Gibson and Chase (2002) have found that students that have participated in a summer school program have developed more positive attitudes towards science and towards science careers compared to students that did not participate in the summer school program.

Bell et al. (2003) found that students that had taken part in an 8-week science apprenticeship program working alongside scientists covering a range of science procedures including research design, data collection, and data analysis, did not change their views of scientific inquiry and the nature of science considerably. Bell et al. (2003) argue that the extent to which explicit discussions about the NOS and scientists' work were vital for whether students would change or not their NOS views. The only student of the 10 participants that shifted his/her views of scientific inquiry was the one that had some explicit discussions about the nature of scientific knowledge and investigations with her scientist-mentor. This demonstrates the important role that scientists have in such interactions with students, and that just doing science, even if it is in an authentic context does not necessarily mean that students' will gain an informed understanding of the nature of scientific practices and even the range of activities that scientists need to engage on an everyday basis. Thus, time for scientists to discuss and reflect about their work with students might be required in addition to the authentic hands-on experiences that students are given.

The importance of providing audiences with opportunities to actively engage with scientists is also discussed in science communication events at museums and science centres. Wilkinson, Dawson and Bultitude (2012) found that providing opportunities for asking questions is a way to make the public more engaged in discussions and interactions with scientists. France and Bay (2010) investigated scientist-student interactions and analysed the nature of the questioning produced by students during these sessions. Prior to the session, they asked students to identify a question they would like to ask, and at the conclusion of the meeting with the scientists, students were asked to state which question asked they thought was the best during the discussion. An analysis of these questions identified five different areas of interest for the students. These were a) science information with questions focusing on procedural and conceptual aspects of the science discussed b) citizen decisions, which were questions that focused on the applications of science; c) questions that focused on the nature of scientific disciplines and how science works, and d) personal responses, with questions that aimed at making links between the science discussed and the students' lives. France and Bay (2010) state that the questions students chose to ask or considered important indicates students' attempts to not only engage with the content and processes of science but also its applications and implications. What is more, comparison of the intended questions to those that students considered as the best revealed that students became increasingly more interested in the personal life histories of the scientists and focused less on science careers.

CONTEXT OF STUDY

The *Meet the Scientist* sessions are part of a wider initiative at the University of Southampton to promote health literacy through science. The LifeLab project aims to engage 11-16 year old students with the science behind chronic diseases and enable them to discover first hand, how their diets and lifestyles lay the foundations for a healthier life, and how their own health is linked to the health of the children they may have in the future (Grace et al., 2012; Grace et al., 2013). The programme involves a continuing professional development (CPD) day for school teachers, a scheme of work incorporating lesson plans and resources for 4 pre-lessons and 6 post-lessons of a "hands-on" practical day at the a hospital-based science classroom. As part of this day, students take part in *Meet the Scientist* sessions where they have the opportunity to meet and talk to scientists, both from academic and clinical backgrounds. This study focuses on the latter part of the activities that students undertake during their visit to the hospital-based science classroom.

METHODOLOGY

To answer our research questions, 20 scientists from 8 different professional areas (bioengineering, genetics, cancer research, asthma research, nutrition, cardiovascular research, placental research, and bone and joint research) took part in this study. The student sample consisted of 180 Year 9 students (14-15 years old) and 43 Year 8 students (13-14 years old). Students were put into groups of 7-8 and each group attended two *Meet the Scientist* sessions on the same day, each lasting between 10 – 20 minutes. Each scientist run between 1 to 4 sessions, with a total of 49 sessions recorded. Students were aware that they would be meeting and talking to scientists, and were encouraged by their science teachers to formulate questions they would like to ask during the sessions. This approach was partly based on that described by France and Bay (2010), who also conducted similar student-scientist sessions with older students. The discussions taking place during the sessions were not guided by the researchers in any way. Scientists that agreed to take part were informed that they would have short sessions with secondary school students where they would be providing information about their work as scientists and would be answering students' questions.

A mixed methods approach to collecting and analysing data was used (Creswell, 2009). Data collection methods included pre- and post-session student questionnaires and audio-recordings of the 49 *Meet the Scientist* sessions. Supplementary data included interviews with some of the participating teachers and scientists' comments and impressions of the sessions they led, which were recorded after the *Meet the Scientist* sessions. The student questionnaires aimed at assessing students' views of scientists and their work. As discussed previously, the 'draw-a-scientist' test is a commonly used tool in investigations of students' views of science. However, it also imposes some challenges such as the fact that it often forces students to make a choice (Barman, 1999). For instance, students are required to choose their scientist's gender, ethnicity and surroundings, although these might not necessarily be representative of their views of how scientists look like or what they do. As the student participants of this study were old enough to be able to provide short written descriptions expressing their views, a questionnaire was used to collect their perceptions of scientists and of their expectations from the *Meet the Scientist* sessions in a descriptive manner. Questions included asking students to 'describe what they think scientists do', 'was there, if anything, that surprised you about the scientists' and was there anything else you would like to ask he scientist'.

The qualitative data from the 49 sessions were transcribed verbatim and then coded thematically using qualitative software analysis Nvivo. A grounded approach to data analysis and the constant comparative method (Glaser & Strauss, 1967) were employed in the analysis of transcripts from the *Meet the Scientist* sessions. An iterative cycle of revision and refinement of the categories identified took place (Patton, 2002). One member of the research team conducted the first round of analysis and then a second member applied the same framework to all the transcripts. Inter-rater agreement reached 100%. The analysis of the student questioning during these sessions was theory-driven, based on France and Bay's (2010) categorisation of student questions.

FINDINGS

Students' views of scientists and their work

The pre-session questionnaires required students to note any words they associated with scientists. For instance, one student wrote 'boring lives, glasses, clever/nerdy, got a degree', and another noted that scientists are 'intelligent and boring people'. Figure 1 provides a synopsis of the words used to describe scientists. As presented in Figure 1, students also used descriptors such as 'patient', curious and creative, although these were not as frequent, as 'clever'.

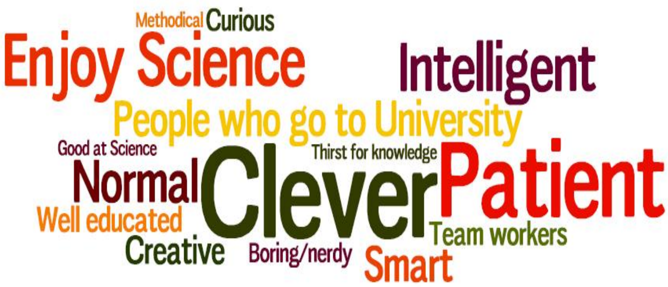

Figure 1: The most frequently used words to describe a scientist

Following the session, students were asked what (if anything) had surprised them about the scientists they met. The most common themes emerging from the analysis of the post-session questionnaires focused on the scientists' appearance and personality. Students focused extensively on how ‘normal’ the scientists appeared to be, with one student stating that the scientists they met ‘were just normal people, and very unlike mad scientists in films’. It was clear the students realised that scientists were ordinary people, with their own hopes and concerns, and that there were many different jobs/careers, which use science and various routes into such careers. Figure 2 illustrates the main elements that students found surprising about the scientists they met.

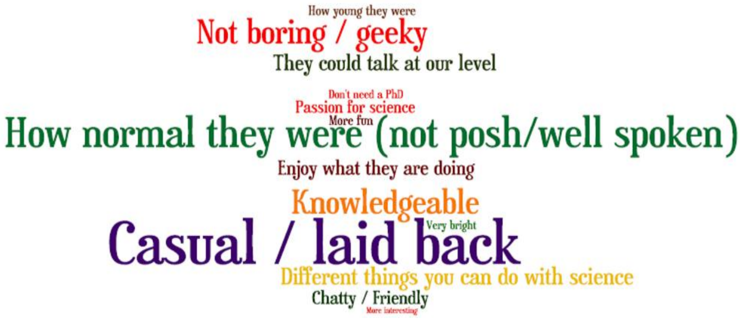

Figure 2: Students’ most frequent replies to the question: *What (if anything) surprised you about the scientists you met*’

The way the scientists communicated with students (at their own level and as ordinary people) had also pleasantly surprised the students, who commented in their post-questionnaire that the scientists ‘could talk at our level’. It therefore appears that one of the most important impacts of the sessions was the change in view from scientists as an elite club to ordinary people like themselves.

Meet the Scientist: student-scientist interactions

In order to answer RQ2, the interactions of scientists and students during the *Meet the Scientist* sessions were analysed. This analysis aimed to provide some insight to the types of session structures and content that students are more likely to participate actively in, and to provide an indication of the types of information that students are interested in discussing in such situations. The results of the thematic analysis are presented in Table 1. The following sections present our findings on the nature of interactions that took place based on (a) the way that the scientists structured their sessions and discussed their work, (b) the extent to which scientists made attempts to engage students with prompts, establishing links and discussing applications of their work and (c) the way in which students engaged in the sessions through their questioning.

Scientists’ discursive actions and structure of sessions

The thematic analysis of the discursive interaction between scientists and students presented in Table 1 shows that in all 49 sessions, scientists spent some time discussing and describing to students the nature of their work. Scientists mostly discussed the nature of their work by describing to students the area in which they were working, the aims of their work and often, the applications or potential findings. Most of the participating scientists came from scientific disciplines relating to human biology and in particular, the area of cancer research. As a result, most of the instances in which the applications or consequences of the scientists’ work related to cancer treatment, finding a cure and the challenges of that. Describing the nature of their work focused on discussions about what the scientists were aiming or hoping to find out through their research. It was interesting that most of the scientists also provided a short rationale for their work based what is known so far in their subject area and what they are hoping to find through their own work.

Table 1
Coding scheme derived from the Meet the Scientist transcripts

Coding theme	Sources (frequency)
Scientist discusses nature of their work	49 (143)
Scientist discusses applications or consequences of their work	34 (60)
Scientist provides information on science careers	36 (92)
Scientist discusses students' science interests and career prospects	26 (86)
Scientist discusses his/her own career pathway	26 (34)
Scientist uses analogies, metaphors or examples	39 (75)
Scientist provides content information	37 (201)
Scientist elicits students' knowledge or understanding of a concept	35 (97)
Scientist explains why their work and/or science is exciting or important	25 (43)
Scientist discusses ideas about science and its purpose (NOS)	30 (58)
Scientist discusses ideas about scientists-appearance	7 (12)
Scientist discusses ideas about scientists-personality characteristics	7 (12)

As the scientists started discussing the nature of their work, they would start prompting students about scientific content, in an effort to elicit what they already know about their subject area. For instance, one scientist began her session by describing the nature of the scientists' work and in doing so, providing content information. At times the concepts presented to students were too advanced for the students' level, although as will also be discussed in the following section, students' asked questions that focused on subject matter.

Student engagement and participation in the Meet the Scientist sessions

Engagement and interaction during the *Meet the Scientist* sessions was explored based two aspects. The first was attempts by the scientists to present their work to a level that the students could understand, either by using materials (e.g. images, videos, posters, microscopes, ultrasound machine) to explain concepts or aspects of their work to the students, or by making links between their work and personal experiences or values with which the students could relate. Images or other prompts were used in 33 sessions by 19 scientists. Attributing personal values or experiences to their work, was another common theme emerging from many of the sessions recorded. More than half of the scientists (14/20) attempted to engage students by making their work relevant or personal to the students' lives or interests, at least in one of the sessions they led.

The second way in which engagement was explored was based on the questions that the scientists asked or promoted the students to ask. Scientists were proactive in asking students questions with 15 of the 20 scientists asking students if they had any questions for them regularly throughout their sessions. What is more, 8 scientists began their sessions by initiating discussion and 'question and answer' exchanges with their groups instead of beginning their sessions with a presentation. This way of starting the sessions seemed to engage students more since it made the students the focal point of the session, and not the scientist.

Eliciting knowledge and understanding was a strategy used by almost all the scientists at some point in the session and aimed at establishing the students' current understanding of concepts explored. However, this was also a strategy that some scientists relied on to engage students and increase participation. For instance, one of the scientists, used this strategy throughout her session. By asking questions, she elicited students' ideas about what the work of a public health nutritionist (her area of work) would involve and then she had the students brainstorming about the areas in which she could be potentially investigating. She said:

> 'we're doing an intervention at the moment with women of childbearing age that are having young babies or that have children under the age of five and what we're trying to do is tackle or look at some of the things that might influence their diets. So who here has the best handwriting or very good handwriting? That was you. Would you mind scribing for us? I'll just get you to write some things. Now, I want us to do a bit of a brainstorm and think about what kind of different things might influence a woman's diet. What do you think?' (CB1)

This scientist used the same structure for the four sessions she had with students and students responded positively to her continuous questioning by identifying all the elements she was investigating.

Students' questioning during the Meet the Scientist sessions

Based on Bay and France's (2010) categorisation of student questioning during scientist-student interactions with 16-17 year olds, we organised the students' questions in four main themes as detailed in Table 2. Students' questions are a strong indicator of their interests and of the students' attempts to actively engage with the topic under discussion and attempt to make links with their existing knowledge and experiences (Chin & Osborne, 2008). Students' questions during the *Meet the Scientist* sessions, focused mainly on conceptual and procedural information based on the scientists' research area and expertise. During the sessions, students were able to discuss and learn about current and innovative scientific research, which was considerably different from the school science they experienced. Consequently, students were genuinely interested in the scientists' work, as indicated by the focus of their questions, which was predominantly on the conceptual and practical aspects of the scientists' work.

Table 2
A summary of the types of questions asked by students Meet the Scientist sessions

Type of question	Example	%
Science information (content & practice)	'What is stem cell research?' 'If you just want to become a nurse, do you have to do a PhD?'	83
How science works	'How long do you think it would take to solve this problem? How much time do you think a scientist would have to devote to trying to answer one question like that? Are we talking a few weeks, months, years, what do you reckon?'	7
Citizen decisions	'What things are you trying to do to help people with diseases?' 'What is your opinion on animal testing?'	5
Personal responses	'Do you enjoy being a scientist?' 'Do you find it fun?' 'What inspired you to become a scientist?'	5

In exploring all the questions that students ask as they take part in the *Meet the Scientist* sessions, it is possible to identify what guides the discussion that are actually taking place, as well as students intentions and own interests. The fact that students' questioning focused predominantly on science content knowledge and information could be based partly on the fact that they had little knowledge of the scientists' research areas and expertise. Chin and Osborne (2008) discuss how students with little prior knowledge tent to ask basic information questions as opposed to students that are more familiar with the topic, which is consistent with the nature of questioning by students identified in the *Meet the Scientist* sessions.

DISCUSSION AND CONCLUSIONS

There are two areas of interest that the findings of this study contribute towards and will be discussed in the following sections. The first is the value of the student-scientist interactions for the students' development of views of scientific practices and of scientists' work. The second is the value of such interactions in terms of science communication and the elements of the environment created during the *Meet the Scientist* sessions, which promoted active participation and fruitful interactions for all members involved, both young people and scientists. The dialogic nature that most of the sessions had, allowed students to interact with scientists beyond the transmission model often adopted in science communication interactions (Bray, France & Gilbert, 2012) where few opportunities are given to the audience to pose questions, and develop a dialogue with the science communicator. In fact, the opportunity to ask questions in public engagement events has been identified by Wilkinson et al. (2012) as a driving factor in motivating the audience to actively participate in public engagement events. Bray et al. (2012) have conducted a Delphi study investigating the essential elements that a science communication course should put forward for benefiting interactions between scientists and the public. They worked with 10 scientists, science communicators and educators on establishing consensus on the key competencies required for effective science communication. They concluded that in such interactions the audience should come first; science communications should be aware of the needs of the audience and attempt to engage them by allowing them to participate in the process, by taking account of their needs and by using techniques such as storytelling to make the topics discussed accessible to them.

During the *Meet the Scientist* sessions, the above conditions were found to be present in various ways. The number and nature of student questioning indicates that the majority of participating scientists put the students first, as Bray et al (2010) suggest, and in this way allowed them to ask questions, and as discussed in the previous section, often prompting them for any questions they might have had. At the same time, the scientists' expectations also framed the discussions that took place. Many saw this as an opportunity to take part in an outreach activity, which is increasingly becoming a requirement in science departments of higher education institutions. This resulted to scientists focusing more on science interests and career aspirations than discussing the nature of their work or their choices in following a science career. Although the purpose of the session shifted in these cases, the fact that scientists focused on career choices meant that students had the opportunity to discuss their own career interests and get advice from the scientists about their options.

Reinforcing the importance of providing students with opportunities to get in contact with practising scientists and interact with them is the fact that although views of scientists and views about the nature of science were not an explicit topic for discussion during the *Meet the Scientist* sessions, these were enhanced as discussed previously. This agrees with suggestions that students need to contextualize their experiences of science in order to make them more personal and see themselves as scientists. Finson (2002) states that 'individuals who have negative perceptions of science or of scientists are unlikely to pursue science courses of study and, subsequently, enter a science/science-related career' (p. 335). This has implications for students' decision making with respect to science careers. If students develop these notions of scientists as normal people then it is more likely that they be more interested in pursuing a science career. Another issue to consider is the vast range of science careers that exist that is often not explicitly made aware to the students. Based on their experiences of school science, students often associate science careers with the three traditional science subjects that they are taught in secondary school. Thus exposing them to the range of options they have and listening first-hand how scientists entered into their line of work, further enhances the possibility of students following a science career pathway (Knox et al., 2003).

The students' own expectations of the *Meet the Scientist* sessions was another factor that seemed to have framed the discussion that took place during these sessions, since in those cases that students were interested in pursuing a science career, their questions focused mainly on this aspect and less on applications or the nature of the scientists' work. We would argue that the students' questions during their sessions with scientists, also indicates the students' active participation in the session and to an extent, their own interests and motivations. For instance, students that were already thinking of pursuing a science career focused their questions around the subject choices they should be making in order to do so. Year 9 students, at the time that the study was conducted, were making choices in school subjects that would determine whether they could go into a science-related field in university. At the same time, some of the scientists were not prepared to answer questions of this nature, especially those that had experienced an educational system other than in the UK. Therefore, future training courses should prepare scientists by raising their awareness of career options and school science choices, in addition to their personal life stories and how they were led into a science career.

To sum, this study demonstrates how short sessions between students and scientists can have a positive influence on students' perceptions of scientists and of their interest and motivation to learn science. The face-to-face interactions with scientists, allowed students to view scientists as approachable and normal people, and start to understand the range of scientific areas and careers that exist. The student-scientist interactions were also valuable for the scientists, who saw this opportunity as a vehicle for science communication. Elements of the sessions that we found to be effective in promoting engagement and interaction between the scientists and the students included putting the students' interests and questions first; using examples from everyday life and discussing applications/implications of their work in order to make it relevant for students; using materials and making links to school science; and, discussing science interests and career aspirations with students. The questions that students ask can be seen as a negotiation of meaning and attempts to establish links between their own lives and the scientists' lives (France & Bay, 2010). Listening to how scientists went into a science career and discussing the scientists' aspirations and choices at their age, can help students narrow the gap between the images the hold of themselves and a possible career in science.

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VOCATIONAL EDUCATION IN SCIENCE TECHNOLOGY, ENGINEERING AND MATHS (STEM): CURRICULUM INNOVATION THROUGH INDUSTRY SCHOOL PARTNERSHIPS

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Abstract: Governments have recognised that the technological trades rely on knowledge embedded traditionally in science, technology, engineering and mathematics (STEM) disciplines. In this paper, we report preliminary findings on the development of two curricula that attempt to integrate science and mathematics with workplace knowledge and practices. We argue that these curricula provide educational opportunities for students to pursue their preferred career pathways. These curricula were co-developed by industry and educational personnel across two industry sectors, namely, mining and aerospace. The aim was to provide knowledge appropriate for students moving from school to the workplace in the respective industries. The analysis of curriculum and associated policy documents reveals that the curricula adopt applied learning orientations through teaching strategies and assessment practices which focus on practical skills. However, although key theoretical science and maths concepts have been well incorporated, the extent to which knowledge deriving from workplace practices is included varies across the curricula. Our findings highlight the importance of teachers having substantial practical industry experience and the role that whole school policies play in attempts to align the range of learning experiences with the needs of industry.

Keywords: vocational education, industry school partnership, work transition, workplace education, STEM

INTRODUCTION

It is widely recognised that student interest in science and mathematics and related subjects (e.g., STEM) is low (e.g., Osborne, Simon, & Tytler, 2009; Osborne & Dillon, 2008). Osborne and Dillon acknowledged that while there are shortcomings in curriculum, pedagogy and assessment, a significant problem has been that school education in STEM has never provided a satisfactory education for the majority and has failed to cultivate the interests of those who might proceed to become scientists, engineers, technologists and trade-related workers. In this paper we document the design of two industry-developed curricula and analyse the alignment of content with the skills and knowledge necessary to appropriately equip students for the school to work transition across two industry sectors.

CONTEXTUAL BACKGROUND

Curriculum development in Queensland is managed by the Queensland Studies Authority (QSA) a statutory body of the Queensland Government. The QSA prepares syllabus documents which are then adopted and implemented in State, Catholic and Independent schools to suit local school needs. School administrators make decisions about which syllabuses to adopt. Implementation relies on teacher judgement in the shaping of curriculum work programs, pedagogical approaches and classroom assessment. These principles allow and enable individuals and cohorts to take different routes through the curriculum terrain particularly in the senior years. For a detailed description of these principles see Luke, Weir and Woods (2008). Curriculum development in this jurisdiction adopts a "low-definition" approach to syllabus design based on informed prescription and informed professionalism. The QSA also registers schools as registered training organisations (RTOs), and accredits and recognises vocational education and training courses as a part of the overall school curriculum. Three levels of subjects are available to students in the senior years 11 and 12: Authority subjects (for university entrance), registered subjects and vocational subjects (both for non-university pathways). All subjects contribute credit to the state's school leaving certificate – Queensland Certificate of Education (QCE). Vocational school subjects contribute towards Certificates which may lead beyond school years to formal trade qualifications which are the responsibility of TAFE (Technical and Further Education) colleges and private RTOs. A recent innovation, however, has been the introduction of School-Based Apprenticeships and Traineeships, which run alongside other QCE subjects. These involve a contract between student, parents, principal and the employer and the student is considered to be both a fulltime student and an apprentice or trainee.

Donnelly (2009), in a review of the literature focussed on the alignment of school curricula with vocational educational needs, has argued that "that the vocational aspect of the school curriculum is less well understood, and more locally conditioned, than are its traditional academic forms." (p. 226). He asserts that there is limited research examining how students are best prepared for a vocational career. One such attempt to address vocational education centred on STEM has been developed in the state of Queensland, Australia. The Queensland Government has set in place a number of initiatives to stimulate the development of a highly skilled workforce to support the growth of Queensland's expanding knowledge-intensive industries. One initiative was the establishment of school-industry partnerships across a number of industry sectors (Kapitzke & Hay, 2007; Watters, Hay, Pillay, Dempster, 2013).

The establishment of partnerships between educational providers and industry is argued to be an important strategy for optimising and sharing new knowledge. In 2004, the Queensland Government established the Gateway to Industry Schools program. This program is a key policy strategy aimed at knowledge transfer and features 1) a public system-wide approach, 2) multiple sectors (i.e., state, Catholic and Independent schools) and global as well as local industry partners, and 3) an inclusive focus on student learning, including both students transitioning into higher education and those moving directly to skilled employment. Around 25% of Queensland schools host Gateway Schools to Industry partnerships across six industry sectors: Agribusiness, Aerospace, Manufacturing and Engineering, Building and Construction, Minerals and Energy and Wine Tourism. We focus on curricula related to two partnerships: Minerals and Energy and Aerospace.

In this paper we set out to (1) document the design of curricula developed collaboratively by schools and industry to appropriately equip students for the school to work transition and (2), document the affordances and constraints in the implementation of these curricula. We explore how these curricula provide opportunities for students to select relevant individual pathways.

THEORETICAL FRAMEWORK

In our approach we focus on the concept of *opportunity*, drawn from an analysis of the relationship between educational opportunity and educational gains reported by Houang and

Schmidt (2008). The word opportunity is defined as a favourable set of conditions that afford chances for individuals to achieve personal goals. It also refers to the chance that educational policies are provided with conditions whereby they can gain traction. Schmidt and colleagues (e.g., Schmidt & McKnight, 1995; Schmidt et al, 2001), in a series of studies of the Third International Mathematics and Science Study (TIMSS), have argued that education policies directly manipulated through curricular resources shape schooling in ways that align with national priorities. Thus students exposed to particular curricular implementations should learn about particular topics emphasised in those curricula. However, the curriculum experienced by the student is often at odds with the planned curricula and the opportunities to achieve intended outcomes are thwarted (Fullan & Pomfret, 1977; Hume & Coll, 2010; Keys, 2007). To investigate the alignment of curricular intentions and outcomes of the Gateway project, we focus below on four dimensions of opportunity: the nature of the curriculum, what teaching practices are employed, what knowledge is valued and to what extent the intended goals are attained through the delivery and assessment of appropriate content.

Appropriate curricula

In its broadest interpretation *curriculum* defines all the learning which is planned and guided by the school, whether it is carried on in groups or individually, inside or outside the school (Kelly, 2009). We use the term *appropriate* to emphasise the extent to which the formal course structures and resources attempt to achieve the intentions of the Gateway project, that is, are they suitable for achieving the Gateway goals of equipping the next generation with the skills and knowledge to make the transition from school to further education or work and fill the skilled jobs of the future.

A curriculum which is appropriate for facilitating school to work transitions would incorporate the following:

1 a clear and consistent focus on *applied learning* in terms of approaches to teaching and assessment processes

2 a clear representation of the workplace practices of the trade concerned

3 a strong focus on embodied, embedded, encultured and encoded knowledge related to the trade, alongside the required embrained knowledge

In conceptualising what knowledge is important for workplace-related curricula, and how it can be framed, we refer to the work of Blackler (1995) whose approach based in the organisational and management literature sees learning as a process of knowledge management. Blackler described five knowledge dimensions represented in workplaces and organisations, which we adopt here: embrained, embodied encultured, embedded and encoded (Table 1).

Table 1

Types of knowledge and how manifested

Knowledge type	Manifestation
Embrained	Conceptual knowledge – inert, declarative, "knowledge about".
Embodied	Practical skills dependent on context – functional, "knowledge how"
Embedded	Understanding the routines and systems of operation or workflow "conditions"
Encultured	Discourses of the field – knowledge of the context "culture"
Encoded	Knowledge captured in code – books, signs, manuals.

Appropriate teaching practices

The way that planned curricula are adopted by schools and implemented depends on many factors not least the history (Goodlad, 1995), beliefs (Keys, 2007), and previous work experience of teachers (Diezmann & Watters, 2013) and the resources and priorities of teachers and administrators. Subject matter knowledge and knowledge of how content is applied are important contributors to effective teaching (Darling-Hammond & Youngs, 2002). Teachers with good subject matter knowledge and knowledge of the intent of the curriculum are able to go beyond the prescribed content and involve students in meaningful and experiential learning. Appropriate teaching practices for facilitating school to work transitions should include practices in which students are afforded opportunities to:

1. visit worksites
2. explore how theoretical knowledge is applied in industry and
3. acquire a sense of purpose in their learning.

For those teachers whose background has been in traditional disciplinary teaching, achieving a change in perspective when teaching courses aimed at industry or workplace related outcomes can be challenging.

Appropriate assessment

Traditionally teachers are guided by assessment and reporting frameworks embedded in curricula. The majority of teachers trained in teacher education institutions are familiar with the assessment strategies adopted in traditional STEM subjects. These normally are centralised examinations or even where school based assessment exists, the assessment practices rely on students' attainment of certain knowledge with limited focus on practical applications of this knowledge. However, teachers require a different understanding of assessment practices for curricula designed to address vocational education and skill development. Most vocational training providers use competency based assessment frameworks in which authenticity is paramount. Gulikers, Bastiaens and Kirschner (2004) argue that authentic assessment requires students to demonstrate relevant competencies through meaningful tasks.

METHODOLOGY

A case study approach was adopted here to examine how industry partnerships impact on factors affecting student learning outcomes such as curriculum, teaching practices and forms of assessment. Our analysis explored the alignment of curriculum between the needs of the workplaces of the partner organisations and student career aspirations. Our focus was on subject offered in years 10-12, including those prescribed for academic pathway students and those not likely to progress to higher education. We probed four areas: understanding of the partnership goals, curriculum and pedagogy, knowledge transfer, and student outcomes. Typical cue questions included "How do you understand the mission of the Gateway Schools programme and the role you play in helping to attain these goals?", "Tell us about activities in classes in the Gateway programme and how they are similar to/different from ones not in the programme." And "What knowledge is regarded as 'relevant' for students entering this industry? Who has made this decision and how was this done?"

Primary data were derived from (a) observations of stakeholder meetings in each industry project, (b) interviews with key stakeholders including principals, teachers, vocational education coordinators, industry personnel and staff from the various coordinating institutions and (c) site visits to document resources, observe classes and conduct focus group interviews with students. Secondary data were obtained from websites, policy documents, curriculum and syllabus documents and teaching materials. Observational data including participating in meetings and site visits were recorded in memos supplemented with photographs where appropriate. Interviews were audio recorded and transcribed, then.coded using NVivo software to conduct a content analysis (Richards, 2009). Codes were grouped into themes which reflected the underlying theoretical framework.

FINDINGS

Case 1: Minerals and Energy

The Minerals and Energy project involves a partnership between 28 government and independent (private) schools and companies in the Minerals and Energy sector. Most of the industry partners are large international mining and electrical utility companies. A coordinating body the Queensland Minerals and Energy Academy, (QMEA) links the partnering groups Skills Queensland (a government body) and the Queensland Resources Council (an industry peak body). QMEA manages the project and funding is provided both by government and industry. Drawing on the framework of educational opportunity we now report on the three dimensions: curricula, teaching practices and assessment.

Appropriate curricula

The partnership provides a wide range of formal and informal opportunities for students to engage with the mining industry involving work experience, trade qualifications, camps and scholarships. These activities collectively meet the criteria for appropriateness outlined earlier and are listed here:

- Certificate I and II in Resource Infrastructure Operations
- Certificate I and II in Process Plant Operations
- Certificate II in Engineering
- Context based modules on power generation in Senior Physics
- QSmart Year 11 and 12 subjects
- Annual Engineering camps in mining locations
- Tours and excursions to mines, power stations, skills centres, TAFEs and universities
- Work experience and training in jobs, trades and professions on sites across the State
- Access to industry mentors to address classes and conduct industry standard training in short courses, traineeships and apprenticeships
- Engagement with tertiary students in a range of workshops related to the industry
- Apprenticeship aptitude test training for those aiming to gain apprenticeships in the resources sector
- Engagement through robotic and Arduino programming activities and teacher professional development
- Scholarships and awards for students to encourage further engagement in the resources sector.

Although the schools offer a range of subjects that provide a pathway to trade careers, we focus our analysis here on one subject that is distinctive in that it was developed in collaboration with industry. The subject, titled *Science, Maths and Related Technologies for Engineering and Electrical School-based Apprentices* (or *QSMART*), and developed by QMEA (QMEA, 2010) is delivered over two years. The content is aimed at providing a pre-vocational grounding in topics relevant to electrical and related trades by integrating a range of topics drawn from mathematics and science. Each subject contributes two credit points out of a minimum of 20 credit points towards a student's senior school Certificate of Education but not for tertiary entrance consideration.

The development process involved a team of industry consultants including engineers, trade apprentice trainers in the electrical trades and school teachers consulting on an initial draft. Industry was concerned that a sufficiently rigorous subject was needed that provided both theoretical and practical content as well as providing opportunities for the development of employability skills, which must be explicitly taught (QMEA, 2011). Such skills included communication, planning, organising, problem solving, technology, initiative, enterprise, self-management independent learning capacity and team working. The course was implemented at Dragline and Black Mountain State High Schools. The consulting industry groups made a commitment to QMEA schools and their students that they would recognise the results of QSMART for entry into Engineering and Electrical apprenticeships, as equal to the results of existing senior QSA Mathematics and Science programs in their recruitment procedures. The scope of the course is outlined in Table 2. It has a strong emphasis on key theoretical understandings (embrained knowledge) with opportunities and expectations that this knowledge will be further developed through practical tasks (embodied knowledge).

Table 2

QSMART course objectives and content

General objectives	Conceptual content organisers
Year 11 Course • students can select and interpret mathematical and scientific information in different Engineering and Electrical trade activities and texts. • students select and use a variety of mathematical and scientific skills and concepts to solve familiar and unfamiliar problems in Engineering and Electrical trade-related contexts. • students can use every day and trade-specific language, symbols, diagrams and conventions of mathematics and science to communicate responses to Engineering and Electrical trade-related tasks. • students can demonstrate skills in communication, planning and organising, problem solving, using technology and self-management; and demonstrate initiative and enterprise, the capacity to learn independently and the ability to work effectively in a team.	The Mathematical Toolbox • Numeracy • Measurement • Algebra for Engineering and Electrical trades • Finance The Scientific Toolbox • Dynamics • Materials • Electricity • Electrolysis and Corrosive Environments
Year 12 Course • students can extract and evaluate the mathematical and scientific information embedded in a range of Engineering and Electrical trade activities and texts. • students can select and apply an expanding range of mathematical and scientific skills and concepts to solve familiar and unfamiliar problems in a range of Engineering and Electrical trade-related contexts.	The Mathematical Toolbox • Numeracy • Measurement • Algebra for Engineering and Electrical trades • Finance The Scientific Toolbox

- students can use a broader range of more sophisticated every day and trade-specific language, symbols, diagrams and conventions of mathematics and science to communicate responses to Engineering and Electrical trade-related tasks.
- students can demonstrate skills in communication, planning and organising, problem solving, using technology and self-management; and demonstrate initiative and enterprise, the capacity to learn independently and the ability to work effectively in a team at an Industry standard.

- Dynamics
- Materials
- Electricity
- Electrolysis and Corrosive Environments

Appropriate teaching practices

Students valued the content of the subject and how it was taught and spoke frequently of its perceived practicality. For instance, in a focus group discussion with students, one girl who was planning on becoming a diesel fitter discussed learning about “cogs and ratios” which she recognised to be relevant to her career intentions. Another boy commented that the ratios lessons gave him insights into the operation of lathes which was part of a Certificate in Engineering he was concurrently studying.

Teaching expertise was the focus of much concern, for two reasons. First the turnover of teaching staff in remote mining locations is high. Often beginning teachers are assigned to remote schools but choose to remain for short periods. Thus there is a lack of continuity and experience. In both case study schools, over a three-year period the subjects had been taught by several teachers.

Second, a lack of industry experience and knowledge can limit a teacher’s capacity to link the classroom content to its workplace setting. For example, the teacher at Dragline SHS, although in his fifth year of teaching, was a novice in teaching QSMART. He noted that in planning, implementation and assessment, he was left to his own devices. However, this freedom created some concerns. He was a teacher who had moved from a coastal town and had limited experience of the mining context:

> I definitely feel inexperienced in that area. I'm quite comfortable with the curriculum content of the subject, but drawing those links - I'm very new to the mining town. Prior to moving to Dragline SHS I had very little knowledge about the process of mining. So I'm finding that's where I need to put the bulk of my work in. It's not learning the content, but learning how to link that content to the actual processes that happen in the mine. … .

A third concern was that, although there was support from the mining industry for the activities (listed earlier), direct links of benefit to QSMART were absent.

Appropriate Assessment

Teachers in both Year 11 and 12 QSMART courses are provided with a comprehensive guide to assessment, with a strong focus on using it formatively to guide students in their learning and contextualising to industry as many as possible of the assessment tasks. These tasks should be meaningful to students in terms of contemporary workplace practices.

The formal assessment in both courses involves four components: a supervised examination, a practical project, a portfolio and a workplace learning journal. The supervised examination provides a formal assessment of key concepts and thus represents assessment primarily of embrained knowledge but contextualised to the electrical trades (Table 3). The portfolio is concerned with proficiency in different forms of communication. The workplace journal aims to provide evidence of proficiency with workplace practices. The practical project provides scope for students to demonstrate their understanding of the concepts by application to a practical task (embodied knowledge). For example, they are asked to choose suitable materials for a particular construction task, drawing on both theoretical and practical knowledge to justify their choices.

Case 2 Aerospace

Aerospace is a partnership between 26 schools and aerospace industry firms, training institutions and universities. The aim of this project is to create pathways for students into Queensland's growing aerospace industries. Industry partners include Boeing Defence Australia, Brisbane Airport Corporation, GE Aviation, the Guild of Air Pilots and Air Navigators, Qantas and Virgin Airways. Central to the partnership on the industry side is a major international aviation training organisation Aviation Australia, owned by the Queensland Government.

A key school in this partnership is an industry-dedicated state high school established in 2007. The first principal was appointed from the aviation training organisation and staff committed to aviation were employed. Its mission is, in partnership with tertiary and post school training providers, "to establish an end to end education model from the classroom to employment with the industry" (Annual report, 2011).

Appropriate curriculum

This school embeds learning experiences focussed on the aviation industry from Years 8-12. For example, subjects Aerospace Communication and Aeroskills Technology are offered in Years 8, 9 and 10. Teachers of other subjects are encouraged to contextualise their work through aviation where possible; for example, a Year 10 English class runs a school-based radio program called 'Wingspan Radio'. These subjects are considered important in helping students to become aware of the aviation industry before they consider pathways in the senior years, when the following subjects become available. Opportunities to learn about the aerospace industry are provided through three Year 11 and 12 subjects designed in cooperation with industry (Table 3). Aerospace Studies, a QSA Authority subject, produced in 2006 and revised in 2011 provides credit towards entrance to university. Aeroskills Studies, a QSA Registered subject provides credit towards the senior school Certificate of Education but not tertiary entrance. A Vocational Education Training subject, Certificate in Aircraft Maintenance Engineering, contributes four credit points towards the senior school Certificate of Education. Complementing these three subjects, students studying various science subjects including Biology and Physics examine aspects of disease management, quarantine issues, the environmental management of flora and fauna around airports, jet propulsion and aircraft crash reports. Business studies students explore practices of running airlines supported by industry personnel.

The development of the Aerospace studies, the flagship subject, was done in collaboration with a range of industry partners. The philosophy was that content related to the aviation industry was to permeate all subject areas from Year 8 to Year 12. Most students enrol at this school specifically because they are interested in Aviation. For some that involved substantial travel or living away from home.

Aerospace Studies and Aeroskills Studies both cover the principles of aerodynamics, but Aerospace Studies also includes topics on airline management and business practices. This subject was described by one teacher as “a quite academic subject” and is recognised as appropriate for students proceeding to university where they can extend their studies. For instance, one local university offers a qualification, Bachelor of Aviation. In contrast, Aeroskills Studies has a strongly practical focus, including designing, making and testing model aeroplanes. This subject grew out of teacher and student extra-curricular interest in model planes; these activities are ongoing and students now participate in national model plane competitions. The third subject, Aircraft Maintenance Engineering, also involves both theory and a large component of practical work, all undertaken at an industry site and contributing to an Aeroskills Certificate IV through the adult vocational training and education authority. As an economic priority area, the Course in Aircraft Maintenance Engineering has been fully funded by the Queensland Government with no fee costs to the students.

Table 3

Aerospace Curriculum offerings

	Aerospace Studies	Aeroskills Studies	Aircraft Maintenance Engineering (AME)*
General Aims/Objectives	Knowledge Understanding Interpretation Communication Critical thinking.	Knowledge Understanding Applied processes Practical skills Attitudes & values	To prepare senior secondary students for a career as an aircraft maintenance engineer
General Content	Aeronautics and astronautics including meteorology, aircraft systems and historical developments. Aviation operations including aircraft traffic management, airport and airline operations. Safety management systems including policy and legislation. The business of aviation and aerospace including organisational structure and HR management	Introduction to the aircraft maintenance/construction Industry Safety in the aircraft industry workplace Basic aerodynamics, aeroplane aerodynamics and flight controls Selection and application of hand and power tools Maintenance practices Basic aircraft hardware Basic aeroplane structures and aircraft materials Propulsion systems Propeller fundamentals Basic electrical and electronics systems	Year 11 Operational Health and Safety in Aviation Physics Basic Aerodynamics Maintenance practices Aircraft aerodynamics Flight control systems Year 12 Aircraft structures Basic aeroplane systems (Airframe), gas turbine engine theory

Appropriate teaching practices

The principal acknowledged the challenges delivering a curriculum that was so intensely focussed on a particular industry. However, he argued that there were two circumstances in his favour. First, having described the network of partners and commitment from industry he argued that the school was developing a reputation and that second, in contrast to normal practices he had been given the authority to hire staff and exercised this authority to recruit teachers with industry experience, albeit not necessarily secondary teachers:

> I think probably though, it is those personalities that are part of our school that will make those connections be maintained, that is you know from one teacher who is a Glider Pilot … I've got another teacher who's training for his private Pilot's license, I've got another teacher (primary) who is from the air force as an aircraft mechanic and they're part of the teaching team. .. If staffed by ordinary teachers, dare I say it, ordinary teachers then it'll probably still function quite well but it'll not be as impressive as it could.

The teacher of Aerospace Studies believed he had the content "in his head" (embrained knowledge) and so he could focus on student learning and providing practical and realistic experiences (embodied knowledge). This was evident in the way he explained his teaching of air flow over aerofoils: "you still get all of those misconceptions coming in, so I find that's something I really get down to hands on and using the aerofoils, using the smoke; many different ways that I can describe it and explain it to try and get through".

Students in particular acknowledged the credibility of teachers as one student commented, "Teachers who deliver will be for the most part are ex aviation … which is really really good as it gives us insight into aviation". Another student acknowledged that because students were so motivated teachers adopted a "fluid instruction" approach suggesting that the teacher responded to the specific needs of students. Students agreed that "The teachers' experiences come across in the stories and the way it (material) is presented". The teachers were seen to have substantial theoretical (embrained) knowledge but it was their depth of understanding and embedded knowledge of the industry that mattered.

Appropriate assessment

In Aerospace Studies students do exams, research-based written assignments and an investigation project presented as a report. As an example students investigate empirically the properties of wind and aerofoil shapes using NASA designed software and wind tunnels. For some students, the course provides an opportunity for students to sit for an exam to acquire a permit to train for an aircraft flying licence. Aeroskills Studies assessment is dominated by practical activities involving manufacturing models of wings and other aircraft components. Opportunities to extend knowledge are done through extracurricular competitions. In the Aircraft Maintenance Engineering program, an assessor from industry visits to monitor teaching and undertake assessment tasks. Much of the practical assessment is done in workshops with resources including a Cessna plane, wind tunnels and other aviation engineering tools. Assessment meets criteria that are set by either the QSA or industry standards. As most students study all three subjects, there is considerable integration of knowledge with opportunities to apply information learnt in the more theoretically oriented subject (Aerospace Studies) in practical situations in Aeroskills Studies and AME.

DISCUSSION

The focus of this study was the substantial challenge of facilitating the sharing and transfer of knowledge from industry to schools. The two case studies are not necessarily representative of all schools participating in the respective Gateway projects. Indeed, these are the more successful examples in part because they are contiguous with the operational face of the industries. That is, the mining schools are directly located above rich mineral deposits and the aviation school is essentially on the flight path of a major international airport. This close physical proximity to the respective industries has facilitated networking and close personal relationships among stakeholders at the local level. Although this situation is particularly the case for the aviation school, there are qualifications for the mining schools where staff turnover is substantially higher.

In principle, industry school partnerships in which curricula are co-developed provide opportunities for contemporary knowledge transfer. In both cases subject outlines revealed a clear and consistent focus on *applied learning* in terms of approaches to teaching and assessment processes. In the aviation case the curriculum was taught by a team of teachers with substantial theoretical and practical knowledge. As former employees of the defence forces and with pilots' licences and mechanical experience these teachers brought considerable embrained, embodied, embedded and encultured knowledge to the classroom. They provided clear links between the theoretical aspects of aviation and the practice.

By contrast, in QSMART, despite industry input during design, it was difficult to identify concepts and processes which would directly represent the *workplace practices* of engineering and electrical trades. The science and mathematics concepts listed in the outlines would appear unchanged in the traditional curriculum for Years 8-10 and include some general applications of the kind that science and maths teachers often include, rather than new concepts or processes derived from engineering or electrical workplaces. Hence, the focus was clearly on the development of embrained knowledge.

Constraints to knowledge transfer may exist in the capacity of teachers to apply their pedagogical and content knowledge to specific industries. The QSMART teachers were highly competent in teaching traditional science and mathematics but lacked understanding of how and where the concepts might be applied. Thus there were shortcomings in embodied, encultured and encoded knowledge – that is the practical on-the-job knowledge that represents the application of theory. Teachers with appropriate industrial experience would appear to be critical to the success of industry school partnerships. In the aviation case this condition was well met. In the mining context this constraint was felt in the QSMART subject, but students were very well provided with industry contact by a wide range of activities; thus the impact of this limitation may have been lessened.

Assessment strategies in the practical subjects described here are strongly mandated by industry and QSA and in most instances assessment was aligned to industry requirements. This was less obvious in QSMART. The involvement of industry personnel needs to be strengthened in those instances where teachers have limited familiarity with the needs of the industry, particularly as industry approaches to assessment are usually based on an unfamiliar competency model.

ACKNOWLEDGMENTS

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ESSENTIALS OF SCIENCE – DEVELOPMENT, EVALUATION AND TRANSFER INTO SCHOOL PRACTICE OF A COMPETENCE ORIENTED SCIENCE COURSE

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Abstract: Scientific literacy is regarded as important for the individual and for society (Gräber & Nentwig, 2002; OECD, 2010). To improve competences in scientific literacy we developed, tested and evaluated a competence oriented science course for grade 11, with emphasis on self-regulation in experimentation at an experimental school in Germany. The transfer into school practice at German general High Schools was begun and accompanied by research on the effectiveness of the course concept, and monitoring of the transfer process. The success of transfer depended on several factors, including characteristics of the innovation, of teachers and of the environment and supporting activities (Gräsel, 2010). One aim of this paper is to present the main characteristics of the course concept and its didactical approach to teaching. Another focus is identifying important preconditions in the procedure of transfer that effect its successful implementation into general school education. The course concept contains basic concepts of science (e.g. Harlen, 2010). Each of these basic concepts is combined with an experiment carried out by students. The teaching approach emphasizes experimentation as a problem solving process (Klahr, 2000) and is thereby meant to foster scientific inquiry. The course aims to increase the degree of self-regulation in a step-wise manner during the experimental work. The positive results of the evaluation of the course suggest that the concept will be accepted by teachers and may be implemented. The results from monitoring the transfer show that it may be impossible to implement the whole course concept in other schools, and that it may be necessary to focus on subsets of the material.

Keywords: curriculum development, scientific literacy, inquiry learning,

INTRODUCTION

Scientific Literacy is regarded internationally as a necessary basic skill (AAAS, 1993; Gräber & Nentwig, 2002; NRC, 1996; OECD, 2010). Despite popular belief, it involves more than factual knowledge of the natural sciences, and instead encompasses a deep understanding of the nature of science and scientific inquiry in general (OECD, 2010; NRC, 1996). Additionally, scientific literacy makes it possible to evaluate social problems and personal decisions on the basis of scientific knowledge (OECD, 2010; NRC, 1996). Mayer’s (2007) model of competences describes key dimensions of scientific literacy (Figure 1). The model outlines the relationships between the standards of acquiring knowledge (nature of science, scientific inquiry and practical work) and cognitive psychological competences (epistemological views, scientific reasoning and practical skills). Mayer proposes that it is only possible to develop the three main competences through an understanding of the three standards of acquiring knowledge: the nature of science, scientific inquiry and practical work. Together this leads to an improvement in scientific reasoning.

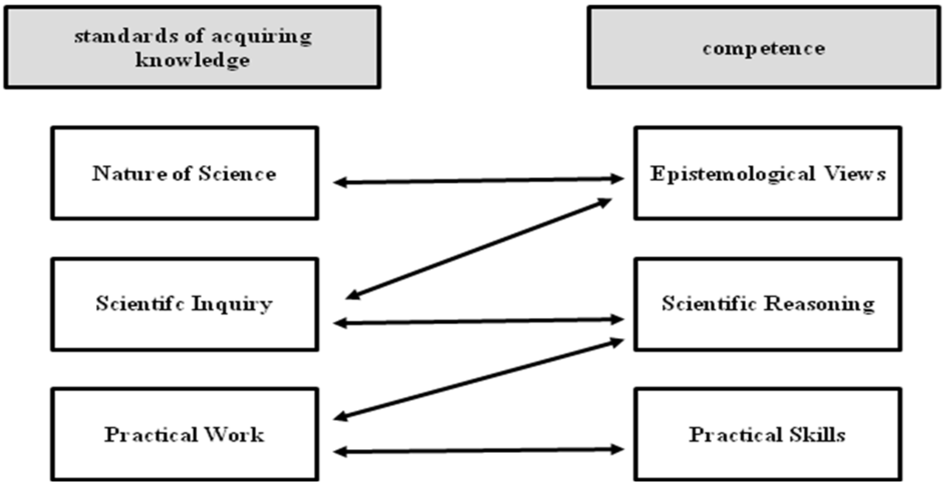

Figure 1: Modell of competence adapted from Mayer (2007)

One approach to scientific reasoning is Klahr‘s “Scientific Discovery as Dual Search Model” (Klahr, 2000) (Figure 2). He describes scientific reasoning as a problem-solving process that involves a search in two spaces: a space of hypotheses and a space of experiments. The aim of a search in the space of hypotheses is to generate a universal, precise and testable hypothesis on the basis of previous knowledge or existing data or observations. The search in the space of experiments involves testing the hypothesis established in the previous step. It consists of developing an experiment to test the hypothesis, making predictions about the outcome of the experiment and executing it, followed by comparing the predictions with the actual results. The result of the search in the experiment space is a representation of evidence that is then analyzed in the next step. The evaluation of evidence either supports or falsifies the hypothesis.

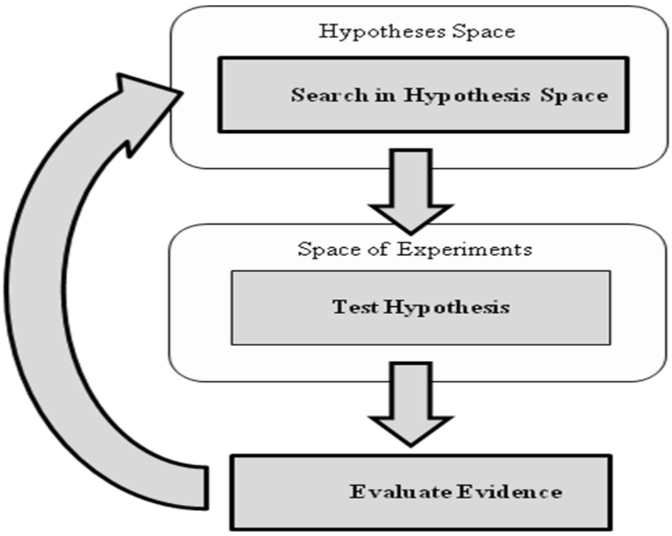

Figure 2: SDDS-Modell (adapted from Klahr, 2000)

Motivation plays an important role when investigating learning performance. According to Deci and Ryan (1996, 2000**)** three basic psychological needs are involved in the development of motivational behavior: the needs for autonomy, competence and social relatedness. They underscore different types of motivation, and can thought of as a continuum of regulatory styles. These range from extrinsically motivated behaviour as the purely controlled form of regulation, to over-introjected, identified and intergrated regulation, to intrinsically motivated behaviour as the purely autonomous form of regulation (Deci & Ryan, 2000; Ryan & Deci 2000, 2006). Regarding the learning process, intrinsic motivation argues that learning takes place because it is associated with a positive experience and thus is done for the task itself and not due to any external pressures or rewards (Deci & Ryan, 2002). Subsequently, an intrinsically motivated student learns for its own sake. Extrinsically motivated learning is prompted by the desire to ensure positive consequences, and avoid negative ones (Deci & Ryan, 2002). An extrinsically motivated student does not learn for the sake of learning or because he is interested in the subject but because of an external reward, such as marks. Several studies have shown that intrinsic motivation is an important factor in high-quality learning (Deci & Ryan, 2000; Ryan & Deci, 2000). Autonomous types of extrinsic motivation are also associated with academic outcomes (Deci & Ryan, 2000). Learning environments that support the satisfaction of students' autonomy, competence, and relatedness are correlated with greater intrinsic motivation and autonomous types of extrinsic motivation (Niemiec & Ryan, 2009). Other key factors involved with motivation and achievement in learning environments are "Dealing with mistakes" (Reusser, 1999) and "quality of instruction" (Slavin, 1999).

The implementation of innovation takes time in the field of education. It is usually difficult to create change. In particular, if the innovation was not self-generated, its implementation is only possible under certain conditions (Gräsel, 2010). Many concepts evolved from science education research or developed from science education researchers did not find their way into school practice or their implementation was never completed. As such, it is necessary to examine the circumstances of transfer processes during the implementation of new concepts. In following with Gräsel (2010) the success of transfer depends on several factors. These include the characteristics of the innovation (e.g. limited complexity, advantage of the implementation), of teachers (e.g. motivation, feeling of competence to assimilate the implementation) and of the environment and supporting activities (e.g. teacher training, networks).

We used this theoretical background to produce guiding questions for the evaluation. First, we developed a course concept with a focus on scientific literacy, where we described the relevant characteristics of the concept and its approach to improving the students' competence in scientific inquiry effectively. The second research question was concerned with identifying important side preconditions in the procedure of transfer that might affect its successful implementation in general school education.

DESIGN OF STUDY AND METHODS

To improve competences in scientific literacy, we developed, tested and evaluated a competence oriented science course with emphasis on self-regulation in experimentation for the 11th grade at an experimental school with a heterogeneous student body in Germany. The transfer into school practice at German general High Schools was begun and accompanied by research on the effectiveness of the course concept, and monitoring of the transfer process.

In this project, teachers at the experimental school and scientists at the university cooperated in order to link curriculum development and educational research. Seven teachers from an experimental school together developed the course concept, planned single lessons, learning material and tests. Their work was consulted and evaluated by scientist. The aim of the cooperation between teachers and scientists at the experimental school was an evidence-based, reflected and well documented pedagogical practice. Accordingly, this practice is based on three steps: development, trial and evaluation.

The study focused on monitoring the implementation process and preconditions of transfer. It involved an evaluation of a workshop with teachers from cooperating schools, as well as the analysis of a questionnaire completed by participating teachers. The workshop consisted of a theoretical phase organized as a lecture on the course concept, and results of the evaluation. During the workshop, teachers (n = 5) visited classes in which the course concept was taught. This was followed by a discussion of the pros and cons of the course concept and its transfer into a school setting. The discussion was audio recorded. To evaluate the teachers' point of view, we developed a questionnaire to assess the relevant improvable aspects of the curriculum, and the transfer process. The focus in the discussion and the questionnaire lay in facilitating the implementation of the course concept by addressing the school's specific needs. At the end of the school year, science teachers at cooperating schools (n=13) were asked to complete a questionnaire describing their interest in participating in a workshop about competence-oriented science-courses.

RESULTS

Principles of Curriculum Development

The one-year course concept for eleventh-graders was focussed on different aspects of scientific literacy. First, one aim was to demonstrate several basic concepts or big ideas in science from different angles, and using an interdisciplinary perspective. Second, it introduced the hypothetico-deductive way of thinking in order to improve knowledge on scientific inquiry and the nature of science. As such, every theoretical consideration of a scientific concept was combined with an experiment carried out by students. Within these experiments the degree of self-regulation was gradually increased to improve students‘ involvement, motivation and learning. Fourth, we emphasized the communication of scientific methods and results, especially in reports.

The one-year course was organized into 9 modular units. Seven units included an experiment carried out by the students. The course curriculum began with an introduction to scientific inquiry and to the hypothetico-deductive approach to science. It also contained basic concepts of physics, chemistry and biology. The course ended with a section on science in historical contexts and social environments. The assumptions of the course concept correspond with international discourse on scientific literacy. Curriculum development was based on Mayer's Model (2007). The course concept focused on Scientific Inquiry and Scientific Reasoning. The hypothetico-deductive approach was enacted by students at several points and referred to Klahr‘s Scientific Discovery as Dual Search-Model (Klahr, 2000). The didactical approach is described in Figure 3. The different steps in the experimentation process were introduced by the teacher at the beginning and made available to the students by the end of the course. Step by step, the students became comfortable with self-regulated experimental work. We predicted that this approach would satisfy the basic needs as described by Deci and Ryan (1996, 2000**)**. We also predicted that experiments carried out in small groups would support feelings of social relatedness. The students were expected to eventually perceive a higher degree of autonomy, and if the learning process was successful, that they would experience competence in those experiments. The fulfilment of basic needs was expected to lead to more self-regulated qualities of motivation. A high degree of self-regulation during experimentation implied opportunities for the students to make mistakes. A constructive way of dealing with mistakes was emphasized and thus offering learning opportunities. Because of the given curriculum completed with cooperatively worked-out teaching aids, it was assumed that the quality of instruction would be high because the curriculum and the teaching aids were developed cooperatively.

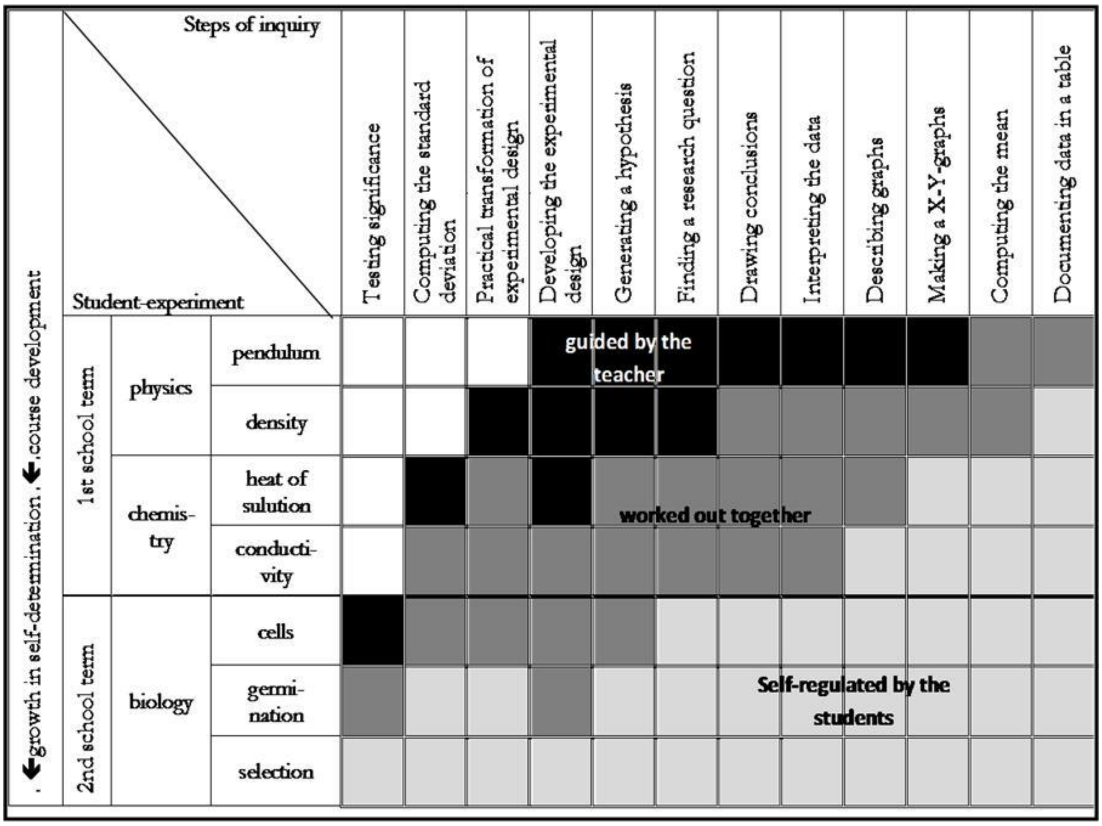

Figure 3: Overview of the competences and their implementing in relation to the experiments executedincreasingly self-directedly by the students throughout the course.

The students developed their competence in the communication of scientific results by discussing their results and the experimentation process with each other and the teacher. On the other hand, the students had to write several lab reports with a gradually increase in self-regulation. By the end of the course, the students were able to write one lab report completely on their own. Writing a report is the key to helping students reflect on their experimental work and to draw conclusions from the data to the theory.

In cooperation with teachers and the scientific staff, teaching material was developed and used in adapted versions in the courses. Material was developed for teachers and for students. The structure of the manuals for experimentation and the assisting materials for data analysis was guided by the degree of self-regulation and methodical competence in the execution of experiments and data analysis.

Monitoring of the transfer into school practice

In order to answer the second research question, we worked to identify factors that affected the successful implementation of the course concept into the regular school curriculum. One factor which is important for the success of transfer is that an advantage of the implementation is distinctly visible for teachers (Gräsel, 2010). A prior, one-semester version of the course concept with the topic ‘salt’ was evaluated. Statistical analyses showed increasing competence in scientific inquiry over the course of the semester, whereby low-achievers benefitted the most (Hahn, Stiller, Stockey & Wilde, 2013). The evaluation of the improved, two-semester, version of the course concept in school years 2010/11 and 2011/12 showed benefits of the course concept on scientific inquiry, nature of science, motivation and supporting teaching-and-learning conditions as compared to regular science classes (Hahn, Stiller, Stockey, & Wilde, 2013, August; Stiller, Hahn, Stockey, & Wilde, 2011, September; Stiller, Hahn, Stockey, & Wilde, 2012, September).

The evaluation of the workshop and the questionnaire showed conditions relevant to the teachers. During the discussion and in the questionnaire, the participants stressed that the transmission of the hypothetico-deductive model for the natural sciences was necessary at their school. Moreover, they emphasized the heterogeneous student body in their schools and due to that the need to find a way to deal with it. The implementation of the course concept seemed to be limited by frame conditions such as curricular demands, the separation of subjects, and furthermore by the teachers attitudes. The results for participation in workshops showed that eleven out of thirteen teachers had an interest in participating in a workshop on the course concept and hence in the concept itself. The teachers described several reasons for participating, or interest in participating in the workshops, e.g. they were interested in the course concept (n = 5), to get information to implement the course concept (n = 1), to get information to adapt the course concept or parts of it (n = 3), to develop a course concept on their own (n = 5) and for the exchanges with colleagues (n = 4). Particularly, the teachers were interested in an introduction to the course concept, in learning material and the opportunity to work with it. Only two teachers had no interest in the course concept. Summarizing, most teachers were very interested in the course concept and willing to set to work on the implementation of this concept.

DISCUSSION AND CONCLUSION

The success of transfer depends on several factors. One aspect concerns a visible advantage of an implementation (Gräsel, 2010). The evaluation of the course concept showed positive results, suggesting that is was beneficial to teachers. The evaluation of transfer conditions showed that the teachers described as an aim in their course development the transmission of the hypothetico-deductive model in the natural sciences, and the need to find a way to deal with heterogeneity. These are relevant aims referred to in the course and may therefore be seen as positive conditions for transfer and implementation. Furthermore, teachers were interested in workshops concerning the course concept. This interest can also be considered a positive requirement of transfer. However, both the frame conditions and the teachers' attitudes present a major challenge to the transfer process.

The question now is what can be done to support the transfer into regular schools. Two aspects are obviously of high relevance. First, it seems very difficult to implement the whole course concept in other schools. As such, it will likely be necessary to create separate learning modules. Second, learning differences in learning requirements among the students should be addressed by developing learning material that recognizes the heterogeneity of the students. The development of learning material that considers these two aspects should be the next step in this project. Another step should be to offer workshops which emphasize the curriculum and the learning material.

Taken together, learning materials seem to be critical to the process of implementation. The results from the evaluation of the transfer process gave clues to developing more advantageous learning materials. The instructions for the experiments should be usable independently from the school curriculum, should have different levels of self-regulation, and the instructions should contain further materials to reinforce the experiments. The materials for basic knowledge should be designed in the same way. They should contain different levels of difficulty, and include the possibility of being carried out in learning circles. Concerning social form, it should be possible to use a variety of social forms depending on the students‘ needs, for example, individual work or working with a partner. There should also be instructions for teachers that explain how the experiments are to be carried out and their possible results. It should also state how and when the experiments could be implemented in the school curriculum.

In conclusion, monitoring of the transfer process produced helpful hints to promote the development of the learning material, as well as opportunities for implementation.

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TEACHERS' PERSPECTIVES REGARDING A NEW SUBJECT: "SCIENCE FOR THE CONTEMPORARY WORLD"

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Abstract: This research analyses the implementation of a new subject for the post-compulsory secondary school called "Science for the Contemporary World" (SCW). The main goal of this research is to identify the differences between the Implemented Curriculum (IC) as reported by teachers, and the Potential Curriculum (PC) according to official documents and science education literature.

For this purpose we have identified the teacher's perception of the subject during their first year implementing it. The results show four ways of perceiving the PC, three of them in agreement with a competence-based framework while the last one, associated with standard teachers, completely distort the proposed rational of the subject.

Keywords: Science for Public Understanding, teachers' perceptions, scientific literacy

RATIONALE

The aim of this paper is to show an analysis on how teachers perceive the PC of "Science for the Contemporary World" (SCW). This analysis is done according to the three relevant dimensions that characterize each curricular design and practice, which are *why*, *what* and *how* to teach?

FRAMEWORK

During 2006, the education law was modified in Spain generating a new official curriculum that included a new subject for the post-compulsory secondary school: *science for the contemporary world* (SCW). The main goal was reducing the deficit of scientific knowledge of citizens within a *science for all* and contextualised perspective.

We have characterized the PC of this subject based on both the rational of the official syllabus and contributions from Science Education literature. Frameworks such as STS, Science for all, and SSI were reviewed. This characterization process let us identify three intended didactical goals:

a) **Promote the development of competences/capacities to perform well in society**. This goal is not related to the concept acquisition of classical science subjects, but about how students learn to *mobilize* concepts, procedures and scientific attitudes, in order to solve a complex problem and make rational decisions (DeSeCo, 2001). These complex problems are typically part of public discourse today, and require certain sets of skills and abilities from those engaged in reasoning and argumentation about them (Forbes & Davis, 2008). In this sense, SCW is framed within the competence-based framework in which the use given to content is related with the high-order thinking skills (argue, justify, evaluate,...).

b) **Emphasize science as a product of culture.** This objective is based in an argument of Millar (1996) when discussing the different aims of scientific literacy, according to which science is an important part of our culture that all citizens should be able to understand, appreciate and use for its intrinsic value and what it says about human activity. In addition, this didactical goal emphasizes a cognitive and socio-cultural view of the NOS, as Science is seen as one the products that our culture produces which rules of the game students' need to know.

c) **Use relevant contexts to address the learning of contents**. In SCW it is expected that contents are taught in context, with the selection of contexts as one that it is relevant to students and allows meaningful learning of scientific knowledge, so that it can be transferred to other contexts and situations. From the educational point of view, the approach would allow a balance between teaching science as preparation for science and science education for citizenship (Gilbert, Bulte, & Pilot, 2010).

To reach these goals, SCW has to be conceptualized and implemented by teachers adequately. In this sense, we focus our study on teachers' perceptions of the subject in order to analyze the different views or models of the subject they hold. In particular, we want to identify the differences between the Implemented Curriculum (IC), as reported by teachers, and the Potential Curriculum (PC), according to official documents and science education literature.

RESEARCH QUESTIONS

The purpose of our research is operationalized in three research questions:

- What are the crucial aspects that characterize teachers' views of the subject (IC)?
- What relation there is between the consonance of these views with the CP and the teachers' didactical experience?
- What are the different coherent ways to interpret the CP (models of the subject) that co-exist during its first year implementation?

METHODS

The gathered data consists of 10 semi-structured interviews to teachers teaching SCW for the first time. The interviewed teachers had different scientific backgrounds and were selected according to their didactical experience. One group includes teachers currently participating in innovative groups in science education (IT: T1, T2, T3, T4, T5) and the other were standard teachers without specific contact with the science education research field (ST: T6, T7, T8, T9, T10).

The interviews were analyzed at different levels of analysis according to the Constant Comparative Method (Huberman & Miles, 2002), for constructing both the theoretically and/or empirically-based categories.

At the first level of analysis we did a categorization regarding teacher’s perceptions on what? Why? and how to teach?, organizing the most relevant aspects into a systemic network. These ideas were also analyzed according to their consonance or dissonance with respect to the PC for each category.

At the second analysis level, we wanted to know the relationship between a consonant or dissonant implementation of the PC and teachers' didactical expertise, comparing the perceptions and reported implementations of IT and ST for each category.

Finally, we have identified 4 different models or ways of understanding the subject, by doing an analysis of the internal coherence between the three key dimensions. The consonance of these models and its possible hybrids with the PC is also analyzed.

RESULTS

Due to spatial restrictions, the results of the first two levels of analysis are included at lesser detail than the third one. The complete results can be found in Pipitone (2013).

Global characterization of teachers' perception about SCW

In the following, we present the results of the 1st level of analysis, including the most relevant categories identified in teachers' views of their implementation of SCW.

View on the nature of the science to teach

One of the categories that we identified as more relevant in framing teachers' views of the subject it is their *view of the nature of the science they have to teach.* In this sense two main visions have been identified (Fig.1): science perceived as grounded in dogmatic thinking (Porlán & Martín del Pozo, 2004) and science seen as based on a moderate rational thinking (Izquierdo, 1992)

Table 1

View of Science

Categories	Sub-categories		Teachers
View on the nature of the science to teach	Grounded/based in a dogmatic thinking		T6,T7,T9,T10
	Grounded in a moderate rational thinking	Epistemic view	T1,T8
		Social view	T2,T3, T4,T5

The first view includes those teachers who speak of a science to be taught that is traditional and far from the complexities of today's problems. As an example:

> *"We often find these students have not studied any biology since eighth grade, no science at all. There are some issues that are difficult to understand [...], especially the latest advances [...],* ***some biology concepts should be reinforced,*** *and you have to explain them well."(T10)*

In contrast, some teachers' believe that the subject should promote a more complex view of science. This includes teachers referring to the subject as portraying a view of science adequate in classical epistemic terms (regarding the generation of knowledge) and also those emphasizing the social implications and controversial nature of the scientific enterprise, which include ideas from the STS (Bybee & McInerney, 1995; Yager, 1996) and SSI movements (Albe, 2007; Kolstø, 2001; Zeidler et al., 2005).

The latter two views of the nature of the science to be taught in SCW (epistemic and social) are both consonant with the CP, whereas the previous one distorts its rationale.

Main learning objectives for students

Despite the general objectives of the SCW subject are defined by official syllabus, teachers' perceptions show that the finality they assign to the subject is different.

The objectives of the subject are mostly divided from those that refer to mere acquisition of scientific knowledge to those that explicitly refer to the mobilization or use students' should give to the scientific knowledge they learn within the subject. This implies an important division between teachers that hold a view compatible with a competence-based framework for science teaching with those who do not (Table 2).

For the latter, the main objective of the subject is improving students' scientific general culture, understood as helping students' to be superficially informed on the latest scientific advances or on the leading edge of science.

> *"SCW helps to give you a general idea of what's happening around you, but it's not a decisive subject for your future, especially if you're not planning to go into science"* [T10]

In contrast, those teachers who hold a view more related with students' use of knowledge give a more profound meaning to the idea of general culture (reflecting finality related with the concept of scientific literacy) and can include as a focus important uses of scientific knowledge. In this sense, their views range from a focus on learning basic science to act in the actual society (application of scientific knowledge in different contexts and situations) to an emphasis on particularly important HOTS such as critical thinking or argumentation.

> *"train future citizens to have a* ***critical view of science or current affairs*** *[...], learn to be critical, to have an opinion"*[T3] *"we discussed everything in class... I think reflecting on our actions and learning from what we do is the spirit of the subject, that's it*" (T1)

Table 2

Main learning objectives for students

Categories	Sub-categories		Teachers
Learning Objectives	Acquisition of scientific knowledge	Information (general culture)	T6, T7, T9, T10
	Mobilization / use of scientific knowledge	Scientific literacy (general culture)	T1, T2,T3,T4,T5 T8
		Critical thinking	
		Argumentation	

When analyzing the consonance or dissonance of these views with the PC, it is clear that while the latter views are in agreement with the PC, the view of the subject as mostly informative is not in coherence with the PC and diminishes its importance in the students' curriculum. Interestingly, when relating these results with those of the previous category, we can see that those teachers' with a more traditional view on the nature of scientific knowledge are also those that relate to the objective of increasing our scientific knowledge, whereas those with epistemic or social views of science emphasize as the objective of SCW the uses or application of this knowledge.

Main content to be taught

In addition to the previous views, we found that there is a great diversity of criteria and factors that intervene in teachers' selection of the content to be taught in SCW, and which is related with the multidisciplinary and open nature of its curriculum.

Most teachers (8/10) reflect this definition of the curriculum in their choices of content, including contents from different scientific disciplines. However, in contrast with the CP, they deal with this contents is in an unconnected way, splitting the subject into isolated thematic blocks with no explicit neither coherent relation among them. This fact shows how demanding is for all teachers to deal with multidisciplinary of science, in particular at post-compulsory level. Even when they recognize the problem of content dispersion, they do not manage to overcome it.

> "*the science teacher jumps from talking about the universe to materials, to the cell or to biotechnology-related matters. This resembles a flea flea market ¿doesn't it? [...] this business of teaching something different every day...*" (T3)

Many interviewed teachers highlight the importance of including meta-disciplinar contents or transversal abilities such as critical reading or decision-making, which is in agreement with the CP and the literature in the field (Duschl & Osborne (2002).

When deciding which contents to include, teachers have referred to both internal and external factors to justify their selection of content (Fig. 4). Internal factors are those which depend exclusively on teachers, such as their background as chemist or biologists or their personal interests in some topics. External factors are pre-established ones, such as contents suggested in the official syllabus or the textbook.

Table 3

Selection of content to be taught

<table>
<tr><th>Categories</th><th>Sub-categories</th><th></th><th>Teachers</th></tr>
<tr><td rowspan="5">Criteria for selecting content</td><td rowspan="2">Internal factors</td><td>Mastering of scientific knowledge</td><td>T2,T3, T4, T5, T7</td></tr>
<tr><td>Personal interest</td><td>T3</td></tr>
<tr><td rowspan="3">External factors</td><td>Official syllabus</td><td></td></tr>
<tr><td>Textbook</td><td>All</td></tr>
<tr><td>Media hot topics</td><td>T1, T2, T3, T4, T5, T6, T8</td></tr>
</table>

Interestingly, most teachers have referred to external factors to justify their selection of contents, mostly to the textbook and the hot scientific topics present in the media.

Regarding the textbook, this has been a crucial for all teachers in their first year of implementation of SCW. However, the use they have given to it is very different, ranging from being the one and only teaching resource to one of many available.

Another important external factor, the hot scientific topics available in the media, has also been very common. This has been the case in particular among those teachers with an applied view of science, who have mostly use these topics to introduce real, nowadays situations. However, an interesting bias introduced by this practice is the fact those teachers selecting hot topics have mostly used those related with biology, making the subject less multidisciplinary than requested.

Regarding internal factors, unsurprisingly, a relevant one for teachers has been teachers' mastery of the scientific content, which is related with their background.

> *"I am a chemist, [...] I know little biology, so[...] the part of illnesses and biology, I left it to the last trimester, not for other reason than to have more time to prepare it"* [T2]

Another internal factor, somehow contrasting the previous view, has been teachers' personal interest in certain topics. An example is teacher T3, who is a chemist but who have selected mostly contents from biology to relate them with scientific controversies, following her strong interest in working on aspects of value and ethics.

Teaching and learning methodology

An interesting characteristic of the teaching and learning methodology chosen for the implementation of the subject, which also relates with the previous selection of contents, is the use of activities oriented to develop different transversal abilities, in particular the mastery of argumentation. In a consonant view with the CP, teachers report to have included (or to have the intention to do so) activities not common in other scientific subjects, such as debates and open problem-solving tasks.

However, we have identified different ways of referring to these tasks. While for some teachers they are related with the objective of the subject being the promotion of argumentation or critical thinking, others refer to compliance with the official syllabus as the motive to include low-profile versions of them, thus distorting the CP.

In addition, there are teachers that do not refer not even rhetorically to the teaching strategies recommended in the official syllabus to justify their teaching methodology, using traditional lecturing and textbook exercises as their main teaching strategy.

> *"the class was mainly a lecture, that is, my explanation, giving out notes, writing on the blackboard or making comments. After that, we did some exercises at the end of the lesson, which were related to what I had previously explained" [T10]*

View on Evaluation

One of the most critical aspects related with the implementation of a subject such as SCW is, from the research viewpoint, its evaluation. Taking into account that SCW promotes the introduction of new and innovative activities for the promotion of challenging educational goals (within the competence-based framework), this implies a demanding adaptation of the evaluation framework (Black & William 2009).

In this sense, interviewed teachers have shown great concern and difficulty to evaluate the most innovative activities, such as debates, in particular regarding the scientific content involved.

> *"One of the most complex parts [is evaluation] How do you evaluate a debate? How do you evaluate participation? all this is .... the most difficult part, and it is an important part!"* [T3]

This implies that evaluation is, in fact, problematized mostly regarding its summative function, rather than its formative role. As a consequence, references to evaluation are either not done or do not refer to how to guide the teaching and learning process, focused on identification and marking of students' outcomes in particularly challenging activities.

Subject perception according the teacher expertise.

In our research we were interested in identifying whether the previously mentioned views of the subject could be related with teachers' previous didactical experience. As a consequence, we did a second level of analysis to compare consonant and dissonant views for standard and innovative teachers (See Table 4)

As we can see, for most categories there is a close relation between being involved with science education innovation (T1 to T5) and being able to implement a challenging subject such as SCW in a way consonant with the PC. On the other hand, most standard teachers (T6 to T10) show dissonant views. This is particularly problematic, as one expects these teachers to be more representative of the majority of teachers than the innovative ones, which signals the importance of really understanding curriculum reform as problematic and needing CPD support.

In addition, Table 4 shows that there are interesting categories for which both innovative and standard teachers face the same challenges, such as dealing with the multidisciplinar character of the subject in an inter-connected way or using adequately formative assessment with innovative activities. In this sense, our analysis points out the categories that would require more effort not only regarding the professional development of teachers, but also from the research field point of view, as these mostly un-solved problems also within the research field.

Regarding the *View of the nature of the science to be taught*, we found that the most innovative teachers understand that science in SCW should be taught from an applied or controversial perspective. Therefore, they consider the importance of teaching science within an adequate view of NOS that emphasizes social and cultural aspects, thus closely related to theoretical frameworks such as STS or SSI. On the other hand, ST view of the science to be taught is much more related with a simplistic and dogmatic view of science.

Table 4

Consonant and dissonant views of SCW for innovative and standard teachers.

Categoría	Sub-categorías		Consonant	Dissonant
View on the nature of the science to be taught	Grounded/based in a dogmatic thinking		T6,T7,T9,T10	
	Grounded in a moderate rational thinking	Epistemic view	T1,T8	
		Social view	T2,T3, T4,T5	
Learning Objectives	Acquisiton of scientific knowledge	Information		T6, T7, T9, T10
	Mobilization / use of scientific knowledge	Scientific literacy	T1, T2,T3,T4,T5 T8	
		Critical thinking	T1,T3, T4,T5 T8	
		Argumentation		
Selection of content to be taught	Meta-disciplinar contents		T1, T2,T3,T4,T5, T7 T8, T9	
	Disconnected topics		T2, T3, T4, T5, T6, T7, T8, T9	
	Internal factors	Mastering of scientific knowledge	T2, T5	
		Personal interest	T3	
	External factors	Official syllabus/ Textbook	All teachers	
		Media hot topics	T1, T2, T3, T4, T5, T6, T8	
Teaching-learning methodology	Innovative/ competence-based activities		T1, T2, T3, T4, T5, T8	T6,T7, T9,T10

Regarding *the main learning objectives to be developed*, the crucial difference found between the objectives of "Acquisition of scientific knowledge" and " Mobilization /

use of scientific knowledge" can also be related with the previous didactical knowledge of teachers, with ST mostly holding the traditional view related to an academic perspective, where a science lesson involves learning new scientific concepts, in order to acquire a higher level of scientific knowledge. On the contrary, IT show a view of the subject where the capacity to use knowledge in context (for solving real problems, make decisions, have a critical viewpoint) becomes crucial.

With regard to the *Selection of content to be taught* we found that the most important difference is that, for those teachers holding views more consonant with the PC this selection is more problematic and implies that internal factors such as disciplinary background and teachers' interest have an important role. We relate this issue with the fact that, to teach within a competence-based framework, emphasizing application of science within a social and cultural perspective requires a mastery of knowledge not necessary for teaching just more content present in the textbook.

Regarding *the teaching-learning methodologies* considered suitable for SCW we found another significant difference between both groups of teachers. While IT teachers use more participatory teaching strategies that promote critical thinking and argumentation from their students, ST refer to a more traditional class based on lecturing where the teacher's role is limited to conveying knowledge in a mostly transmissive way.

Identifying the different ways to understand SCW

In the previous sections we have seen that the most relevant aspects that characterize teachers' view of the subject SCW are sometimes related. In a third level of analysis we have grouped the views that show coherence among them, to identify different models or ways of interpreting the subject. In the following, they are described.

Epistemic Model

The *Epistemic model* is defined as a subject that let us know what science is and how it works. As such, the most important goal is to deepen the scientific knowledge of students, not only *of* science but also *about* science, within an adequate epistemology.

> *"[The goal of the subject is] on one hand to see* ***the great theories*** *that allow us to see the world. Some of the most important are: where do we come from? How do we work [...]? And on the other hand,* ***how science works****" [T1]*

Regarding content, this model suggests not to focus on introducing new contents but to revisit basic scientific knowledge (key scientific models) in a deeper way, by refining them and allowing students to work on them from an epistemic point of view. This implies, on the one hand, that the subject is conceived as a place where the pupils thoroughly go into and reflect on what they've already studied. On the other, that the subject is focused on the aim to enable the students to get to know what science is and how scientific knowledge is generated. In this sense, this perception of the subject's aims (why to teach?) takes aspects related to history and philosophy of science into account.

Utility Model

The *Utility model* defines a subject that helps us in dealing with everyday science-related contexts. The *Utility model* is essentially based on working on scientific content which has already been taught in order to understand, interpret and actively take part in the science we may come across in everyday life situations. Hence, the teaching and learning is devoted to the mastery of applying science to daily contexts that the students can face in their life, and not the mastery of the content per se.

> *"We will do* ***things that are day-to-day,*** *and they are things which, even though in Greek philology graduates are perhaps interest to you, because* ***maybe one day you'll have to decide*** *if you want assisted reproduction or not [...], and to decide that they must know something"* [T4]

As such, this model of the subject is essentially focused on providing an outlook on applied science approaching scientific concepts from various real-life situations that require mostly critical thinking and decision-making skills. This demands from the student to recognize the science involved in a particular real problem or situation, and to make decisions by means of a solid foundation in scientific knowledge.

Controversial Model

The *Controversial model* defines a subject that overall help us to recognize and argument our positions in controversial contexts, where decisions involve ethical and value-driven aspects. In this sense, within this model it is encouraged that students make decisions when facing up controversial and/or uncertain circumstances they may encounter throughout their lives. In this sense, it focus on problems where the scientific justification is not the only reference for interpreting the facts and influence decisions, which resembles frameworks such as SSI**.**

As such, this *Controversial model* do not only concentrates on the science involved in a particular situation, but also on the limits of the science concerning these issues and gives importance mostly to critical thinking and argumentation as crucial abilities to be developed:

> *"[The objective of the subject is to] train future citizens to have a critical view of science or current affairs […], learn to critical, to have an opinion and know that all are valid, that all can be defended"* [T3]

Academic Model

The *Academic model* defines a view of the subject as one devoted to learn more science, reinforcing previous knowledge by learning about the new scientific advances. This model emphasizes the need to learn updated scientific knowledge without the critical thinking standpoint, prioritizing conceptual scientific knowledge without problematizing simplistic ideas on the NOS.

As such, it is basically a subject which considers that students who learn more scientific concepts will have a better knowledge foundation to interpret scientific advances. In this sense, it is regarded as a complementary subject to other more important, traditional (disciplinary) scientific subjects, which can be used to increase the number of hours devoted to science lessons in order to consolidate the previously learnt concepts in science.

> *"These students more often have done nothing of biology since eighth grade, no science at all. There are some issues that are difficult to understand […], most of all last advances […], some concepts of biology should be reinforced, and you have to explain them well"* [T10]

Models: Consonance or dissonance with the PC and their combinations.

The analysis of the identified models show that, despite their differences, the *Epistemic model*, *Utilitarian model* and the *Controversial model* can be considered all in agreement with the PC. In contrast, the *Academic model* distorts the purpose of the rational of the subject and is therefore not consistent with the PC.

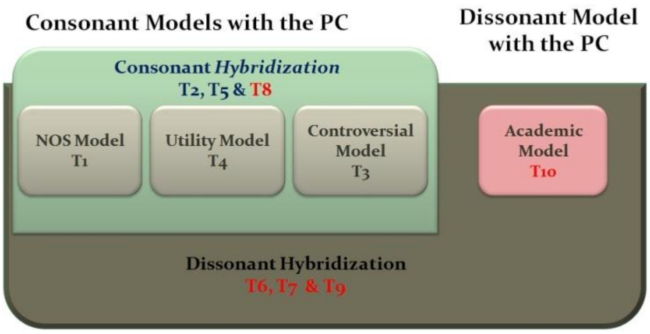

Figure 1. Models of the subject

When explicitly relating teachers with these models, we have found that most teachers were identified with more than one model at a time, showing a rich combination of views that sometimes was consonant and sometimes dissonant with the PC. This situation let us define combinations of our proposed models.

For example, all IT teachers can be associated with coherent consonant models or a consonant hybridization of them, which is in fact richer than the more coherent views. combine consonant models. On the other hand, most ST were related with a dissonant hybridization, where aspects of the consonant models were merged with aspects of an academic view of the subject.

CONCLUSIONS

The most important conclusions of this research can be summed in three main ideas:

a) The way to characterize a subject from the ideas expressed by the teachers;

b) the relationship between the didactical expertise of teachers and the coherent implementation of CP;

c) the four coherent ways to understand the CP and their respective combinations.

Regarding the first idea (a), the main categories that describe a curricular implementation such the one we have analyzed are: the View on the nature of the science to be taught, its Learning Objectives, the Selection of content to be taught and the Teaching-learning and Evaluation methodology. In this sense, a focus on these aspects and how they relate in a coherent or incoherent way to each other has shown productive in order to characterize different, sometimes subtle, views of the subject.

Regarding the second idea (b) we have found that, unsurprisingly, the curricular implementation of a new subject, despite challenging for all teachers, strongly depend on the teachers' didactical expertise. That gives not only importance to the didactical background of teachers for adequate implementations, but signals that when this background does not exist or it is insufficient, the implementation is very likable distorting the original rationale.

As a summary, our findings show most innovative teachers hold a view based on teaching science for the scientific competence, within an applied/controversial perspective of science and using a variety of methodologies to achieve critical thinking and argued decision-making as main purposes. In contrast, standard teachers, despite recognizing their need to change their implementation of the subject, end up doing the subject as complementary / additional to traditional science subjects.

Regarding the last idea (c), the main conclusion from this study is that, when implementing a new subject, different subject models coexist, being more or less consonant with the PC depending on the didactical expertise of the teachers implementing it. In general, teachers with better didactical background hold more consonant models regarding what and why to teach. However, all teachers find how to teach a challenge, which signals the importance of practical teacher education that goes beyond the acquisition of the mere rhetoric of the reforms.

These points to the fact that for most teachers (as most teachers are ST) implementing a new subject with an innovative rationale is a challenge that, without support, it is not overcame in spite of teachers' mastery of the reform rhetoric. As expected, teachers do not need as much discourses and documents regarding the rational of the subject as they need practical ideas and examples of how to teach in this way, being the teaching practice the main challenge. Empirical studies like this one evidence again the need to rethink the way innovations are introduced in the curricula, as literature has already shown.

This study has also implications for teacher education. The goal of SCW as implemented goes from a competence view to help citizens make decisions to a view limited to keep the society scientifically informed. Teachers can situate themselves within this spectrum, in addition to being introduced ways of teaching of IT teachers that fit the PC.

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QUESTIONING IN NATURAL SCIENCE TESTS AND TEXTBOOKS: A LOOK INTO THE PORTUGUESE CURRICULUM

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Abstract: Natural Science Portuguese Curriculum highlights the development of conceptual, reasoning and communicative competences, which are crucial in our society. In fact, as we live in a world extremely influenced by science and technology, it is fundamental to be scientifically literate, in a way that enables us to understand our world and to take serious and responsible decisions. So, the Portuguese Curriculum emphasizes the development of critical thinking and high cognitive level competences, suggesting strategies and methodologies under the scope of an inquiry-based learning approach. Within this approach, which favors students' active engagement and a personal construction of knowledge, questioning is considered a powerful tool in the learning process. However, questions of a high cognitive level are those that are more relevant to an effective and significant learning of science. A case study was developed in order to evaluate the implementation of the Natural Science Portuguese Curriculum in a school from the north of Portugal. Integrated in this case study, this research analyses the nature of questions applied in Natural Science textbooks and Natural Science tests, according to their cognitive level. Results show that the number of questions of high cognitive level is low in textbooks, as well as in tests, revealing some inconsistences between curriculum suggestions and what is really done in science classes. With these results, authors claim that it is important to coordinate curriculum demands with teachers' knowledge, as well as with science textbooks elaboration.

Keywords: natural science curriculum, inquiry-based learning, questioning, textbooks, tests.

INTRODUCTION

As we live in a knowledge-based society, extremely influenced by science and technology, it is crucial that our students develop their scientific literacy. The Portuguese Natural Science Curriculum (PNSC), implemented in 2001, was developed in order to attain this purpose, for students to be critical about the world and to make responsible decisions.

In spite of the importance given to science education, the number of students pursuing science-related careers is decreasing (European Commission, 2004) and scientific literacy level in Europe is low (European Commission, 2004; Freire et al., 2013). These conclusions are of concern as all students need to be educated to be critical consumers of scientific knowledge (Osborne & Dillon, 2008).

With the implementation of PNSC it was intended to achieve specific objectives related to contents, but also related to teaching and learning methodologies, taking into account the European recommendations (Freire et al., 2013). The curriculum, being organized around competencies, emphasizes the creation of inquiry learning approaches which promotes an active involvement of student and a self-regulated learning. In fact, under the scope of an inquiry-based learning approach, "science teaching is no longer only about students' acquisition of content knowledge" (Kim et al., 2013, p. 291). Students should be provided with opportunities to observe and gather evidences, to decide their value, to discuss ideas and to suggest scientific explanations (Kim et al., 2013). It is very important that the process of learning science becomes meaningful, relevant and interesting, developing students' autonomy as learners (Vasconcelos et al., 2012). In this context, questioning is considered to be an essential tool for the learning process (Chin & Chia, 2004; Dahlgren & Öberg, 2001) and for students to develop inquiry competences, as it encourages students to find solutions to different problems (Torres et al., 2012; Vasconcelos et al., 2012).

As high cognitive level questions are considered to be the most relevant to the development of inquiry competences, critical and high order thinking, we considered important to evaluate the nature of questions used in science classes, either in classroom contexts or in formative or summative contexts.

Questioning

Questioning is very common in our daily life as well as in the classroom context (Palma & Leite, 2006; Vasconcelos et al., 2012). In school, questions are considered to play a crucial role as they may prompt imbalances that may encourage students to surpass themselves, to research and to seek for new solutions (Giordan & Vecchi, 1996; Vasconcelos et al., 2012). For this reason, there are many studies regarding questioning in the classroom which involves not only teachers' questions but also students' questions and textbooks' questions, among others (Vasconcelos, et al., 2012). Many studies reveal that while teachers formulate too many questions, students rarely formulate them within a classroom context (Cuccio-Schirripa & Steiner, 2000; Oliveira, 2008; Vasconcelos et al., 2012). Moreover, most of students' questions are of low cognitive level, which are considered to restrain the development of high order thinking skills and other relevant competences. As Dillon (1990, p. 7) stated ''children everywhere are schooled to become masters at answering questions and to remain novices at asking them''.

In fact, Costa and collaborators (2000) advocated that asking questions may not be an easy task for all students, pointing out many aspects that may influence students' questioning: (i) failure to detect difficulties and to understand their own state of comprehension; (ii) personal variables, as motivation, achievement and self-esteem; (iii) social constraints and contexts; (iv) evaluation processes, which may discourage students from asking questions.

However, many authors argued that it is central to promote students' questioning, as students may: (i) understand that inquiry is a natural component of scientific subjects; (ii) reveal their own thoughts and conceptions when raising questions; and (iii) evolve to higher levels of conceptual complexity (Chin & Kayalvizhi, 2002; Marbach-ad & Sokolove, 2000; Schein & Coelho 2006). Moreover, students become more aware of their own concerns (Orlik, 2002) and become more curious and enthusiastic when they try to solve and to answer to their own problems/questions (Chin & Kayalvizhi, 2002).

Additionally, it is also relevant to mention that some studies reveal that students pose many questions if they have opportunities to do so (Costa et al., 2000) and that they would also ask high cognitive level questions if they had opportunities to develop abilities to ask questions (Leite et al., 2012; Oliveira, 2008).

Furthermore, the quantity and quality (in terms of cognitive level) of questions formulated by students may vary according to the scenario (Dahlgren & Öberg, 2001; Loureiro, 2008; Oliveira, 2008; Torres, et al., 2013), the methodologies applied, and depending on whether they are formulated individually or in group (Palma & Leite, 2006).

Having in mind all the advantages referred and that students' questions may prompt a significant knowledge construction and solving problems capabilities, it is essential to create conditions for students to develop and to improve their questioning skills (Chin & Kayalvizhi, 2002). In spite of the relevance of both high and low cognitive level questions (low cognitive questions can lead to the raise of questions of high cognitive levels), good questions are those that generate processes of logical thought development and a meaningful learning.

There are different taxonomies that were used to classify questions. Bloom's taxonomy is a very well-known that influenced teachers' practices, as they started to match the questions they ask with the skills they are trying to develop (Allen & Tanner, 2002). This teachers' awareness is very important as teachers' questions are a frequent component of classroom talk that may play an important role as a powerful tool in mediating students' knowledge construction, influencing the type of cognitive process that students engage in (Chin, 2007).

Dahlgren and Öberg (2001) conducted a study concerning the questions that university students formulated when faced with different scenarios. Questions were analysed and grouped into different categories: (i) *Encyclopaedic questions*; (ii) *Meaning-oriented questions*; (iii) *Relational questions*; (iv) *Value-Oriented questions* and (v) *Solution-oriented questions*.

In other study, Chin and Chia (2004) analysed the kind of questions students ask individually and collaboratively when working through a PBL approach. Questions were classified into 4 categories: (i) *Validation of common beliefs and misconceptions* – questions that refer to common beliefs and misconceptions and that are asked for some validation; (ii) *Basic Information Questions* – which are related to Encyclopaedic questions suggested by Dahlgren and Öberg (2001); (iii) *Explanations* – questions that are similar to Relational Questions suggested by Dahlgren and Öberg (2001); and (iv) *Imagined Scenarios* – which refer to a supposed scenario and encourage students to formulate hypotheses.

Despite the diversity of studies and aims regarding science classroom questions' analysis; and the diversity of categories found to classify questions, we may consider that there are many similarities between the taxonomies used (Loureiro, 2008; Oliveira, 2008).

In general terms, we may also group different categories of questions into two broader categories, regarding cognitive involvement of the students: high cognitive level questions and low cognitive level questions (Hofstein et al., 2005). Questions that only require basic information, as one word or a definition are questions of low cognitive levels. On the other hand, questions that imply more complex answers and critical thinking are questions of high cognitive level.

Summing up, high cognitive level questions are the most relevant questions for students to develop high order thinking skills. In this way, students must be faced with and must ask high cognitive level questions.

In this study, we analysed and classified the questions included in science written tests and in science textbooks, according to their cognitive level.

For that purpose, we use one checklist, that results from the adaptation of Leite and collaborators (2012), Torres and collaborators (2012), Dahlgren & Öberg (2001) and Chin & Chia (2004) checklists – Table 1.

Table 1

Types of questions – cognitive level.

Types of questions	Characteristics	Examples
Encyclopaedic	Require a direct, concrete and simple answer, like a definition.	*"What do you mean by sustainable development?"*
Meaning-oriented	Do not have a direct answer and imply the search of a concept meaning.	*"How is acid rain formed?"*
Relational	Involve a connection between two or more concepts, like cause and effect.	*"How is biomass energy use related to global warming?"*
Value-oriented	Demand for a comparison and judgment based on some criteria.	*"Distinguish a star from a planet."*
Solution-oriented	Comprehension of the problem and looking for solution(s).	*"What can we do to mitigate the environmental problems of our planet?"*
Imagined Scenarios	Deal with imagined scenarios and promote the formulation of hypotheses.	*"Could the human species become extinct due to the excess of toxic and chemical waste?"*

According to Hofstein (2005), encyclopaedic questions are those of low cognitive level, as they only require basic information and all the remaining ones (meaning-oriented, relational, value-oriented, solution-oriented and imagined scenarios) are of high cognitive level, as they require more complex answers, critical thinking and the connection between contents.

METHODS

This study is part of a broader research aimed at evaluating the implementation of the Portuguese middle-school sciences curriculum (from 7th to 9th grade). A multiple case study was taken in order to deeply evaluate how teachers face and implement the curriculum, students' experiences and how different aspects interfere with curriculum implementation.

This work is integrated in a study case developed during the last school year (2011/2012), in Oporto, north of Portugal. A wide variety of instruments were used to collect the evidences taken from different participants (science teachers, students, school director) and documents (written tests, textbooks, school rules of procedure).

In the present work, we analyse the questions presented in science written tests applied and in science textbooks used during the last school year, according to their cognitive level. This analysis was based on the checklist mentioned above (Table 1).

The analysis focused on all the questions included in the written tests and textbooks but, in the last one, excluded questions given within learning activities. After a deep discussion about the checklist, data collection was done by two of the authors.

RESULTS

The results show that, generally, a high rate of questions that appear both in the textbooks and on written tests are of low cognitive levels - encyclopaedic questions - 48,9% in natural science textbooks (NSTB) and 78,8% in natural science written tests (NSWT).

Table 2

Cognitive level of textbooks' questions.

Textbooks / Types of questions	NSTB7		NSTB8		NSTB9		Total	
	f	**%**	**f**	**%**	**f**	**%**	**f**	**%**
Encyclopaedic	28	75,7	8	36,4	52	43,0	88	48,9
Meaning-oriented	4	10,8	10	45,5	52	43,0	66	36,7
Relational questions	2	5,4	1	4,5	15	12,4	18	10,0
Value-oriented	1	2,7	3	13,6	1	0,8	5	2,8
Solution-oriented	0	0	0	0	1	0,8	1	0,6
Imagined Scenarios	1	2,7	0	0	0	0	1	0,6
Without classification	1	2,7	0	0	0	0	1	0,6

Legend: f=frequency; %= percentage; NSTB7= 7th grade Natural Science Textbook; NSTB8 = 8th grade Natural Science Textbook; NSTB9 = 9th grade Natural Science Textbook.

Although the high number of encyclopaedic questions in 7th grade NSTB, this number decreases in 8th and 9th grades and meaning-oriented questions acquire more relevance (table 2). This increment in the cognitive level of the questions over scholar years seems to be consistent with the increase of students' level, age and development. Additionally, in 9th grade NSTB there is also a slight increase in the number of relational questions.

However, value-oriented and solution-oriented questions, as well as questions of imagined scenarios only appear in NSTB with a very low rate.

Some examples of each type of questions that appear in NSTB are provided in the table below (table 3).

Table 3

Examples of question found in Natural Science Textbooks.

<table>
<tr><td rowspan="2">NSTB7</td><td rowspan="2">Encyclopaedic (75,7%)
Where is the centre of the Universe?
What are fossils?</td><td rowspan="2">Meaning-oriented (10,8%)
How was it possible to obtain the knowledge of the universe?</td><td rowspan="2">Relational (5,4%)
Why is oceanic crust younger than continental crust?</td><td>Value-oriented (2,7%)
Does volcanism only have negative effects?</td></tr>
<tr><td>Imagined Scenarios (2,7%)
What will be the next steps and upcoming discoveries?</td></tr>
<tr><td>NSTB8</td><td>Meaning-oriented (45,5%)
Why do ecosystems are in a state of dynamic equilibrium?</td><td>Encyclopaedic (36,4%)
What are natural resources?</td><td>Value-oriented (13,6%)
Are scientific and technological innovations good or bad to mankind?</td><td>Relational (4,5%)
How do living beings interact with the environment?</td></tr>
<tr><td rowspan="2">NSTB9</td><td colspan="2">Encyclopaedic (43,0%)
What does quality of life means?</td><td rowspan="2">Relational (12,4%)
What are the consequences that result from the manipulation of genetic material?</td><td>Value-oriented (0,8%)
How can we distinguish food from a nutrient?</td></tr>
<tr><td colspan="2">Meaning-oriented (43,0%)
How do ovarian and uterine cycles occur?</td><td>Solution oriented (0,8%)
How can we prompt community health?</td></tr>
<tr><td></td><td>>%</td><td colspan="2">←————————</td><td><%</td></tr>
</table>

Legend: %= percentage; NSTB7= 7th grade Natural Science Textbook; NSTB8 = 8th grade Natural Science Textbook; NSTB9 = 9th grade Natural Science Textbook.

On the other hand, the number of encyclopaedic questions in NSWT is always high, reaching its maximum in the 9th grade, contrarily to what was expected. Although this fact can be related to the type of contents evaluated, students of the last year of middle--school must be faced with more questions of high cognitive level (table 4).

Indeed, the number of value-oriented questions diminishes over the scholar years, reaching its minimum in the 9th grade. Questions of imagined scenarios and relational questions are hardly found and solution-oriented questions are not present in these NSWT.

Table 4

Cognitive level of written tests' questions.

Written tests / Types of questions	NSWT7		NSWT8		NWST9		Total	
	f	**%**	**f**	**%**	**f**	**%**	**f**	**%**
Encyclopaedic	56	76,7	243	76,7	100	86,2	399	78,8
Meaning-oriented	2	2,7	31	9,8	6	5,2	39	7,7
Relational questions	0	0	8	2,5	1	0,9	9	1,8
Value-oriented	14	19,2	29	9,1	8	6,9	51	10,1
Solution-oriented	0	0	0	0	0	0	0	0
Imagined Scenarios	1	1,4	2	0,6	0	0	3	0,6
Without classification	0	0	4	1,3	1	0,9	5	1,0

Legend: f=frequency; %= percentage; NSWT7= 7th grade Natural Science Written tests; NSWT8 = 8th grade Natural Science Written tests; NSWT9 = 9th grade Natural Science Written tests.

Some examples of each type of questions that appear in NSWT are provided in the table below (table 5).

Table 5

Examples of question found in Natural Science Written tests.

NSWT7	**Encyclopaedic (76,7%)** *What is the definition of minerals?*	**Value-oriented (19,2%)** *Distinguish a star from a planet.*	**Meaning-oriented (2,7)** *Explain why satellites are important.*	**Imagined Scenarios (1,4%)** *Formulate a hypothesis to explain why there is no life in the planet Mercury.*
NSWT8	**Encyclopaedic (76,7%)** *What do you mean by sustainable development?*	**Meaning-oriented (9,8)** *Explain why does energetic resources are important.* **Value-oriented (9,1%)** *Distinguish an autotrophic from a heterotrophic organism.*	**Relational (2,5%)** *Establish a relation between leaf size and water availability.*	**Imagined Scenarios (0,6%)** *Imagine that the cactus of this ecosystem had progressively disappeared due to an insect plague. Please anticipate the probable changes that might occur as a result of this situation.*
NSWT9	**Encyclopaedic (86,2%)** *What do you mean by risk behaviour?*	**Value-oriented (6,9%)** *What is the main advantage of using this contraceptive method [condom] in relation to the others?*	**Meaning-oriented (5,2)** *Why is this gene recessive?*	**Relational questions (0,9%)** *Establish a relation between the thickness of both ventricles and their function in the bloodstream.*
	>%	←		<%

Legend: %= percentage; NSWT7= 7th grade Natural Science Written tests; NSWT8 = 8th grade Natural Science Written tests; NSWT9 = 9th grade Natural Science Written tests.

CONCLUSIONS AND IMPLICATIONS

We may conclude that, although the national curriculum emphasizes the development of inquiry and high order competences, the analysed textbooks and tests rely on questions of low cognitive level. Indeed, in NSWT, this number increases as students get older. According with these results, the authors consider that it will be important to improve textbooks, by including material and questions consistent with an inquiry-based approach. To attain this purpose, it would also be important to adjust the way textbooks are selected, are made and are chosen by teachers.

Textbooks improvement may have direct consequences in students learning, as well as consequences in teacher practice, as they are dependant on textbooks as a source of information. On the other hand, we think that teachers should be prepared and supported for inquiry-based teaching, either in their initial or in their continuing training, in order to be consistently engaged with new curricular demands.

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STUDENTS' AND TEACHERS' PERCEPTIONS OF SCHOOL-BASED SCIENTIFIC LITERACY PRIORITIES AND PRACTICE: A CROSS-CULTURAL COMPARISON BETWEEN CYPRUS AND GERMANY

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Abstract: Scientific literacy is an issue of paramount importance in every modern society. However, when it comes to public understanding, it seems that there is no consensus regarding what aspects should be addressed within the regular science education curriculum or how scientific literacy should be promoted. Additionally, despite the fact that teachers and students are the main stakeholders in each educational system, their voices are usually neglected. In this context, the present study employed a Delphi approach, seeking to investigate empirically the extent of any consensus between students and teachers in Germany and Cyprus, comparing their assessments regarding what science education aspects should be prioritized as well as in which extent these aspects are currently practiced. The outcome of this cross-cultural research revealed that except some minor differences, students and teachers in both countries perceive in general large discrepancies between a desired status and the status quo in science education. More specifically, science education, as currently practiced, was defined by elements from the "classic" scientific disciplines giving much emphasis on content as well as on the promotion of conceptual understanding. On the other hand, many of the greater aims of general science-related education that students and teachers gave priority to, such as the relation of science with students' interests and everyday life or the development of inquiry skills, are only rarely taken up in science classes. Following this reasoning, future educational reforms in both countries should do well to invest more efforts in order to bridge this gap between priority and praxis.

Keywords: Curricular Delphi study, scientific literacy, stakeholders, cross-cultural comparison, PROFILES

INTRODUCTION

Scientific literacy has become an issue of paramount importance in every modern society (OECD, 2007). In response to rapid scientific and technological development, several European educational systems, including those of Cyprus and Germany, have made great strides towards achieving scientific literacy for all students. At the same time, it appears that there is no definite consensus among the public regarding what aspects should be addressed within the regular science education curriculum or how scientific literacy should be promoted (Bolte, 2007, 2008). However, without a clear notion of what scientific literacy is to stakeholders, every reform effort only becomes an elusive idea (DeBoer, 2000).

PROFILES (Bolte, Holbrook, & Rauch, 2012; PROFILES, 2010), a European project that aims to promote scientific literacy in Europe and Europe-associated countries, has given much emphasis on examining the views of different stakeholders regarding aspects of science education that are considered desirable for the scientifically-literate individual of today‘s society (Schulte & Bolte, 2012). Stakeholder groups seen as relevant regarding this issue comprise students, science teachers, science education researchers and scientists. Their views were in three stages collected from the different participating countries in the PROFILES project through a Delphi methodology. The application of the Delphi methodology at a European level provides fertile ground not only for comparisons between the different stakeholders' views within each country but also for cross-cultural comparisons between the participating countries, contributing in this way to an insightful look beyond national contexts. This study compares the results between Cyprus and Germany.

THEORETICAL FRAMEWORK

According to Osborne (2003), in most societies, aspects that are both important and salient within a given domain, such as science education, are usually defined by the academic community, which inevitably suggests that the voices of educators, scientists, students or other relevant stakeholders are often suppressed. Considering the fact that teachers and students are the main and final users in each educational system, this study focuses on the presentation as well as on the comparison of students' and teachers' views regarding the promotion of scientific literacy through science education in both Germany and Cyprus. In this context, the present study seeks to investigate the following questions:

1. What similarities/differences exist between the teachers' and students' assessments regarding aspects of what should be prioritized in science education, within and between the two countries?
2. What similarities/differences exist between the teachers' and students' assessments regarding the extent in which the identified aspects are realized in science education practice, within and between the two countries?

RESEARCH METHOD AND DESIGN

A Delphi study represents a collective decision making process aiming to reach a consensus between the different stakeholders involved (Helmer, 1967; Linstone & Turoff, 1975). During the first round of the three-stage International PROFILES Delphi Study on Science Education (Figure 1), participants were asked to answer into an open-ended question regarding aspects of desirable science education. This question was specified as to situations and contexts science educational processes should be embedded, topics and fields that should be emphasized and competences and qualifications that should be enhanced regarding to promote scientific literacy. By the end of this round, all of their statements were grouped under thematic categories (Schulte & Bolte, 2012). During the second round, the stakeholders assessed on a six-tier scale the priority and the realization in practice of 88 (Germany) and 76 (Cyprus) emerged categories regarding desirable science education.

This study compares the statistical outcomes between secondary school students from Cyprus (N=48) and Germany (N=34) as well as between science teachers from Cyprus (N=18) and Germany (N=50). Mean values for each category both for students and teachers were calculated. In a second step, all of the categories were ranked according to their means. For the analysis, the ten highest and ten lowest mean values in the students' and teachers' assessments in Germany are contrasted with the ten highest and ten lowest values in the students' and teachers' assessments in Cyprus respectively, both for science education priorities and practice.

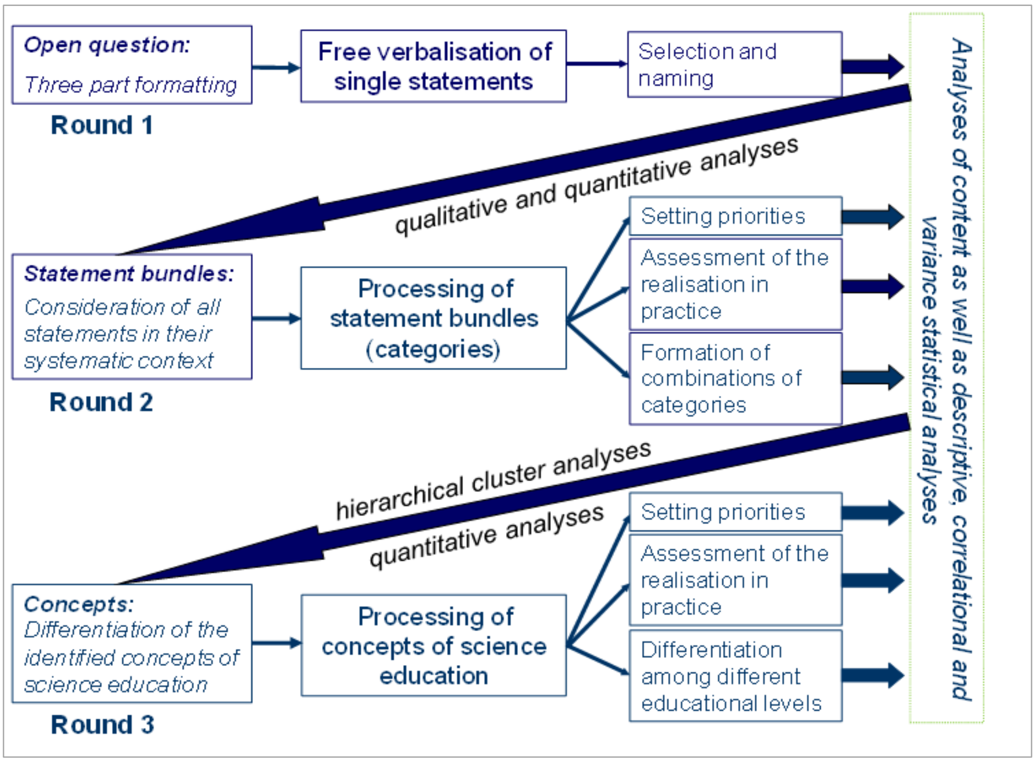

Figure 1. Method of Data Collection and Data Analysis in the PROFILES International Curricular Delphi Study on Science Education (Bolte, 2008)

RESULTS

Assessment of science education priorities

The results show that German students and teachers placed high priority on aspects that are related to the students' interests and thus motivate them. They also highly valued competences like applying knowledge, acting reflectedly and responsibly, and critical assessment as well as issues related to everyday life. Similarly, Cypriot students and teachers gave high priority to the instruction of topics that are more related to students' interests and daily lives (e.g. health/environment related issues) and prioritized contexts that can motivate students and actively involve them in the learning process. Furthermore, in addition to an emphasis on conceptual understanding, teachers attributed high priority to other types of aspects of scientific literacy relating to inquiry or basic scientific skills, while students highlighted personal competences and democratic attitudes. Students and teachers from both countries did not assign high priority on scientific sub-disciplines such as zoology, microbiology, earth science, paleontology etc. Tables 1 and 2 provide more information on the prioritization of science education aspects in each country.

Table 1

Ten Highest and Lowest Mean Values of the Priority Assessments of German and Cypriot Students

GERMANY				CYPRUS			
Category	*n*	*M*	*SD*	Category	*n*	*M*	*SD*
Comprehension / understanding	27	5,1	0,874	Equipped classrooms	48	5,4	1,005
Motivation and interest	27	5,0	1,038	Pers. competences	48	5,3	,949
Environment	29	4,9	1,012	**Health / medicine**	47	5,3	1,276
Working self-dependently / structuredly / precisely	26	4,9	0,993	Environment	48	5,3	1,062
Analysing / drawing conclusions	26	4,9	1,143	Problem-Solving	47	5,2	,770
Students' interests	33	4,9	0,857	**Comprehension / understanding**	48	5,2	1,045
Experimenting	26	4,8	1,120	Democratic attitudes	48	5,2	1,299
Critical assessment	26	4,8	0,732	**Students' interests**	48	5,2	1,078
Health / medicine	29	4,8	1,071	**Experimenting**	48	5,2	,975
Judgement / opinion-forming / reflection	27	4,8	1,001	Use of audiovisual material	48	5,2	1,255
…	…	…	…	…	…	…	…
Thermodynamics	28	3,8	0,967	Integration of assessment practices	47	4,3	1,293
Earth sciences	29	3,7	1,192	Scientific literacy	48	4,3	1,391
Empathy / sensibility	25	3,6	1,075	Socio-scientific issues	47	4,2	1,313
Out-of-school learning	33	3,6	1,342	Use of sc. terminology	47	4,2	1,388
Industrial processes	30	3,6	1,098	**Earth sciences**	47	4,2	1,469
History of the sciences	28	3,5	1,232	Economics	48	4,2	1,468
Botany	30	3,4	1,406	**History of the sc.**	47	4,0	1,489
Zoology	30	3,3	1,241	Demographics	48	3,9	1,574
Emotional pers. development	31	3,3	1,243	Palaentology	48	3,9	1,403
Astronomy / space system	29	3,1	1,423	Architecture	48	3,9	1,557

Note. *n* = Number of Participants, *M* = Mean Value, *SD* = Standard Deviation

Table 2

Ten Highest and Lowest Mean Values of the Priority Assessments of German and Cypriot Teachers

GERMANY				CYPRUS			
Category	*n*	*M*	*SD*	Category	*n*	*M*	*SD*
Applying knowledge / creative and abstract thinking	44	5,4	0,838	Health problems	18	5,9	,236
Acting reflectedly and responsibly	44	5,3	0,668	**Comprehension / understanding**	18	5,9	,323
Nature / natural phenomena	47	5,3	0,877	Basic scientific skills	18	5,8	,383
Comprehension / understanding	44	5,3	0,624	Inquiry Skills	18	5,8	,428
Critical assessment	44	5,3	0,781	**Experimenting**	18	5,7	,461
Everyday life	47	5,2	0,666	Social skills	18	5,7	,461
Judgement / opinion-forming / reflection	44	5,2	0,774	Positive attitudes towards Science	18	5,7	,461
Rational thinking / analysing / drawing conclusions	44	5,2	0,774	Environmental Actions	18	5,7	,485
Perception / awareness / observation	44	5,2	0,823	Mathematics	18	5,7	,767
Experimenting	44	5,1	0,784	Human physiology	18	5,6	,608
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
Zoology	43	3,9	1,005	Meteorology	18	4,2	,878
Microbiology	42	3,9	1,299	**History of the sciences**	18	4,2	,985
Technical devices	45	3,8	1,043	**Astronomy / space system**	18	4,1	,583
Botany	43	3,8	0,965	Integration of assessment practices	18	4,0	1,085
Emotional pers. development	50	3,8	1,222	Non PC games	18	3,9	1,305
Earth sciences	42	3,7	0,939	Architecture	18	3,8	1,215
Analytical Chemistry	45	3,6	0,806	Lectures	18	3,7	1,320
Industrial processes	45	3,5	1,121	**Earth sciences**	18	3,7	,840
History of the sciences	44	3,5	1,110	Palaentology	18	3,4	1,243
Astronomy / space system	41	3,1	1,352	Digital games	18	3,4	1,335

Note. *n* = Number of Participants, *M* = Mean Value, *SD* = Standard Deviation

Table 3

Ten Highest and Lowest Mean Values of the Practice Assessments of German and Cypriot Students

GERMANY				CYPRUS			
Category	*n*	*M*	*SD*	Category	*n*	*M*	*SD*
Terminology	28	4,8	0,917	Mathematics	48	4,2	1,779
Curriculum framework	31	4,7	0,815	Physics	48	4,0	1,762
Science – chemistry	31	4,5	0,850	Environmental Actions	48	4,0	1,368
Genetics / molecular biology	28	4,4	0,959	Physics modules	48	3,8	1,389
Chemical reactions	30	4,4	0,968	Use of textbooks	47	3,8	1,537
Models	28	4,4	1,311	**Ch. reactions**	48	3,8	1,633
Structure / function / properties	30	4,3	0,952	Human physiology	48	3,8	1,468
Content knowledge	26	4,2	0,951	Health problems	47	3,8	1,614
Matter / particle concept	29	4,2	1,114	**Science – biol.**	48	3,8	1,477
Science – biology	31	4,2	0,980	Environmental Phenomena	47	3,7	1,390
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
History of the sciences	27	2,9	1,207	Current Issues	48	2,5	1,571
Empathy / sensibility	25	2,9	1,236	Earth sciences	47	2,5	1,472
Consequences of technol. Developments	27	2,9	1,199	Palaentology	48	2,4	1,569
Neurobiology	28	2,8	1,156	Interaction with experts	48	2,4	1,485
Knowledge about science-related occupations	25	2,7	1,308	**Out-of-school learning**	48	2,4	1,300
Ethics / values	26	2,6	1,169	Nuclear Physics	47	2,4	1,512
Current scientific research	26	2,6	1,137	Non PC games	48	2,4	1,424
Out-of-school learning	32	2,5	1,107	Digital games	48	2,3	1,277
Emotional pers. development	32	2,4	1,014	Meteorology	47	2,2	1,366
Astronomy / space system	27	2,2	1,178	**Astr. / space**	47	2,2	1,414

Note. *n* = Number of Participants, *M* = Mean Value, *SD* = Standard Deviation

Table 4

Ten Highest and Lowest Mean Values of the Practice Assessments of German and Cypriot Teachers

GERMANY				CYPRUS			
Category	*n*	*M*	*SD*	Category	*n*	*M*	*SD*
Curriculum framework	48	4,8	1,225	Physics modules	18	4,6	1,037
Content knowledge	43	4,5	1,241	Mathematics	18	4,6	1,037
Chemical reactions	46	4,4	1,236	Physics	18	4,6	,984
Structure / function / properties	46	4,4	1,181	Human physiology	18	4,5	,857
General and inorganic chemistry	45	4,3	1,148	Natural phenomena	18	4,3	1,179
Organic chemistry	43	4,3	1,049	**Matter / particle concept**	18	4,2	,808
Ecology	43	4,2	1,067	Chemical phenomena	18	4,2	,943
Matter / particle concept	46	4,1	1,272	Study of the cell	18	4,2	,857
Science – biology	46	4,1	1,272	Terminology	18	4,1	1,183
Nature / natural phenomena	47	4,0	1,043	Physics theories	18	4,1	1,183
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
Limits of scientific knowledge	45	2,6	0,883	History of sc. theories	18	1,9	1,056
Occupation / career	47	2,6	1,074	Architecture	18	1,9	,938
Consequences of technol. Developments	44	2,6	1,061	Interaction with experts	18	1,9	,900
Ethics / values	44	2,4	1,108	Nuclear Physics	18	1,8	,786
Out-of-school learning	49	2,4	0,913	Geology	18	1,7	,895
Current scientific research	44	2,4	1,064	**Out-of-school learning**	18	1,7	,907
Occupations	45	2,4	0,963	Digital games	18	1,6	,984
Astronomy / space system	41	2,3	1,078	Non-pc games	18	1,5	,707
Knowledge about science-related occupations	44	2,3	0,943	Meteorology	18	1,4	,608
Emotional pers. development	49	2,2	0,808	Palaentology	18	1,3	,461

Note. *n* = Number of Participants, *M* = Mean Value, *SD* = Standard Deviation

Assessment of science education practices

In both countries, the highest mean values in the students' and teachers' assessments were assigned to scientific disciplines such as biology, physics or mathematics and to the teaching of traditional topics (e.g. chemical reactions, matter/particles concepts). Furthermore, the assessments from both countries place emphasis on the traditional teaching practices currently employed. For instance, teachers and students in Germany highlighted that there is great focus on the promotion of content knowledge while students in Cyprus gave emphasis on the employment of traditional approaches such as using textbooks or terminology. The results also indicated that aspects rated as important in the science education priority assessments were perceived as less present in science education practices in both countries. Tables 3 and 4 provide more information on these results.

DISCUSSION

Our cross-cultural comparison rendered a significant contribution to clarifying the socially desirable goals of science education for the promotion of scientific literacy in Cyprus and Germany, setting up the base for a successful curriculum reform. Despite some minor differences that might have mainly resulted from the cultural differences, both students and teachers in Cyprus and Germany considered the same, overall, categories as especially important or practiced. More specifically, students and teachers in both countries gave high priority to:

(a) the instruction of scientific issues related to students' interests and lives,

(b) the employment of scientific inquiry and

(c) the development of scientific skills and attitudes.

On the other hand, the comparison of the science education practice assessments indicated that in both countries, aspects relating to

a) traditional scientific disciplines,

b) content knowledge and

c) traditional teaching approaches

were considered as prevailing in local science educational practices. It can be concluded from these considerations that students and teachers, in both countries, perceive large discrepancies between an ideal state and the current status quo in science education. Future educational reforms in both countries should do well to invest more efforts in order to bridge this gap between priority and praxis.

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THE EU PROJECT SECURE (SCIENCE EDUCATION CURRICULUM RESEARCH) IN GERMANY (SAXONY)

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Abstract: The aim of the research project SECURE is to make a significant contribution to the European society to improve MST (Mathematics, Science, and Technology) curricula and their implementation throughout the EU in order to prepare children from an early age on future careers in MST. The research focuses on learners of 5, 8, 11, and 13 years old and their MST teachers and covers three different aspects of curricula: the intended curriculum (represented by the formal written curricular documents), the implemented curriculum (as perceived by the teachers) and the attained curriculum (learning experiences of the students as well as experiences in teaching of the teachers). Questionnaires and interview guidelines for learners and their teachers are used to study the implemented and the experiential curricula in a quasi-longitudinal study. Some results from Germany (Saxony) as one out of ten partner countries of the research group are described. The focus is lying on two aspects: 1. learning activities and 2. out-of-school learning experiences. The outcomes of these two aspects are analyzed in depth taking into consideration the different school types in (early age) education (kindergarten: children of the age of 5, primary school: learners aged 8, and secondary school: learners of the age of 11 and older students aged 13). Possible difficulties and discontinuity in the educational process of learners that might occur crossing the gap between primary and secondary school are discussed.

Keywords: curriculum, evaluation, gender issues

INTRODUCTION

The SECURE project is funded by the European Union under the 7th Framework Program. The aim of the research project is "*to make a significant contribution to the European knowledge-based society by providing relevant research data that can help policy makers to improve Mathematic Science Technology (MST) curricula and their implementation throughout the EU in order to prepare children from an early age on for future careers in MST…*" (SECURE, 2010). The research focuses on the MST curricula offered to learners of 5, 8, 11 and 13 years old in 10 European countries, which are Austria, Cyprus, Belgium (Flanders), Germany (Saxony), Italy, Poland, Sweden, Slovenia, The Netherlands and The United Kingdom. The four different age groups were chosen to ensure that the whole spectrum of different education levels is covered, starting with the early age learning in the kindergarten as preparation for primary school, primary education and the transition to the secondary school, which are handled very differently depending on the country. Several abstracts as well as articles show these differences in the educational process in the ten different European states (De Meyere, Sokolowska, Folmer, Rovšek, & Peeters, 2013 article submitted; De Meyere, Sokolowska, Folmer, Rovšek, & Peeters, 2013 article submitted; Michelini et al., 2013; Michelini, Santi, & Vercellati, 2013 article submitted; Peeters, & De Meyere, 2012; Rovšek & Bajc, 2012; Sokolowska, Ireson, & Brzezinka, 2013 article submitted; Sokolowska et al., 2012 article submitted). The overall aim of the SECURE project is to provide "*relevant research data about the MST curricula and their delivery and translating them in recommendations for stakeholders*" (De Meyere, Rovšek, & Peeters, 2013).

RESEARCH FRAMEWORK

The research instruments were provided by the project partners from SLO, The Netherlands. The instruments included guidelines for the curriculum screening of the existing STEM-curricula in each country, questionnaires for teachers as well as learners, and interview guidelines in a semi-structured way for teachers and learners. These different research instruments were based on the so called curricular spider`s web (Thijs & van den Akker, 2009). This spider web (see figure 1) offers a way to visualize the relationship between different curricular aspects. The core (*rationale*) and each of the nine threads represent the main subjects and the components of the curricula as such.

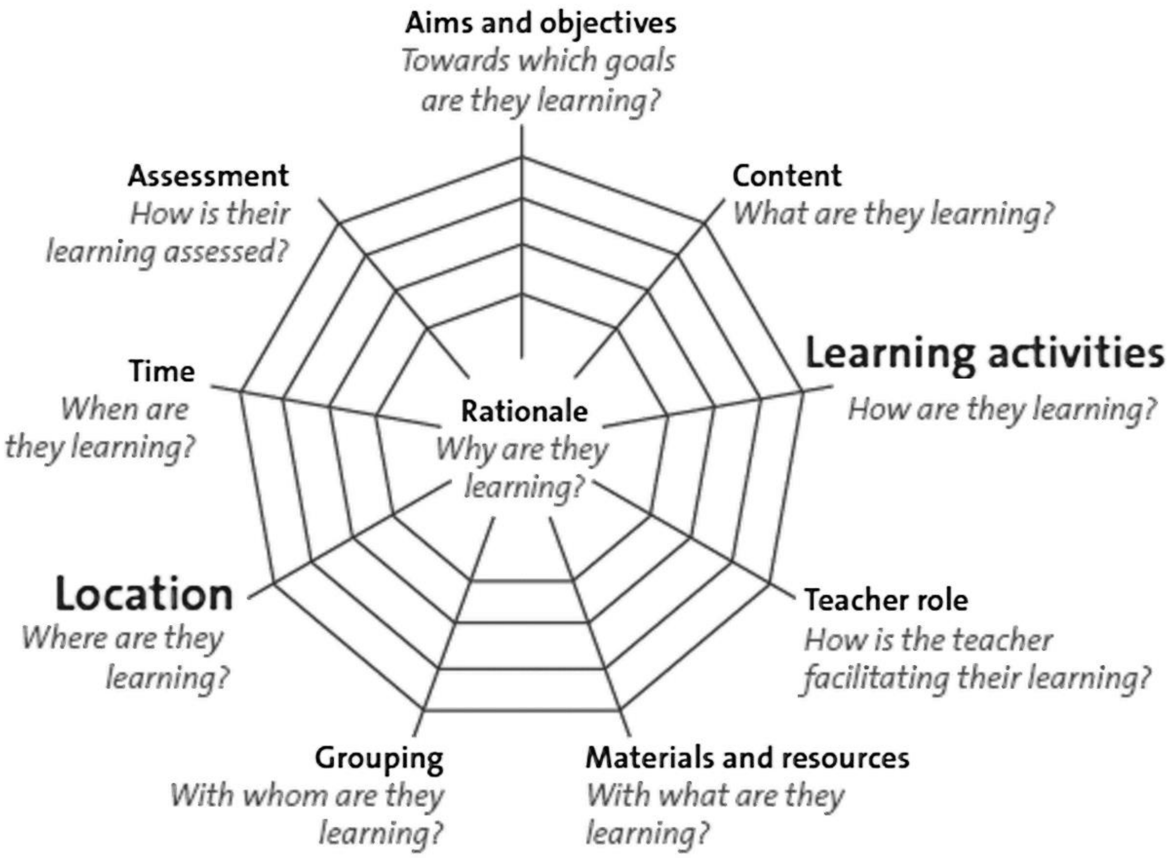

Figure 1. Curricular spider`s web ("*they*" refers always to the learners).

Authentic activities, for example the use of everyday objects, are seen to be important to activate students for learning. Also cooperative learning is relevant to reach this activation of learners during their lessons. Therefore in this article we will only focus on the results of two curricular aspects: *learning activities* with the key question "*How are they learning?*" and the component *location* with the key question "*Where are they learning?*". Learning activities include aspects of cooperative learning such as *learning in groups* or *alone*. The analysis of *location* includes *out-of-school experiences* (compare Wilhelm, Messmer, Niederhäusern, Rempfler, 2011).

METHODS

Questionnaires for teachers and learners were used taking into account the different school subjects, resulting in two different questionnaires for teachers of mathematics and science/technology. Both MST teachers and learners answered questions from their point of view among other aspects about *learning activities* and *location*. With this as a basis the possibility of contrasting and comparing the results from teachers and learners questionnaires could be realized. To analyze these two curricular aspects all in all 254 learners and 26 teachers filled out the questionnaires in primary school (the majority of the students were aged 8 years old). In secondary school 277 learners of 11 years old and 36 of their MST teachers filled out the questionnaires and in the age group of 13 years old learners 235 students were asked as well as 37 MST teachers. The qualitative analysis of interviews was done according to the methodology of Mayring (Mayring, 2002). The quantitative data of the questionnaires were just analyzed in a descriptive way as shown in the chapter results.

RESULTS

1. Learning Activities

We concentrate on the above described school types with learners of age 8, 11, and 13. The analysis of questionnaires contained the application of learning modes in the different MST subjects including the frequency of their application during the lessons. Pupils were asked about their own activities during class and their own personal perception of the lesson. Those questions were aimed to analyze the intensity and frequency of the students` activities and were contrasted with the teacher's perception of their lesson.

The two different ways of perceptions were compared. Figure 2 shows the frequencies of *group work* as perceived by teachers in different school types, a distinction was made between mathematics teachers and science & technics teachers according to the used questionnaires. Figure 3 show the same facts from student's perspective.

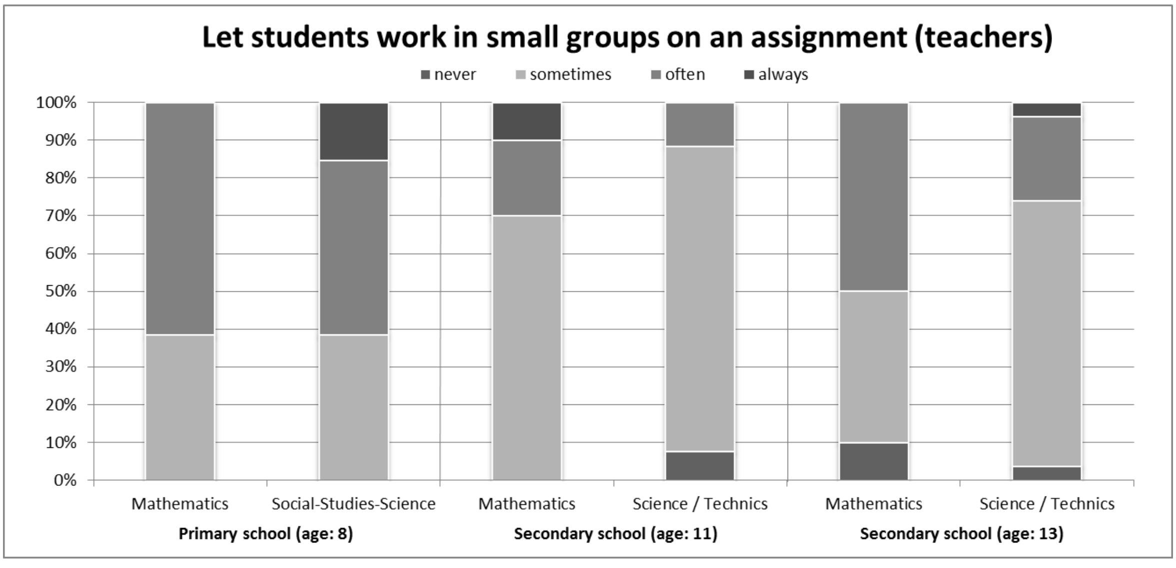

Figure 2. Frequencies of *group work* perceived by teachers, results for the item "*How often do you let students work in small groups on an assignment?*"

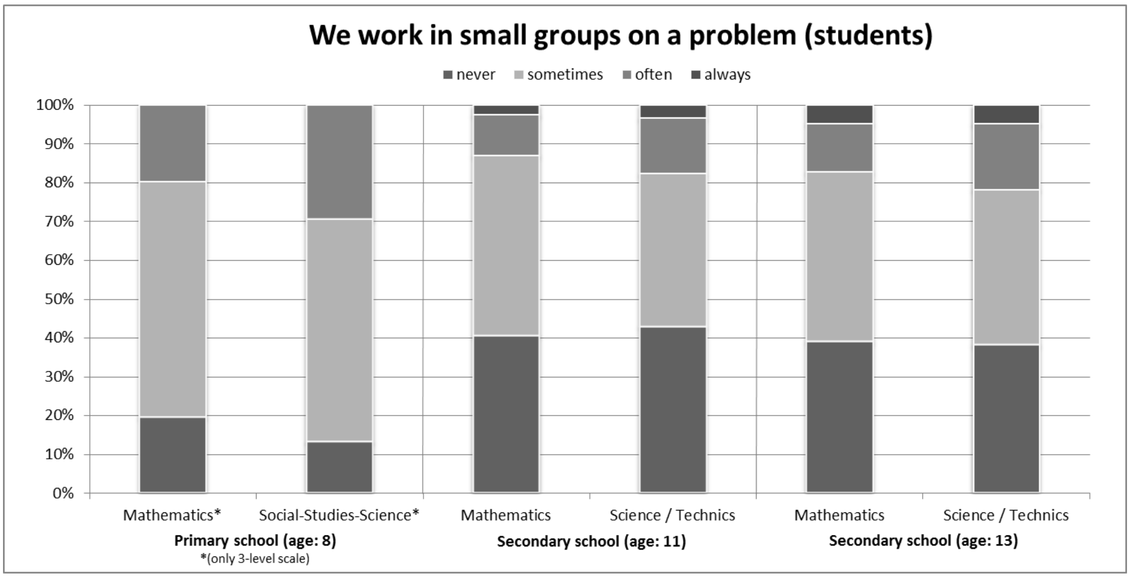

Figure 3. Frequencies of group work perceived by learners, results for the item *"We work in small groups on a problem."*

Comparing teachers' and learners' perceptions the differences increase with increasing age group. In primary school the perceptions of teachers and their learners are more similar to each other than in secondary school. During social-studies-science in primary school teachers claimed to use the activity *working in groups* more often. Comparing the teacher's perception of using *small group work* during mathematics (see figure 2) the frequency decreases in passing from age group 8 to 11, then it slightly increases in higher grades (comparing age group 11 and 13). Remarkably is the massive difference in perception between teachers and pupils about the degree of frequency. Seidel already described the six aspects of lesson perception (Seidel, 2003). One possible explanation for this difference might be the different understanding of the meaning of the phrase *"working in small groups"*, since pupils often choose the option *"never"* in the vast majority of the cases.

Figure 4 and 5 indicate that the working mode of *"solving problems individually"* is quite often preferred by primary teachers and it is also an essential element of lessons in higher grades (in secondary school).

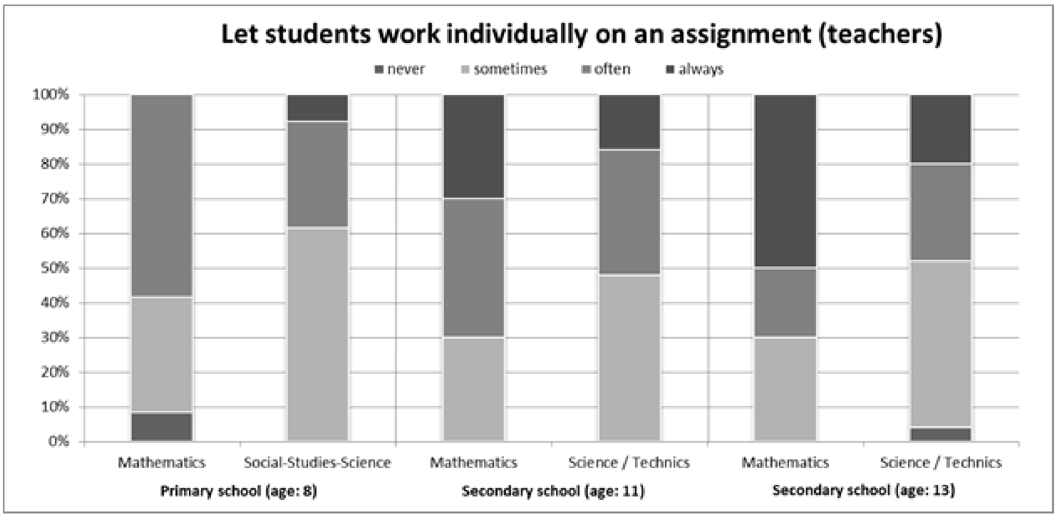

Figure 4. Frequencies of individual work perceived by teachers, results for the item "*How often do you let students work in individually on an assignment?*"

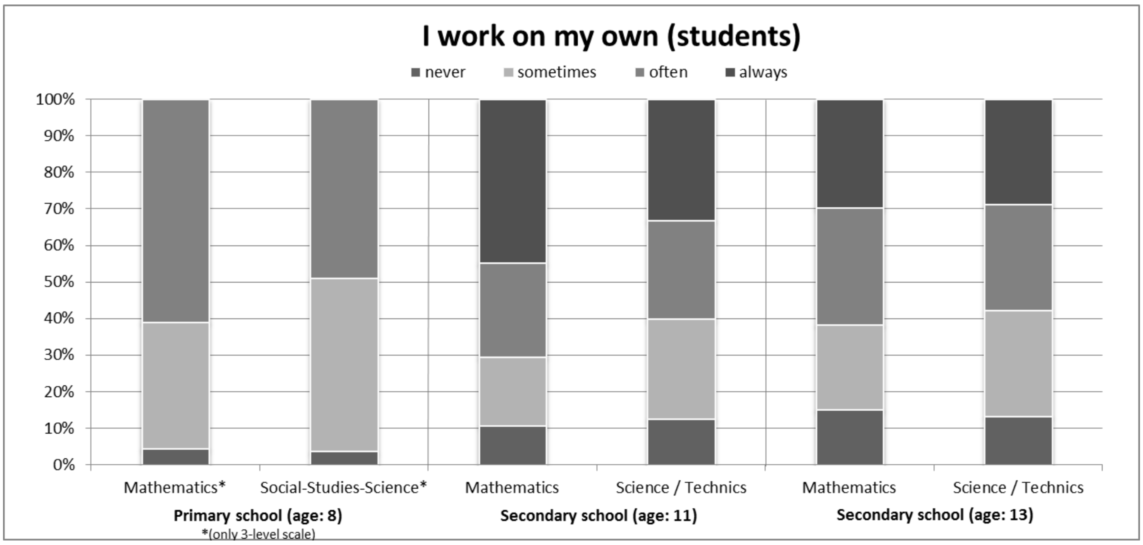

Figure 5. Frequencies of individual work perceived by learners, results for the item "*I work on my own.*"

Quite astonishing are also the great differences in the frequencies of individual work perceived by learners in primary and secondary school (see figure 5). There might be a sort of gap between primary and secondary education considering the different teaching and learning activities in social-studies-science and MST subjects (biology, physics, and chemistry). The percentage of individual work increases from left (age group 8: primary school) to right (age group 11 & 13: secondary school).

2. Location: Out-of-school learning experience (e.g. excursions)

Learners as well as teachers were asked about out-of-school learning experience, especially about doing excursions. The students answered the question *"Where do your lessons take place?"*. The exact two items in the questionnaire for learners (8, 11, 13 years old) were first: *"I go outside the school building to work on a mathematics (or science) exercise or project."* and second: *"We go on an excursion."* The corresponding items in the questionnaire for the teachers were the two following items: *"I feel it is important to plan mathematics (or science) activities outside the classroom."* and *"How often do you do the following activities* (in this case: *excursions) in teaching?"*. The evaluation of the results was done in comparing the frequencies in a relative way (for learners percentages were given) and in absolute values for the number of teachers.

The focus of this special aspect about outside-school learning is lying on the differences between the various school types.

Kindergarten

Starting with the kindergarten as first step of elementary education, it should be underlined that the organization of daily work is totally different from that employed in primary and secondary schools (for further information see Sächsisches Staatsministerium für Soziales, Ed., 2007). The education in kindergarten is characterized as *holistic process*. Each of the six learning fields including mathematical and science education described in the Educational Plan are interconnected to each other and cannot be seen isolated from the others like e.g. arts education. Because of this difference, the following information was only related to the interviews with 12 educators in kindergarten. The answers showed that out-door-activities and excursions normally take place regularly.

Primary School

In primary school 254 learners aged 8 years old answered the question about out-of-school experiences in the two subjects mathematics and social-studies-science.

Mathematics: 71% of them believed that they never go outside the school building and 53% expressed that excursions never take place in their mathematics lessons. Among the mathematics teachers there were 9 out of 13 who considered out-of-school learning places as very important, but only 6 out of 12 teachers answered, that they really do any excursions.

Social-studies-science: Social-studies-science is the second MST subject in primary education students were asked for. Most of the learners (84%) think that at least sometimes they go outside the school building to work on science problems during their lessons. Also most of them (86%) said that at least sometimes excursions take place. The answers of the 13 teachers were reflecting the learners' statements. All of the educational staff believes that out-of-school learning places are more or less important for the subject social-studies-science. Therefore it is not surprising that all of the teachers answered that they do excursions at least during some lessons. One can summarize that learners' and teachers' statements fit relatively well together. Out-of-school learning places play a large role in primary education, especially in social-studies-science.

Secondary School

In Saxony after 4 years of primary school learners change to secondary school, this transition is considered as a sensitive process in student's learning pathway (Maaz et al. 2010; Filipp, 1995). Therefore the focus of this research lies more on the differences between age group 8 (primary school) and age group 11/13 (secondary school) than between learners of age 11 and age 13. In secondary school 277 learners aged 11 years old and 235 students aged 13 years old filled out the questionnaire for learners. 36 MST teachers in the age group 11 and 37 MST teachers in the age group 13 participated in the research. The following table 1 shows the number of learners who reported that they don’t do any excursions.

Table 1

Percentage of learners who report of no excursions.

Age Group	Mathematics	Biology	Physics	Chemistry
11	81%	42%	80%	not yet taught
13	88%	56%	72%	89%

Most of the learners (72-89%) think that during their lessons in mathematics as well as in physics and chemistry no excursions take place. For biology only about half or even less learners agreed with this statement. Maybe the explanation is that biology is a subject treating more or less the living nature/environment. Therefore it might be comprehensible that more excursions are integrated as important activity in the learning process in biology lessons. During physics and chemistry lessons, activities treating more or less the non-living nature might also be arranged in an easy way inside the classroom.

The teachers were asked what they think about out-of-school learning places and what they do during their lessons (e.g. going on an excursion).

Mathematics: 13 out of 20 teachers for mathematics considered that out-of-school learning places are important for a good mathematical education but only 7 teachers answered that they go on an excursion at least during some lessons.

Science: The vast majority of the science teachers (42 out of 53) agree with the statement that out-of-school learning places are important for a good science education in school. But only 33 of the surveyed teachers answered that they do excursions at least during some lessons. Comparing the answers of the two different age groups in secondary school, it might be remarkable that the number of science teachers supporting of the importance of out-of-school learning is nearly the same in both grades. But when teachers were asked if they really do excursions, the amount of teachers teaching students of age group 13 is much higher (see table 2) than the number of teachers of learners aged 11. Therefore one can summarize that the outcome might show that teachers in lower grades of secondary schools do less excursions. Maybe the teachers of lower grades feel more time pressure or they are less inclined to go outside school with their class than teachers in higher grades. This effect is only observed in the results for science teachers but not for the mathematics teachers, maybe because of the lower number of participants.

Table 2

Comparison of absolute numbers of teachers of age group 11 and 13.

Age Group	Overall number of science teachers	Teachers with a positive view on the importance of out-of school learning places	Teachers doing excursions at least sometimes
11	26	19	12
13	27	23	21

DISCUSSION AND CONCLUSION

This research is a quasi-longitudinal study and allows to compare the experiences made by teachers and learners during MST lessons in the different school types in Germany (Saxony). But while drawing comparisons one has to keep in mind that the subject social-studies-science includes also aspects of society, local history and geography. Therefore it might be tricky to compare social-studies-science taught in primary school to the natural science subjects like biology, physics, and chemistry in secondary school. But regardless of the special subject taught there might still be a small gap between primary and secondary school (Heine, Willeke, Best, & Pospiech, 2013, Möller, K., & Labudde, P., 2012). In primary school the regular use of many different learning forms (like group work, individual learning, out-of-school learning places, station work etc.) is very common, whereas in secondary school the variety of learning activities changes and also decreases. In primary education, out-of-school learning is considered to be more important, maybe due to the more phenomenological approach to natural science. Therefore the problem that has still to be solved is to reduce this gap between primary and secondary education. For a continuous educational progress especially in MST subjects, which are important for students' future career in a more technical environment, the communication between the responsible persons for primary and secondary educations has to be stimulated. Also teacher education at university and teacher trainings are an important milestone to address this issue.

ACKNOWLEDGEMENTS

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INTENDED, IMPLEMENTED AND ATTAINED MST CURRICULA ACROSS EUROPE: WHAT CAN RESEARCH TELL US?

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Abstract: A rigorous research program conducted by the SECURE consortium scrutinizes and compares current mathematics, science and technology (MST) curricula for pupils aged 5,8,11 and 13 in ten EU member states, as they are intended by the authorities (in legal documents), implemented by the teachers and perceived by the learners. The research at all three levels is designed in accordance to the curricular spider web (van den Akker, 2003) with addition of the item "attitude". The instruments used consist of a transnational comparative screening instrument for MST curricula, as well as school data collection instruments: teachers' and learners' questionnaires and interview protocols. Research in altogether almost 600 classes (i.e. 150 classes of each age) has been done with involvement of ca. 9000 learners and 1500 teachers. Cross-country summary of national curricula documents and the analysis of the collected school data reveal a wide common ground in all ten partner countries. In this contribution a part of the research concerning the average European results on learners' attitude towards MST school subjects, teachers' attitude towards teaching and the presence of the goals belonging to the affective domain in MST written curricula, is presented.

Keywords: mathematics, science and technology, curriculum, primary education, lower secondary education

BACKGROUND AND FRAMEWORK

SECURE is founded as a collaborative project under FP7 to provide data and research results of current mathematics, science and technology (MST) curricula across Europe. The overall aim of the SECURE project is to make a significant contribution to the European knowledge-based society by providing relevant research data that prompt public debates on this issues. Based on good practices and other research results, SECURE will formulate a set of recommendations for policy makers and other stakeholders on how MST curricula and their delivery can be enhanced. These improvements would need to focus on encouraging and preparing children from an early age on for future careers in MST. At the same time curricula should make MST more accessible and enjoyable for all children so that they will always keep a vivid interest in mathematics, science and technology, understanding the importance of their societal role.

Rationale and Purpose

The role of the affective domain in learning was recognized many years ago and for at least 40-50 years it has been studied intensively by researchers, among others, in mathematics and science education (e.g. Middleton & Photini, 1999; Osborne et al., 2003; Logan & Skamp, 2008). Recently this domain has also appeared in the field of view of the policy-makers, becoming together with knowledge and skills, one of the three main components of, so called, key competences for lifelong learning, issued by European Council less than a decade ago (European Council, 2006; Key Competences, 2007):

> Competences are defined here as a combination of knowledge, skills and attitudes appropriate to the context.

Cognitive and affective components of learning have been lately researched (together or separately) in a large number of studies, including world - wide studies, such as PISA, 2012 (of 15 year olds), TIMSS, 2011 (of 10 and 14 year olds) and ROSE, 2009, (Sjøberg & Schreiner, 2010 ; of 15 year olds). Nevertheless, apart from research on educational practices, the joint studies on mathematics, science and technology education barely ever come onto the stage. As to our knowledge, also addressing several different stages of schooling in one study is not a common practice. The SECURE project was established to fill this gap by providing research outcomes on state-of-the-art MST curricula, their implementation and their perception by teachers and learners of four purposeful chosen and well-distinguished ages of early schooling.

Theoretical Framework

Different meanings of "curriculum" can be found in different contexts of educational research (Taba, 1962; Jackson, 1992; Pinar, Reynolds, Slattery & Taubam, 1995; Walker, 2003). To get a complete overview of the curriculum, its analysis should be done at five different levels with respect to the curriculum users (van den Akker, 2003): Supra (international), Macro (national), Meso (school, institute), Micro (classroom, teacher), Nano (pupil, individual).   In 2003, van den Akker proposed curriculum representation on a spider web (Figure 1), with Rationale located in the center and nine other components (Aim and Objectives, Content, Learning activities, Teacher role, Materials and Resources, Grouping, Location, Time, Assessment) placed around it, becoming the nine threads of the spider web, connected at five curriculum levels. It is worth to notice that the spider web does not address the affective domain, which becomes especially important starting from the Meso level downwards.

As it is already known from other studies, attitude and interest in MST may consist of a large number of components (Osborne et al., 2003; Kobella 1989) and can be researched from different angles (e.g. "attitude towards MST in general", "attitude towards school MST" etc.). They may also overlap with each other or even with other constructs, such as 'motivation', 'self-esteem' and so on (Logan & Scamp, 2008). For the purpose of this study 'attitude' is limited to 'attitude towards school MST subjects" (Osborne et al., 2003).

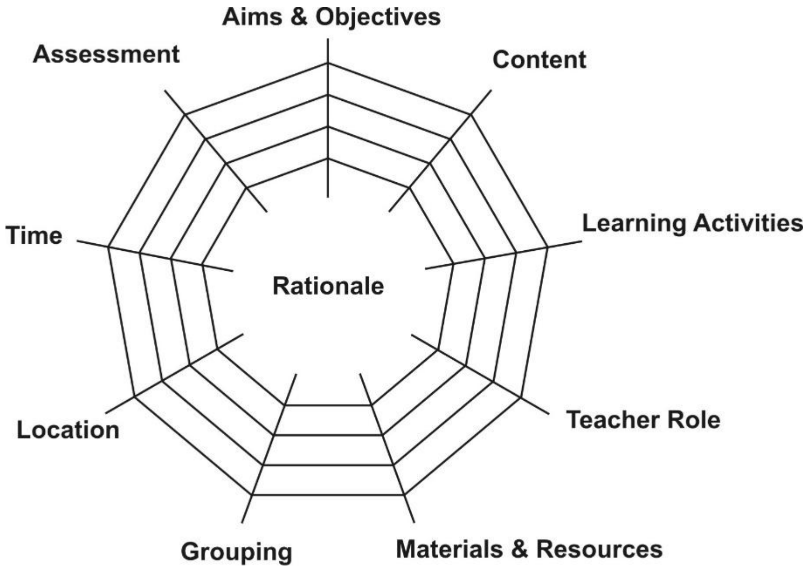

Figure 1. Curriculum spider web, based on the original work of van den Akker (2003).

RESEARCH QUESTIONS

The research instruments developed in SECURE project enabled us, among others, to study the attitude and motivation towards school MST subjects from learners' perspective, as well as teachers' perception on their attitude towards teaching MST subjects and on motivating the learners, and to search for information on goals belonging to the affective domain, detected in core curricula documents.

Learners' opinions about the sources of motivation towards MST school subjects and teachers' opinions about importance and difficulty of motivating the learners towards MST subjects have been already addressed elsewhere (Sokolowska et al., 2014). Thus in this part of the study the research questions are the following:

RQ1. Are there any indications of addressing the affective domain (in particular, attitudes towards MST) in core curricula?

RQ2. What is the teachers' attitude towards teaching MST subjects?

RQ3. What is the learners' attitude towards MST subjects across Europe?

RQ4. Does the learners' attitude change across ages or differ across genders?

METHOD

A total of 11 partners in 10 EU countries were involved in the project: Austria, Belgium (limited to Flanders), Cyprus, Germany (limited to Saxony), Italy, the Netherlands, Poland, Slovenia, Sweden and the United Kingdom (limited to England). The SECURE research was focused on 5, 8, 11 and 13 year old learners, their science curriculum and their teachers. The choice of these ages was done to investigate in a comparable way among the involved countries the bridges and the gaps that exist in curricula, on one hand - between kindergarten and primary school and, on the other hand - between primary and middle schools.

To ensure a profound view on the MST-curricula at the different levels, the research focused on:

(1) The formal intended MST-curriculum by comparing written MST curricula in the 10 participating EU countries. It was decided to focus on mathematics, technology and (natural) sciences (restricted to biology, chemistry, physics and whenever appropriate, also to physical geography).
(2) The implemented MST-curriculum which takes into account the perceptions of teachers who put the curricula into practice in the day-to-day class activities.
(3) The attained experiential curriculum which focuses on the learning experiences of the pupils, the final and most important recipients of the MST-curricula.

Data collection in schools took place in two phases: a pilot study, conducted only in four member countries (Germany, Italy, the Netherlands and the United Kingdom) and, then, the systematic, core studies. The pilot study involved a small number of classes and was performed to test and evaluate the first version of the school data collection instruments. After piloting, the instruments were redesigned and in all ten member countries the systematic collection of data in schools has been performed in 15 classes of each age group of learners. On the whole almost 600 classes, 1500 teachers of mathematics, science and technology, and 9000 learners have been involved in the study.

The research framework was constructed upon the curriculum spider web (van den Akker, 2003) with an additional “attitude” component. This item is indispensable for researching perceptions of teachers and learners, and can be considered as both, the result of previous learning process and a prerequisite of education in the future (Sokolowska et al., 2014). As such, it lies at the heart of the research of needs in education.

The research instruments consist of a curriculum screening instrument (CSI), and of the school data collection instruments: teacher questionnaires, learner questionnaires (limited to 8,11 and 13 year olds) and interview protocols for all age groups of pupils and their teachers. The outcomes obtained from interviews will not be included in this study.

RESULTS AND DATA ANALYSIS

Study of core curricula documents revealed a great diversity of schooling systems and approaches to legal documents, which also counts for addressing the affective domain of learning. In particular when screening the curricula documents, the question has been asked, separately for each subject: ‘*Are there any goals belonging to the affective domain (awareness, appreciation, willingness, satisfaction, attention, motivation, attitude etc.) mentioned for MST education?*’ The outcomes in terms of degree of emphasis put on the affective domain in eight European countries are shown below for mathematics (Table 1), science (Table 2) and technology (Table 3). It is worth to notice that no distinction between different aspects of the affective domain, listed above, is provided in the tables.

Table 1

Results of screening core curricula documents searching for answer to the question: 'Are there any goals belonging to the affective domain (awareness, appreciation, willingness, satisfaction, attention, motivation, attitude etc.) mentioned for mathematics education for 5, 8, 11 and 13yo learners?'

Country	*5yo*	*8yo*	*11yo*	*13yo*
Austria	all mentioned	yes	yes	yes
Belgium	over a dozen	over a dozen	over a dozen	over a dozen
Cyprus	some	some	some	some
Germany	mentioned	a few	no	no
Italy	no	no	no	no
Poland	no	no	no	no
Sweden	no	one	one	one
Slovenia	some	some	some	some

Examples of expressions found in mathematics part of the core curricula in connection to attitude, motivation and interest:

> **Belgium (5,8 and 11yo)**: Pupils should learn how to enjoy the search for solutions of a problem.
> **Belgium (5,8 and 11yo)**: Pupils should appreciate mathematics as a dimension of human inventiveness.
> **Slovenia (8,11 and 13yo)**: Pupils develop confidence into their own mathematical competencies, responsibility and positive attitude towards work and mathematics

For mathematics it is visible that in one-third of the cases the affective domain does not influence mathematics curricula, with Italy and Poland being the only two countries not addressing this aspect at all. In 38% of the cases the affective domain is mentioned occasionally, and only in 28% more attention is put on that aspect, mostly in Austria and Belgium. It is worth to notice that the emphasis put on the inclusion of affective domain aspects into mathematics curriculum does not differ much with age in most countries.

Examples of expressions found in science part of the core curricula in connection to attitude, motivation and interest:

> **Sweden(5yo)**: … the children are stimulated and challenged in their interest for science and technology
> **Belgium(8 and 11yo):** "(learners should) have fun with activities allowing them to explore the world"
> **Slovenia (8yo)**: …wider general goals of education are implemented, such as… emotional goals (positive self-esteem, attitude towards nature)
> **Belgium (13yo)**: (education must develop) general and specific attitudes and the growth towards active learning should be central in the learning process

In science curricula the lack of goals belonging to the affective domain is reported again in one-third of the cases, however stronger emphasis is visible in the others. As concern each particular country, the picture is more mixed across ages than in the case of mathematics, but in general, the older the learners are, the less attention is paid to goals belonging to the affective domain. The most emphasis is put there in Slovenia, Cyprus and, again, in Austria.

Table 2

Results of screening core curricula documents searching for answer to the question: 'Are there any goals belonging to the affective domain (awareness, appreciation, willingness, satisfaction, attention, motivation, attitude etc.) mentioned for science education for 5, 8, 11 and 13yo learners?'

Country	*5yo*	*8yo*	*11yo*	*13yo*
Austria	all mentioned	yes	yes	yes
Belgium	a few	a few	a few	some
Cyprus	many	many	many	some
Germany	some	one	a few	a few
Italy	no	no	no	no
Poland	no	one	a few	no
Sweden	yes	no	no	no
Slovenia	some	many	many	many

Table 3

Results of screening core curricula documents searching for answer to the question: 'Are there any goals belonging to the affective domain (awareness, appreciation, willingness, satisfaction, attention, motivation, attitude etc.) mentioned for technology education for 5, 8, 11 and 13yo learners?'

Country	*5yo*	*8yo*	*11yo*	*13yo*
Austria	some	yes	yes	yes
Belgium	no	no	no	yes
Cyprus	no	a few	some	some
Germany	no	a few	one	no
Italy	no	no	no	no
Poland	one	one	a few	one
Sweden	yes	yes	yes	yes
Slovenia	no	a few	some	some

Examples of expressions found in technology part of the core curricula in connection to attitude, motivation and interest:

> **Belgium (13yo)**: The technics course should increase the interest of students in engineering (Lisbon Objectives)
> **Belgium (13yo)**: (a learner) needs knowledge, skills and attitudes in the domain of technics in its broad meaning.

For technology, again in one-third of the cases the affective domain is not mentioned at all, in others it is not so much pronounced as for science. Among eight countries the greatest emphasis is put on it in Austria and Sweden.

The conclusion is that in general across MST subjects the affective domain is most frequently approached in science, a bit less in mathematics and the least – in technology education. The goals belonging to the affective domain are mentioned for older learners a bit more often in technology and a bit less frequently in science, while for mathematics the picture is more homogenous. Among eight countries only Austria seems to put similar emphasis on affective domain across all ages and MST subjects.

In order to study the learners' attitude towards MST subjects the following procedure is adopted. Questionnaires for 8, 11 and 13 year olds contain sets of items, comprising of four exactly the same questions about positive attitude towards each subject: mathematics, science and technology and one additional statement, included only for 11 and 13 year olds (Table 4).

Table 4

A sub-set of items on attitude towards school MST subjects, included in learner questionnaires.

Questionnaire for 8yo	**Questionnaire for 11 and 13yo**
1. I like the things I learn in *the subject*	1. I like the things I learn in *the subject*
2. I enjoy learning *the subject*.	2. I enjoy learning *the subject*.
3. I would like to do more *the subject.*	3. I would like to do more *the subject.*
4.The subject* is boring.	4*.*The subject* is boring.
	5. I like *the subject* more than most other subjects.

*Reversed items

For 8yo learners only three levels of agreement has been anticipated for each statement, whilst for 11 and 13 year olds a 4-point Likert scale has been attributed to each statement. In order to facilitate a comparison between ages, each answer was scaled as follows. For 8yo 'no' has been given a value of '1' , 'a bit' – a value of '2' and 'yes' – a value of '3'. For 11 and 13yo 'I completely disagree' has been given a value of '1', 'I disagree' has been equated to '2', 'I agree' has been given a value of '3' and 'I completely agree' has been equated to '4'. Answers given by each pupil to all items in the sub-set were summed up and the sum was every time rescaled to the range 0..10 (Johns, 2010). It is worth to notice that whenever more than one science subject is taught at a certain age in the particular country, all the answers collected for different science subjects are summed up and jointly rescaled to range 0…10, accordingly. The issue of rescaling two Likert scales with differing responses is not new and was elaborated for example by Attwood et al. (1993) for the case of 2- and 4-point scales, showing correlations of not less than r = 0.88. The averages over the entire sample of learners, questioned in 10 European countries are presented in Fig.2.

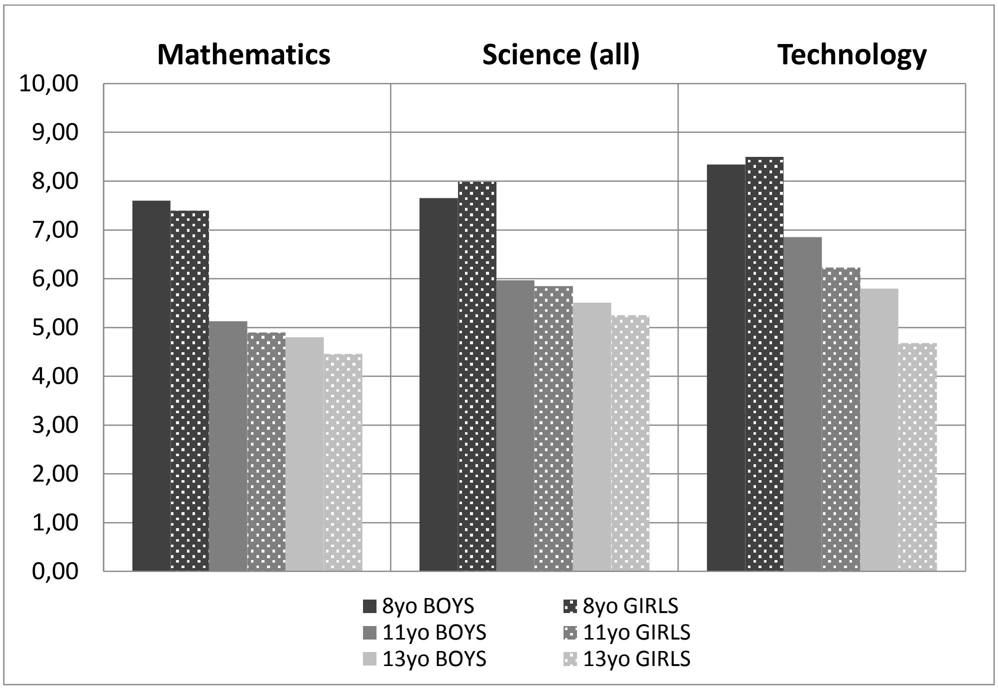

Figure 2. Attitude towards MST subjects across ages and genders in ten European countries. Results for science comprise all science subjects.

The results reveal that for all three subject domains the learners' attitude decreases with age. For boys the greatest drop in positive attitude is always observed between age 8 and 11, and between 11 and 13 – the decrease is much less pronounced. For girls the trend is similar, except for technology, where decreasing trend prevails across all three ages. The boys show better positive attitude towards all subjects across primary and lower secondary schools, except for age 8, when in science and technology the girls seem to score higher in their attitude than the boys. It must be notice that across countries a variety of science and technology subjects is taught across ages, so the results in Figure 2 show only a general tendency. More detailed elaboration of the outcomes with division on separate subjects is out of the scope of this paper and will be presented elsewhere.

A huge difference in attitude towards MST school subjects between ages 8 and 11 requires investigation of teachers' attitude towards teaching. In teacher questionnaires two relevant questions have been asked, as listed in Table 5.

Table 5

A sub-set of items on attitude towards teaching school MST subjects, included in teacher questionnaires .

1. I enjoy teaching *the subject.*
2. Teaching *the subject* worries me, because I do not always know the answers to pupils' questions.

A 4-point Likert scale has been attributed to each statement. For the above mentioned subset of items, unlike for learners, a strategy of averaging each item separately was implemented. Different levels of agreement have been assigned different values, emphasizing a greater gap between disagreement and agreement, than between two levels of disagreement, as well as two levels of agreement. Thus 'I completely disagree' has been given a value of '-1', 'I disagree' has been equated to '-0.5', 'I agree' has been given a value of '+0.5' and 'I completely agree' has been equated to '+1' (Sokolowska et al., 2014). The average results for ten European countries available across four ages, 5, 8, 11 and 13 are presented in Fig.3

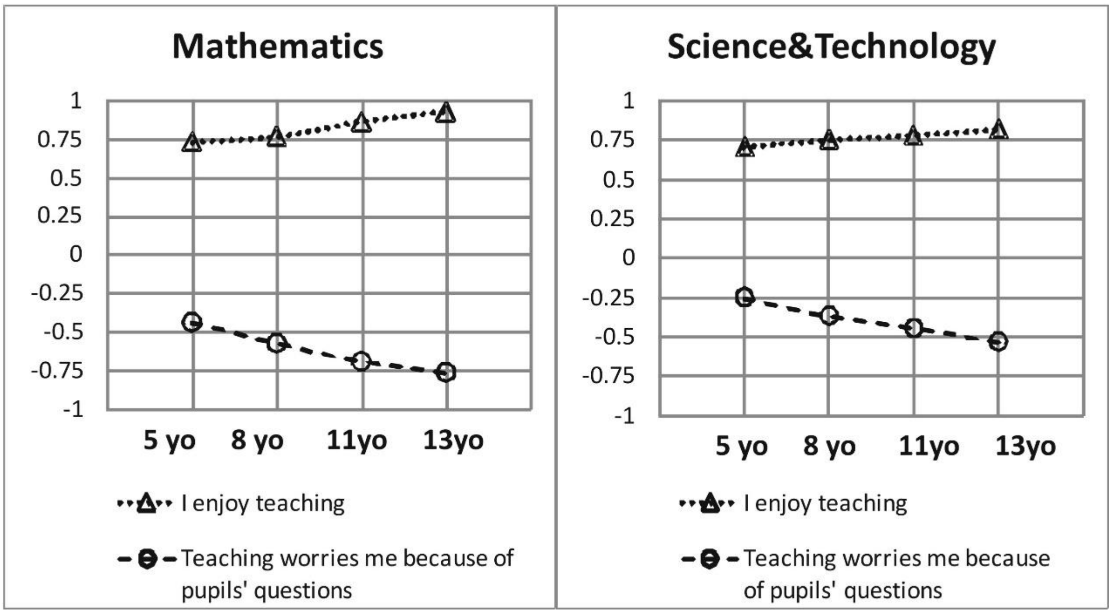

Figure 3. Attitude towards teaching MST subjects across ages in ten European countries. Results on the right comprise all science and technology subjects.

The statements listed in Table 5 have a reverse meaning in a sense that positive answer to the first question should imply a negative answer to the second one. This trend is, indeed, visible in both graphs in Figure 3. In general, it can be seen that teachers' enjoyment of teaching slightly increases with age of pupils, and despite the MST subject, teachers are more self-confident teaching older learners.

CONCLUSIONS

The study presented a limited selection of the data collected in the SECURE project researching MST written curricula, their implementation in everyday practice and perception of teachers and learners. In particular the affective domain appearance in the curricula documents, learners' attitude towards MST school subjects and teachers' attitude towards teaching have been investigated across pupils' ages and different subjects.

Screening the core curricula documents revealed that the affective domain of learning, in particular goals putting emphasis on awareness, appreciation, willingness, satisfaction, attention, motivation, attitude etc. in MST education are not frequently detected in legal documents. Thus the message about their importance may encounter the problems to be transferred from research in education and general European vision (e.g. expressed in the key competences) to an everyday practice, because, as SECURE research showed elsewhere (de Meyere et al., 2013), *'whatever is happening in the classroom, never goes beyond the emphasis encountered in the legal documents'.*

A non-sufficient attention paid to the affective domain seems not to have consequences on very young learners, at the beginning of schooling, but may have an impact on them in the course of further education, as occurs from learners' response to the questionnaires. A substantial drop of the pupils' positive attitude towards MST school subjects has been detected between age 8 and 11 for all MST subjects across ten European countries of diverse school systems and curricula, comparably to the outcomes reported recently by Turner and Ireson (2010) on a much smaller scale. This tendency is not followed by teachers' attitude towards teaching. On the contrary, the teachers of all subjects show a very good positive attitude and self-confidence, even slightly increasing with learners' age. This contradiction is even more pronounced when the results on the impact of all three items: topics, activities and teachers on pupils' positive attitude towards MST school subjects are called (Sokolowska et al. 2014). A substantial drop of the influence of all three items is visible, again, between age 8 and 11. The results show as well that despite the age, ST teachers have the least impact on pupils' positive attitude towards those two subject, much smaller than topics and activities experienced in the classroom.

Thus the joint results reveal the need for more attention to be given to the affective domain at different levels of MST curricula, by (1) inclusion in legal documents more specific goals linked to motivation, attitude and interest of pupils, (2) highlighting the importance of the affective domain in teacher pre-service education and (3) giving the teachers training supporting development of pupils' motivation for, interest in and attitude towards MST subjects.

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PERCEPTIONS OF TEACHERS AND LEARNERS ABOUT THE MATHEMATICS, SCIENCE AND TECHNOLOGY CURRICULA IN TWO EUROPEAN COUNTRIES

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Abstract: It is described how teachers and learners perceive the mathematics, science and technology (MST) curricula they are engaging with in two different educational systems, those of Austria and Cyprus. Curricula are significant policy statements that often intend to provide binding specifications on content, methods and/or anticipated learning outcomes. They function as guidelines for the creation of teaching-learning resources, for setting the approach and emphases of assessment and for framing the efforts and practices of teachers. The Austrian curriculum documents have a descriptive character and lay emphasis on the process of learning, whereas the Cypriot curriculum documents are more specific and content oriented. The main purpose of our study was to examine, through a mixed-methods approach, the existing MST curricula as interpreted by their users, mainly teachers, and as experienced by the students. The research targeted teaching and learning at the ages of 5, 8, 11 and 13 years of age, as representative of pre-primary, primary and lower secondary education. For this purpose, we have collected data from teachers and learners through interviews and questionnaires. In our analysis, the focus lays on the perspectives and rationales of teachers and students on MST learning and their perceptions of aims and objectives of MST curricula. Their notions on how the curriculum is applied in the school context through learning activities and the way they understand their roles when engaging with these activities are also explored. Environmental aspects, such as materials and resources students and teachers have access to, along with the support structures of the educational systems such as professional development provisions, have an influence on the learning reality which must be taken into account when developing curricula.

Keywords: curriculum, educational system, learners' interest, teachers' perception

INTRODUCTION

Next to what should be taught, a curriculum also combines thought, action and purpose, being "[…] a specific, tangible subject that is always tied to decision making within institutions […]" (Null, 2001). In this study, diversions between the educational systems of Austria and Cyprus on their published curricula, as well as on aspects like the way teachers are trained, and materials and resources available for teaching practice are taken into account, in an effort to identify routes of differences and similarities on perceptions of teachers and learners between the two countries. The research is part of the 7th framework project SECURE (Science education curriculum research) which investigates mathematics, science and technology curricula and their implementation in ten European countries. Based on the three common curriculum representations (Goodlad, 1979; van den Akker, 2003), their further distinction was the foundation of the projects' research. Looking at the 'intended', 'implemented' and 'attained' curriculum the following items were addressed: the visions and intentions in the documents, the interpretation and actual process of teaching and learning as well as the learning experiences as perceived by learners (van den Akker, 2003). Learning outcomes which are also part of the attained curriculum were not targeted in this study as it emphasis lays on the perceptions of teachers and learners. Nevertheless, as learners' gaining knowledge is a major aim of school education and as such also included in the evolving curricula over the school years, links are drawn to achievement effects in context.

Since the curricula in Austria and Cyprus are very different, in particular in the conceptual aspects rather than on the subject content, it seems worthwhile to take these data out of the overall SECURE data set and perform a detailed investigation: To which extent are these differences also reflected in the teachers´ and students´ perceptions of the curriculum and in the actual teaching?

Variations between the two educational systems

As one major difference, teacher training does not only defer on the degrees that qualify teachers but partly also on the level of education which it is situated at. For kindergarten, teachers have to pass a five year vocational school on the level of secondary education in Austria, whereas a bachelor degree on general education at university is required in Cyprus. In both countries, a bachelor degree on tertiary level qualifies primary school teachers. Variations occur again in the teacher training for lower secondary schools. Teachers in Cyprus teach one subject only and must have a bachelor degree in their specific discipline, followed by an obligatory one-year course on pedagogy and didactics at university before teaching in school. In Austria, teachers for secondary school either complete a bachelor study at the University of Teacher Education or attend a general university earning a master degree which also qualifies to teach in upper secondary schools, both involving content, didactic and pedagogy training in two or more subjects.

Moreover, the age of learners enter lower secondary school inhere variations. Whereas learners in Austria cross over from primary to secondary school when being 10 years old, in Cyprus they do this step by the age of 12 years. For the sample used in the research, this concretely affects the age group of 11 years old as those learners are being educated in primary school in Cyprus while attending lower secondary school in Austria.

Furthermore, the choice of textbooks is made on a different level. Those, teachers and learners have available in class for their MST lessons are provided by the Ministry of Education for all public schools in Cyprus. In Austria, the choice of textbooks is on school level. Out of a list of approbated textbooks and teaching aids which is provided by the Ministry of Education, the decision is made at teacher's conferences, taking into account also opinions of parents' representatives.

METHODOLOGY

Targeting teaching and learning at ages 5, 8, 11 and 13 years, we have worked with a sample of each 15 kindergartens, primary and lower secondary schools in both countries. Two cities and their suburbs as well as countryside schools were visited in Cyprus. Austria focused on the province of Styria. Diversification in location was guaranteed by selecting a third of visited schools being located in a city, town and on the countryside. In a meeting with headmasters, participating classes were specified. Questionnaires for learners of 8, 11 and 13 years have been designed within the SECURE program and were completed with researchers present; teachers of all age groups and MST subjects in chosen classes were also given questionnaires. Additionally, learners and teachers from 6 schools per age were interviewed. Concerning kindergartens, learners of all 15 samples were talked to because questionnaires could not be used. Learners were interviewed in groups of 4, each 2 boys and 2 girls, teachers individually. For analysis, the basis consisted of a questionnaire sample of 1651 learners and 352 teachers as well as the interview sample of 264 learners and 128 teachers, both gathered in the two countries.

For interviews with both learners and teachers, semi-structured interview guidelines were used with questions related to the curriculum spider-web components, as formulated by the model of van den Akker (van den Akker, 2003). The category *motivation and interest* was added, going into depth on issues targeted in the questionnaires as well. Transcripts were coded based on grounded theory (Corbin & Strauss, 1990) according to a pre-set structure of categories related to the curriculum spider-web components. Further subcategories were derived during analysis. By using SPSS, questionnaires were majorly descriptively analyzed. Results presented here were derived from the triangulated analysis of the interview and questionnaire results aligned to the curricula, for conclusion also referring to the variations between the two educational systems of Austria and Cyprus.

RESULTS

The status of the curricula documents for the age group of 5 hold differences as other than in Cyprus, there is no obligatory nationwide curriculum for Austria. Instead a national educational framework plan as guideline was introduced in 2009 only. Kindergarten as well as connected standards are liable accordant to the law on federal level. Age group 5 teachers in Austria welcome the plan to establish kindergartens as elementary part of the educational system. In Cyprus, there have been adoptions in the curricula documents. Cypriot teachers feel good about there being an update with the new curriculum and a new approach. These statements show that in both countries teachers care about the system's evolution and their personal improvement.

Separate curriculum documents are available for kindergarten, primary school as well as lower secondary school in both countries with the exception of mathematics in Cyprus. This curriculum is for learners from the age of 5 to 18 years, covering general aims and didactic principles of mathematics and subject areas with examples of activities in two chapters with a total of almost 500 pages. The science and technology curriculum for Cyprus for 5 year olds include five chapters covered within less than 200 pages and including parts on the rationale, the role of the kindergarten teacher, lesson development as well as subject areas with examples of activities. Comparing the Austrian educational framework plan for all educational sectors, there are five chapters, including relevant parts of less than ten pages with the role concept of teachers and principles of educational processes, education and competences as well as educational sectors. An additional module for the last year of pre-primary school illustrates a more in-depth characterization, including scientific basis, information for development and differentiation of competencies as well as impulses and examples for design of learning environment and educational processes in less than 25 pages. As mentioned before, those documents are not binding for but still put into practice by the vast majority of kindergarten teachers. Whereas for primary as well as for secondary school for science and technology in Cyprus each four chapters include relevant parts of subject areas with objectives per each, teaching methods and assessment methods in less than 25 pages per subject, there is a difference between those in Austria. In primary and lower secondary school curricula the chapters of general educational aim as well as general didactic principles are in common. Besides, within the total of nine chapters in primary school, additional MST relevant parts consists on determined hours of obligatory subjects and one about educational and teaching task making a total of about 75 pages. Last mentioned additionally includes subject matter, didactic principles of subjects, structured in different experience and study context which are further specified in the subject matter. The only six chapters for lower secondary school contain to the before mentioned also one about school and lesson planning combined with the definition of core curriculum and the extension area of subject matter. Subsidiary and autonomous determined hours of subjects in addition to educational and teaching tasks with didactic principles of subject matter are those parts concerning MST subjects as well summing up to 25 pages about general and five to six pages for each subject. For Austria, in addition to the curricula documents, teachers also need to take into account many promulgations.

The strong content focus in the Cypriot curriculum can be seen among teachers, defining themselves mainly as instructors, strongly targeting on achieving aims. Despite the more descriptive character of the Austrian curriculum documents, teachers feel a similar commitment to cover the curriculum as teachers in Cyprus. In both countries, most of the teachers think that the level of the curriculum is suitable for learners. Nevertheless, the curricular load and appropriate time are not experienced as balanced which has a negative effect on implementation especially of practical approaches. Austrian teachers feel challenged when balancing low with highly interested or talented learners and deal with this individually. Whereas Cypriot teachers emphasize on weaker learners, average achievers are the main focus in Austria.

In Cyprus, most of the teachers agree that aims and objectives are visible and comprehensible in curriculum documents, in Austria the majority of teachers agrees on them being general and formulated broadly and clearly. As can be seen in figure 1, only twenty percent of mathematics teachers in Cyprus as well as science and technology teachers in Austria disagree that the curriculum gives them a clear view of what is expected from learners. Those teachers responding with *do not know/not applicable* come from kindergarten, therefore reflecting the uncertain situation mentioned at the beginning of this section. An objection raised in the case of Cyprus is in the spiral organization of mathematics curriculum, causing some problems in teachers' opinions which may be confounded by newly introduced curriculum innovations. Having a framework plan in Austria, certain specifications on how to reach goals are missed sometimes as the emphasis of the curriculum is explicit on the process of learning. However, there are teachers who prefer this freedom enabling them to choose objectives for their lessons.

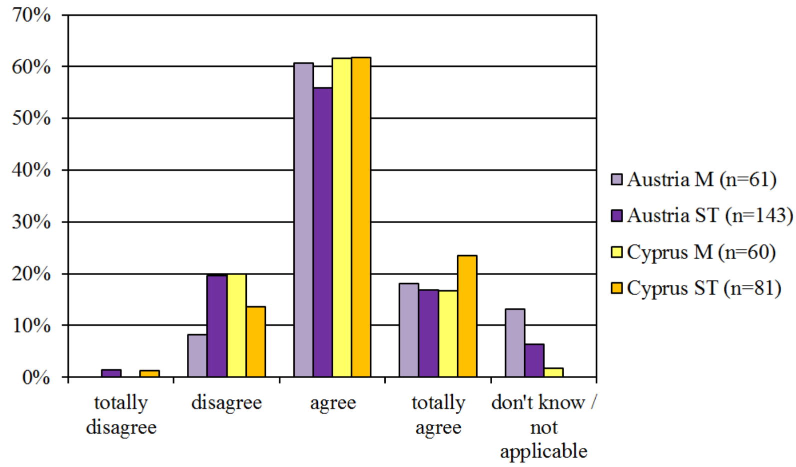

Figure 1. Curriculum gives a clear view of what is expected from learners.

In Cyprus, around seventy percent of teachers indicate to have determined aims and objectives at their schools in all MST subjects with around only half of the teachers stating this in Austria. Whereas colleagues support is offered about the same in both countries, teachers in Cyprus point out to coordinate with others teaching the same lesson in their school about which aims and objectives to emphasize, while in Austria except in the case of mathematics most of them act autonomously.

Teachers and learners of all ages and subjects in both countries highlight the motivating aspects of practical activities, which decrease with age in mathematics. Looking at data from learners in both countries, the frequency of doing practical work correlates with their indication to like the subject because of the activities done in class (mathematics: r_s (1134) = .27, $p < .01$; science: r_s (1139) = .33, $p < .01$; technology: r_s (927) = .36, $p < .01$). The case of technology in Cyprus is a good example as classes have a stronger theoretical approach for age group 13. While the practical approach and learners' interest remain high in Austria with respect to the subject technology, the decrease of practical activities in Cyprus results in a lower level of interest of learners (figure 2 and 3). Learners like experimenting in science for its' own sake, but also emphasize that backing up theory with practical activities help for their comprehending as *"One can understand everything easier through experiments"*. Also carrying out experiments by themselves gives them an extra motive to be engaged in learning activities, as seen when reflecting on their behavior: *"The most important thing is that we can do something by ourselves. We get loud when we only have to listen to the teacher"*. Teachers also see the preference of learners getting active, as stating *"Students like it more when designing and carrying out experiments themselves"*. Practical activities therefore are not only connected to motivation by teachers and learners, which has a medium impact on students' achievement but also to behavior in class according to learners, even having a high one (Hattie, 2009). When doing science experiments, Austrian teachers emphasize on learners working alone or in groups. Cypriot teachers demonstrate approximately half the experiments, the rest are carried out by learners in groups. This may be related to curriculum documents, where practical approach is encouraged in Austria and only implied into content in Cyprus.

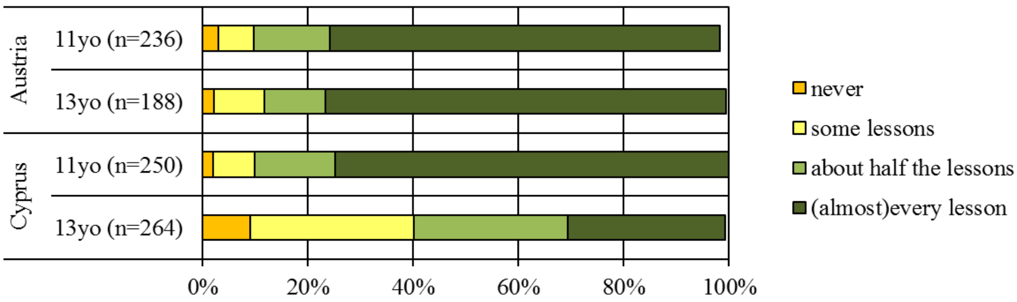

Figure 2. Frequency of practical activities in technology perceived by learners.

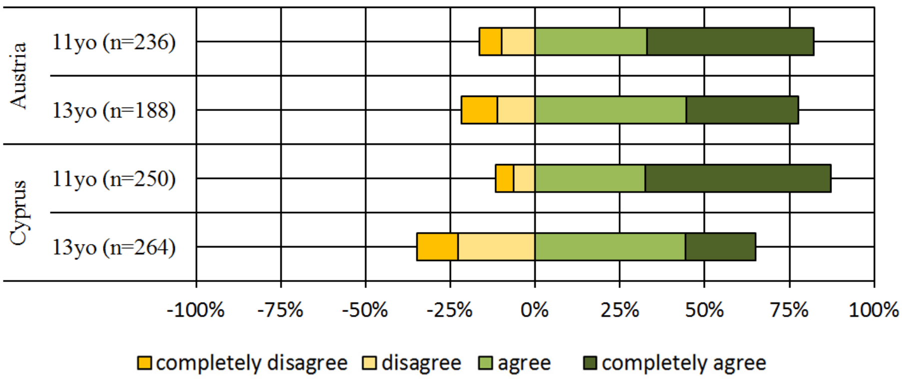

Figure 3. Learners indicating to like technology because of the activities.

A limitation that affects teachers in their practice is the large size of the class. Depending on the subject, between twenty-five and thirty-nine percent of MST teachers in both countries indicate that a large class size limits teaching a lot. Even though this result is in contrast to findings that the class size only plays a minor role in the parameters influencing students' achievements (Hattie, 2009), teachers perceive it as important for their teaching practice. Cypriot and Austrian teachers express the wish for smaller groups like the applied split classes in technology in both countries, as they feel practical activities, especially experiments in science, as well as the respondence to individual needs are easier to implement. *"It would be better if the class was split in order to have less students and work better in groups"* and *"The smaller the group the better I can respond to learners individual needs"* are teachers explanations for their preference of working with less learners. While Cypriot teachers of 8, 11 and 13 year olds say they let work learners in small groups when exercising mathematics problems or constructing in technology, Austrian learners usually work within the total class community or alone. Furthermore, merging learners of different ages for activities is described as valuable for both interest and understanding but is only described for Austria with few existing examples.

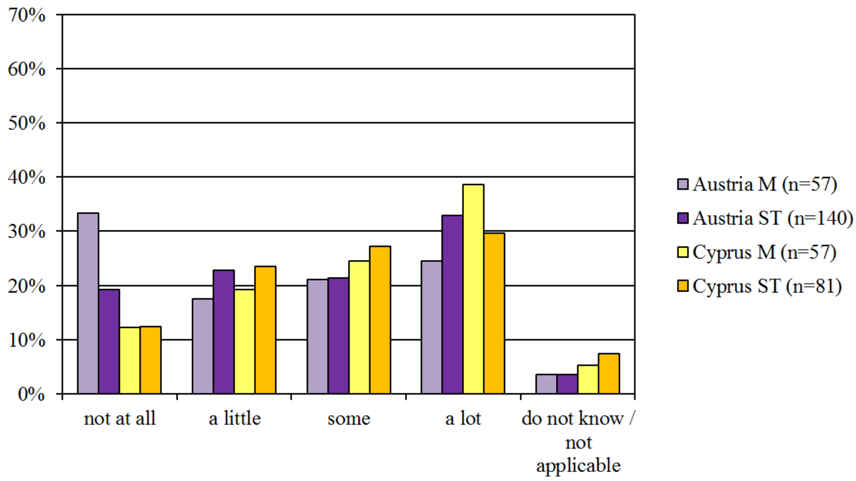

Figure 4. Large class size limits teaching.

In both countries, sympathy for the teacher influences learners' attitude towards subjects. Even though this trend decreases, by the age of 13 years still more than half of the students indicate to like the subject because of the teacher. Going into depth, two main reasons emerge. *"The level of our understanding depends on the teacher"* explains a student the main one as in order to understand and overcome difficulties, prevalently occurring in mathematics, they need good explanations and at times more or different approaches. *"We need explanations in a way that makes sense and not only learn by heart how to solve particular problems (=senseless!)"* Further, also the attitude of the teachers towards learners have an impact as a student expresses *"Sometimes teachers say 'If you did not understand something just ask.' If one then says something they immediately yell as us and say 'Did you not listen?!'"* Teacher clarity as well as the relationship between teachers and learners both have a high influences on students' achievement as well (Hattie, 2009). Successful teaching for Cypriot teachers is mainly connected to make learners aware of the usefulness with nearly a third of mathematics teachers and close to half of science and technology teachers indicating to make connections to the daily life of learners in almost every lesson (figure 5). While there is a degreasing tendency in mathematics in Austria, it stays stable over the ages in Cyprus, dropping by the age of 13 only. This could be due to the fact that at this point, Cypriot learners attend lower secondary school. For science and technology, the relation to learners' daily life is increasing after the age of 5, staying high after while steadily increasing over the ages in Austria. Whereas Cypriot teachers lay their focus more on making aware of the usefulness of MST, Austrian teachers stronger emphasize on enthusing learners for their subject with more than sixty percent in mathematics as well as in science and technology who see motivating pupils as most important factor for successful teaching (figure 6). For both countries, motivating students in mathematics stays stable over the ages. Differences occur for science and technology as teachers find it very important over all ages, whereas in Cyprus this increases over the years.

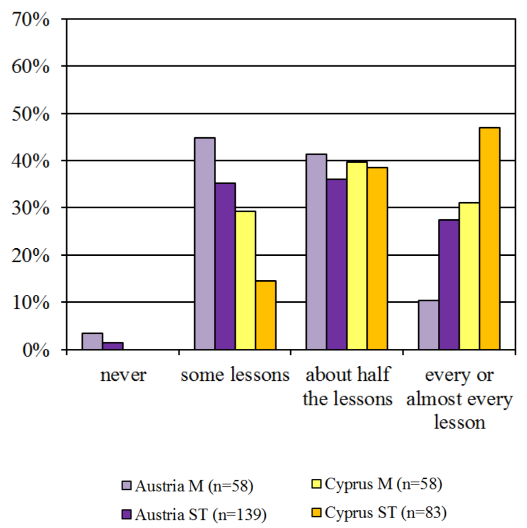

Figure 5. Relate to daily life.

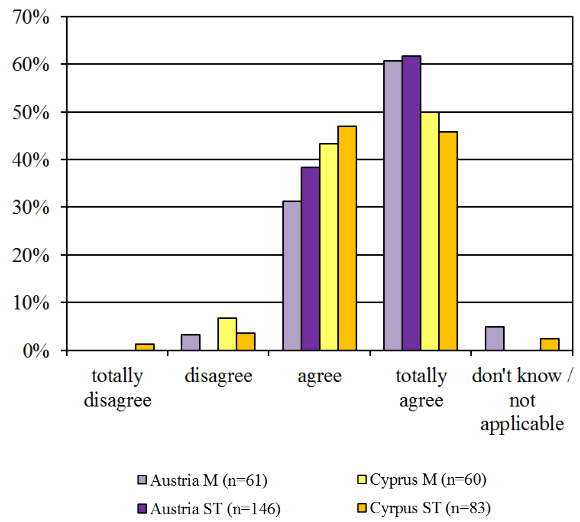

Figure 6. Motivating pupils is most important.

The textbook use of the teacher in class indicates variations among Austria and Cyprus, excluding the age group of 5 year olds as there are no textbooks available for neither country. For mathematics as well as for science and technology, a higher percentage of Cypriot teachers uses textbooks as primary basis of their lessons as can be seen in figure 7. However, the same trend appears for both countries concerning the different subjects: The majority of teachers use the textbook as primary basis when teaching mathematics while it is more often used as supplementary resource for science and technology classes. Those not using a textbook for their lessons are majorly technology teachers only, who hardly get any in Austria and only for 13 year olds in Cyprus. The stronger use of textbooks as supplementary resource in Austria might be explained with the possibility to choose among approved ones on school level. Because of a higher fluctuation of textbooks to work with, teachers can also take advantage of those they have already been working with before. Cypriot learners perceive the frequency of the use of (text)books during class about the same in all subjects, except for technology in primary education where it is less. The perception of Austrian learners is different as they state to use them most in mathematics, followed by science and technology across all ages.

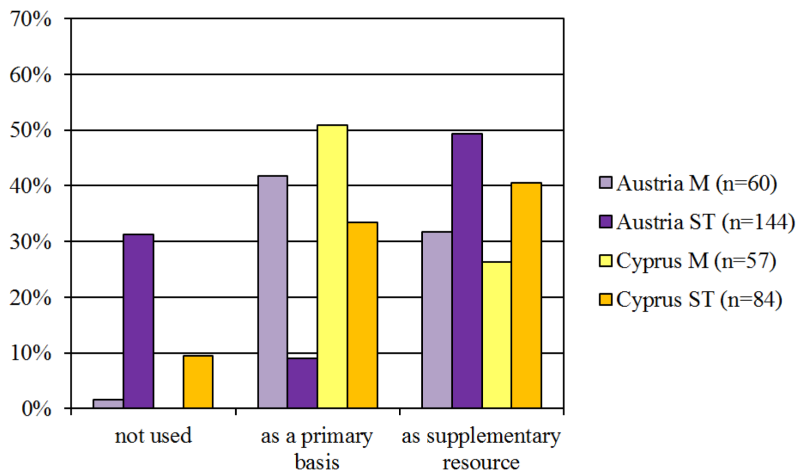

Figure 7. Use of textbooks indicated by teachers.

In both countries, the majority of learners and teachers of all ages think MST to be an important part of education and learners' development as individuals. Also the importance of professional development, having an impact on students' achievements as well (Hattie, 2009), is seen by teachers in Austria and Cyprus. Though professional development seminars take place in both countries, there is need for more, with even above forty percent of science and technology teachers close to half state that the range of courses is not sufficient (figure 8). Also highlighting the lack of professional development courses in the interviews, in particular in class application is addressed: *"There is need for more professional development. Despite some seminars are given quite rarely, we need more practical examples."* Going into detail in comparison, two age groups stick out: For Austria, this is teachers of the age group of 5 years as over sixty percent see more need for professional development courses in all MST subjects. The same appears for more than half of teachers of 11 year olds in Cyprus in all MST subjects. This might also be connected to the teacher training which is on secondary level in Austria but on tertiary in Cyprus for teachers of the age group of 5. Teachers of 11 year olds earn a bachelor degree on general education in Cyprus as this age group is still part of primary school whereas teachers in Austria already focus on specific disciplines in their studies as 11 year old learners are educated in secondary school.

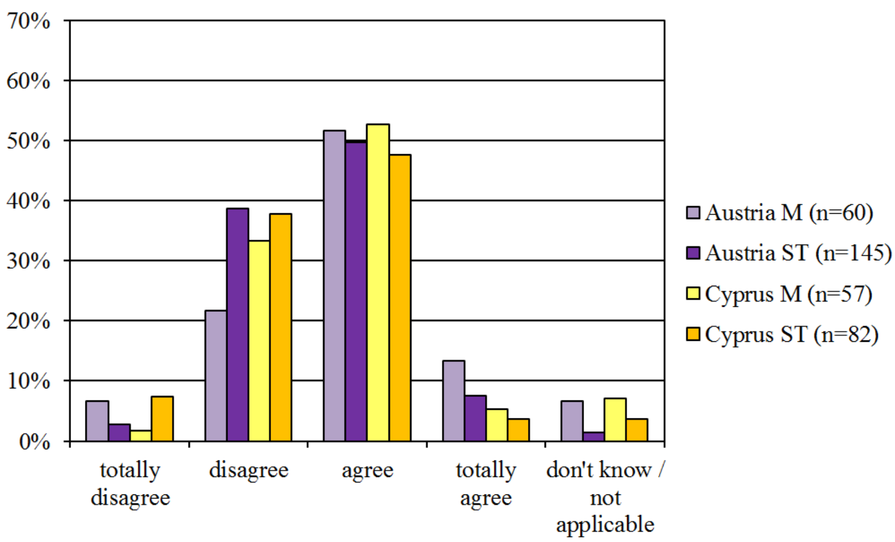

Figure 8. Sufficient range of courses for professional development.

CONCLUSION

According to here shown results, differences in systems and curricula seem to effect teachers' and learners' perceptions and practice. On the other hand, a lot of similarities can be found in the perception of teachers and learners in relation to the implementation in class as well. Even though curricula documents vary in their structure, extent and focus in the two countries, in both teachers are generally satisfied, also when it comes to the suitability of the level for learners. Curricula do have an impact on teachers' perceptions as especially seen when making changes like in mathematics in Cyprus, which leads to restructuring of teaching going along with difficulties for some. Also when it comes to the realization of practical methods, curriculum sets a trend as seen when it comes to the approached versus the implied in content focus of curricula concerning experiments in science. Moreover, they help to clarify what is expected from learners and give teachers the same set of aims nationwide. This is missing for kindergarten in Austria, as the national document is not binding. Materials and resources as the immediate environment have a direct impact on the teaching and learning process analogue in both countries. As those conditions bear a certain resemblance to one another, teachers' and learners' perception of the implementation in class disclose numerous similarities. An exception is the use of textbooks which might be affected by the different level on which they get chosen. Parallels can be seen concerning the wish of teachers for smaller groups of learners in favor for more practical and individual work. Furthermore, also for better class implementation the need of professional development with a bigger range of courses and a stronger teaching practice focus is stated. Aligned, the perceived supportive factor of practical activities on motivation and understanding of learners is addressed. Differences occur concerning the focus put in favor of enthusing learners which is rather on the connection to daily life by teachers in Cyprus whereas it is on motivating students in Austria.

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APPLYING PHYSICS MODELS IN CONTEXT-BASED TASKS IN PHYSICS EDUCATION

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Abstract: Little is known about the processes of how learners apply physics models to problems in real life situations (context-based problems). When students are asked to solve context-based problems they first need to organize the information from the context and link them with their pre-knowledge, which actually means that students need to develop a mental model for the context. This is the starting point for searching physics models that could be used to reason physics solutions for the problem. While the mental representation is only valid for the concrete situation, the physics model allows transfer to other similar problems. The central aim of our study is to investigate which features of the context can be used to help students find physics solutions for the problems. In a first step the process of problem solving in context-based tasks is scrutinized by think-aloud protocols to identify which elements from the context description and the physics model are used, and how they are linked to each other. Data are taken from a pilot video study of ten 10th grade students (from a German middle school) while they solve one context-based problem in optics, mechanics and thermodynamics each. First results suggest that students tend to spend a very short amount of time to acquire an understanding of the problem but often try to apply physics knowledge immediately. Thereby, students try to link elements from the context ('real world') and the physics model ('model world') with opposed effects. It might be assumed that they typically do not manage to overcome the surface structure, which leads to unconstructive solution proposals.

Keywords: problem solving, modelling, context-based tasks, real-life problems, task difficulty

SUBJECT

Authentic real-life problems deal with manifold and complex issues that connect science, society and technology (Pilot & Bulte 2006). When students are asked to solve context-based tasks, they first need to organize the information from the context and link it with their pre-knowledge concerning such context (e.g. Mayer 1992). More precisely, this means that they develop a mental model (Johnson-Laird 1983) for the context, which is the cognitive analogy of the structure of the situation (Reusser 1995). This is the starting point for searching physics models that could be used to reason physics solutions for the problem. While the mental representation is only valid for the concrete situation, the physics model can be transferred to other similar problems. Applying a physics model as a tool of inquiry (Grosslight 1991) means to map the mental model and the physics structure. As scientific models and contexts are related to the given problem (Gilbert 2006), a learner's individual meaning of the context can result in the application of an alternative physics model (Pilot & Bulte 2006). In summary, literature supports the strong connection between the problem's surface structure and the way learners apply physics models.

Nevertheless, there have been few empirical findings on how context-based tasks influence students' understanding (Bennett et al., 2007). At the same time, we already know that such tasks have a positive motivational impact (Bennett et al., 2007), which indicates their application in classrooms. Following this, the central aim of our study is to investigate which features of the context prompt students to find physics solutions for the problems.

As a first step, we conducted a video survey to identify elements from the context description and from the physics model to examine how they are linked to each other in students' argumentation made during problem solving. Therefore, this paper describes how learners apply physics models within the problem-solving process while working on context-based tasks.

The problem solving process generally consists of four steps (Pólya, 1985): *Understanding the Problem*, *Devising a plan*, *Carrying out a plan* and *Looking back*. Klahr (2000) argues that problem solving is an essential process in science and links these steps to finding and testing hypotheses, conducting and evaluating experiments, and analyzing findings. Within the process of scientific problem solving, approved and generalized ideas about processes and principles in nature are applied for generating and reasoning hypotheses and analyzing findings from the experiments (see Table 1). From a nature of science (NOS) perspective these approved ideas could be seen as scientific models.

Table 1

Role of models in problem solving

Problem-solving process (Pólya, 1985)	Role of models in problem solving
Understanding the Problem	Assigning to a known model by searching for a suitable domain in science
Devising a plan	Adapting or specifying the model to the problem
Carrying out a plan	Applying the adapted / specified model (e.g. carrying out experiments to measure variables from the model)
Looking back	Verifying the solution by checking if the empirical findings fit to the model's prescription

For the first step in problem solving, students need to select and organize the information from the context, link it to their knowledge about the situation, and eventually to their knowledge about science in scope of the problem. This results in a *real model* that represents the context. Mayer (1992) describes the difference between expert physicists and novices amongst others by their capability to represent and to categorize a problem. In students' statements, the real model can be identified by bits of information that represent the surface structure of the problem (real world). The physics model is represented by the deep structure, which means that information is part of approved and generalized ideas about processes and principles in nature and can be transferred to a large number of similar problems (model world). Consequently our research question is:

How do learners make use of real models and their combination with physical models to develop a solution in context-based tasks?

For analysis purposes, the distinction between *surface structure* (real world) and *deep structure* (world of physics models) is used as a first approach.

STUDY

The video-study is conducted with a group of ten 10th grade students in German middle-school (approx. 15y, 2f/8m). Each learner works individually on a set of three problems in thermodynamics, optics and mechanics presented in different contexts (N_{Videos}=30, $N_{Students}$=10, t=5 minutes for each task, for context description see Table 2). The participants are encouraged to speak aloud about the ideas and thoughts they have. Meanwhile, video-recordings are made during such process. It is identified that the phase for *assigning* and *adapting* a model to the given problems (see Table 1) cannot be observed separately, as students always combine it in one statement. This phase of problem solving is therefore named *comprehending the problem* since it combines selecting, organizing, and applying information in once. In addition, we also classified the students' statements referring to whether they are based on the surface or deep structure of the context or even combined.

Table 2

Overview of the contexts and report of observations

Topic	Context	Observations
Thermodynamics	In 1991, mountain hikers found a glacier mummy in the South Tyrolean alps. Nearby they discovered a piece of a braided grass pad. Scientists disagree in whether the pad was a kind of cloak or some Stone Age insulating pad.	Students often try to propose solutions based on their experiences (e.g. in camping, or insulating materials in house building), one student actually saw the original piece of the grass pad in a museum. They also tend to argue on the surface structure, as they often mention the density of the grass pad or its water permeability. Statements based on physical concepts such as heat flow or thermal conduction are rarely observed. Also the students often differ between heat and coldness.
Optics	A polishing product commercial shows a picture of a scratched cell phone cover whereon the photo-flash can be seen. The picture nearby shows a polished cover on which you can see not only the photoflash but also the mirror image of the camera and the person who took the picture. Both times light is reflected but only on the polished cover occurs a mirror image.	Different from the previous context, learners are mostly combining the surface structure with the deep structure. A reason might be that there are more similarities between surface structure and deep structure than in the thermodynamics context, e.g. a sketch was shown which is also common to visualize the optical path in geometrical optics. In other words: The surface structure of this context has a higher transparency. Therefore students' arguments are more often leading to a physically acceptable solution. A well-known misconception which could often be observed is the belief in seeing as an active process (like a beam coming from the eye).

Mechanics	A video shows two cars that hit a tree at the almost same (low) velocity. The first car is from the 1930's and doesn't show any signs of bodywork damage while the second, modern car got a big dent in his bonnet. Obviously modern cars are less sturdy than old ones.	Learners tend to combine surface and deep structure in this context, too. Most of them mention the crush-collapsible zone. They also manage to produce solutions that are physically passable although they did rarely manage to make use of the physical language. As an explanation for this we could also assume the surface structure to be more similar to deep structure in compare to the thermodynamics context: The physics focuses of the mechanics' and optics' contexts have visible representatives in the surface structures whereas the thermodynamics' focus (heat/heat flow) has no such representation. Again, one could say this surface structure is more transparent than the thermodynamics'. A misleading statement that could be observed in some videos was referring to the weight reduction in order to save fuel, in other words: To reduce weight engineers decided to choose lighter and therefore weaker materials.

ANALYSIS

As shown in Figure 1, students spent nearly all the time during the problem solving process giving proposals for solution and hardly any time comprehending or verifying the solution.

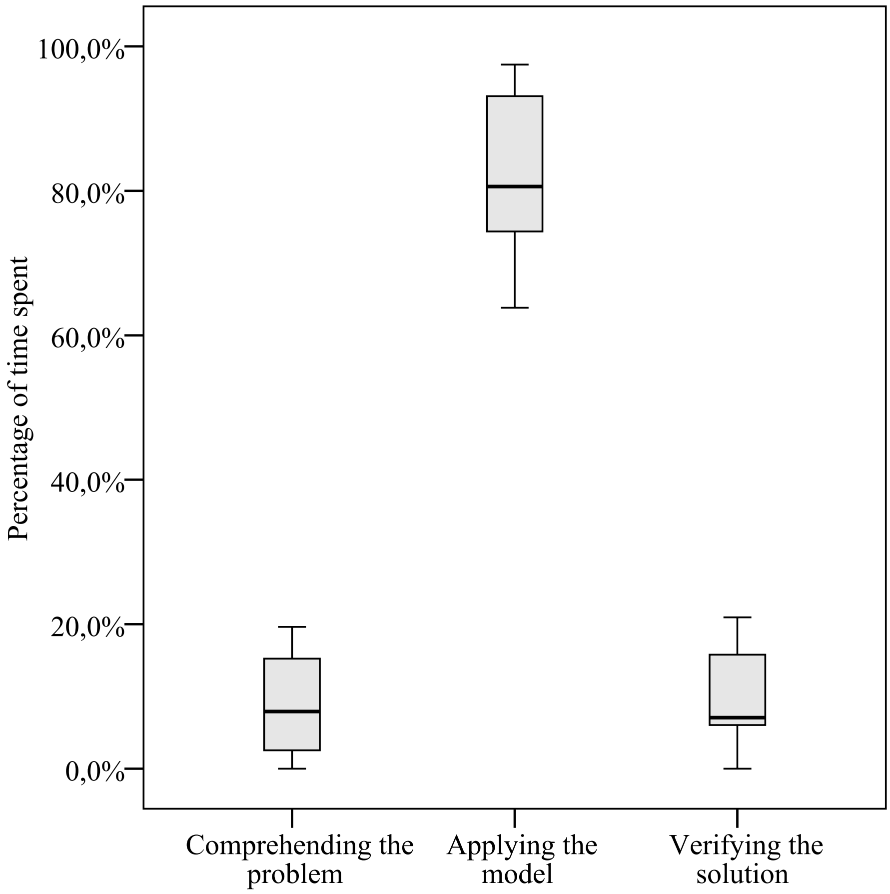

Figure 1. Variable "Steps in the problem solving process". Distributions cannot be considered as equal (Friedman-Test: <.001). Difference comes from: 'CP' - 'AM' & 'AM' - 'VS' (Post-Hoc-Test (LSD): <.001 for both)

As it can be seen in Figure 2, students tend to apply physics knowledge rather than analogies or other proposals when they are looking for a solution.

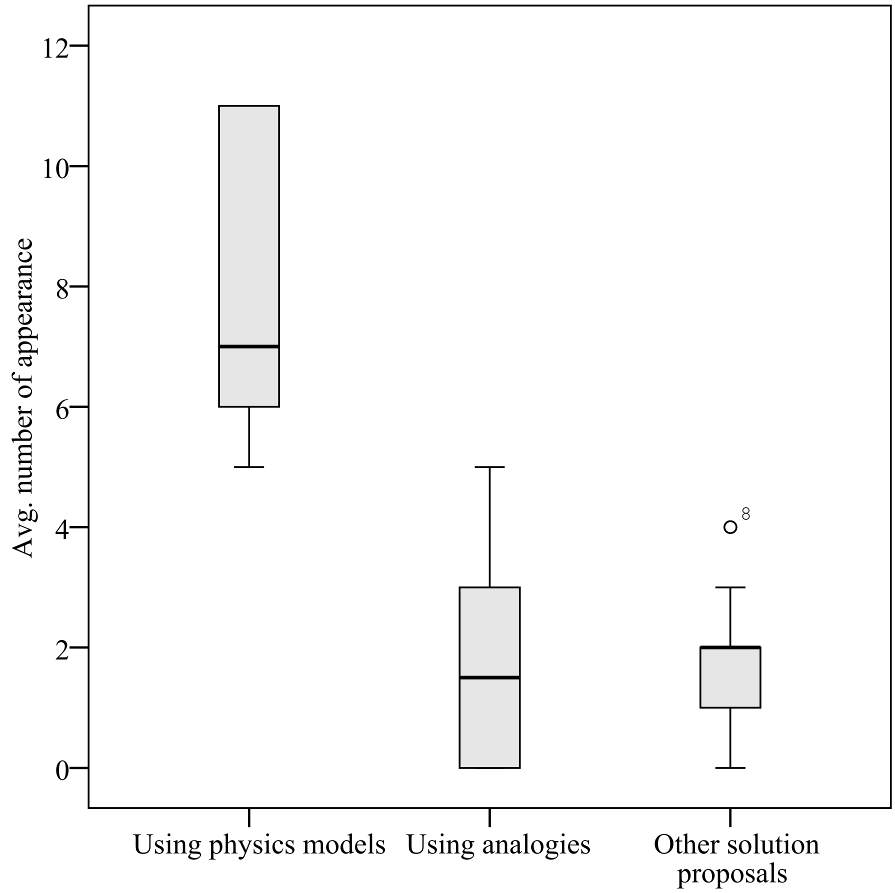

Figure 2. Variable “Type of solution”. Distributions cannot be considered as equal (Friedman-Test: <.001). Difference comes from: 'UP' - 'UA' &, 'UP' - 'OS', (Post-Hoc-Test (LSD): <.001 for both).

Thereby, they rarely manage to apply a physical model in a constructive way, which means meaningful and physically accurate statements that lead to a correct solution. We also observed statements that consist of such elements, but were somehow imprecise or include incorrect conclusions; we named them *constructively with limitations*. Examples are given in Table 3 (translated from German language).

Table 3

Examples of student statements referring to the variable “Quality of solution”

Quality of solution	Student’s statement	Task
Constructively	“Maybe with as much air holes as possible because air doesn’t conduct heat very well.” (person no7, 5:17 – 5:22)	
Constructively with limitations	“It builds an insulating layer so that the heat can’t get on the surface or in other words the cold can’t get through.” (person no10, 3:09 – 3:21	Insulating effect of a sleeping pad (Thermodynamics)
Nonconstructively	“The sleeping pad … it’s sending out heat radiation.” (person no1, 1:52 – 2:01)	

Figure 3 shows the number of such statements during the problem solving process.

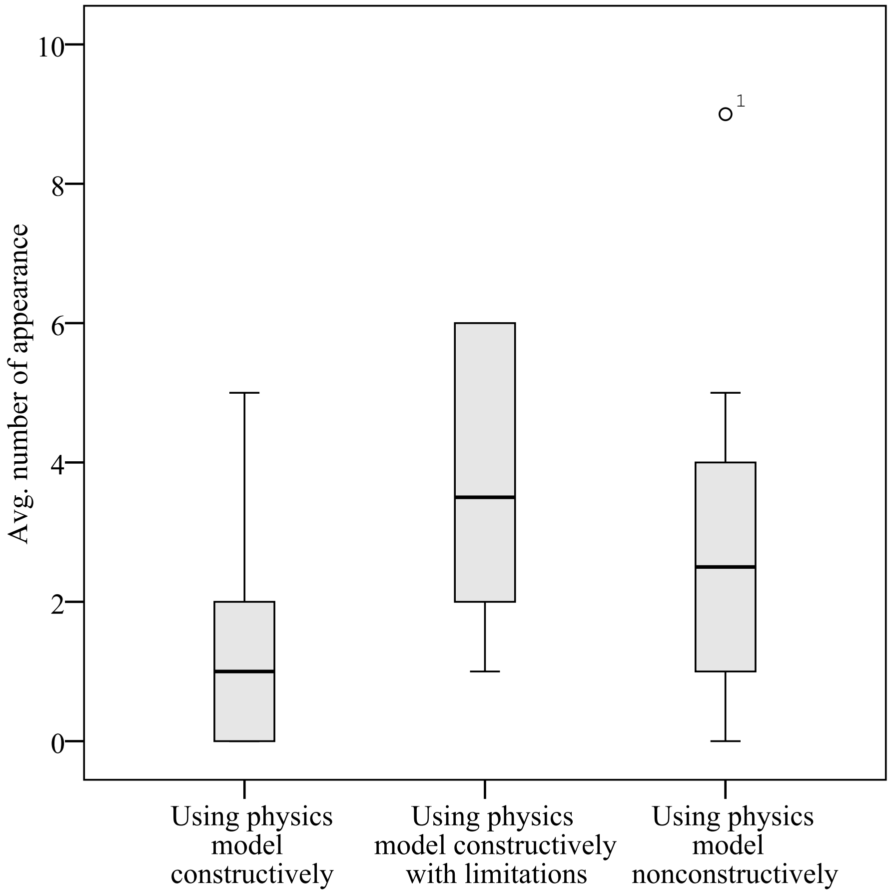

Figure 3. Variable “Quality of solution”. Distributions can be considered as equal (Friedman-Test: .068).

Finally, as it can be seen in Figure 4, we examined that learner arguments are based on the surface structure of the problem rather than on the deep structure, or even combined. Examples are given in Table 4 (translated from German language).

Table 4:

Examples of student statements referring to the variable “Base of physics statement”

Base of physics statement	Statements	Tasks
Surface Structure	“I think it was a sleeping pad, because there is ice and snow and if he put the grass pad on the ground he kept the heat to himself and was protected this way.” (person no8, 1:27 – 1:48)	Insulating effect of a sleeping pad (Thermodynamics)
Combination of Surface and Deep Structure	“The reflected light – that is the mirror image – is mirrored in different directions of the scratches and comes out in a different angle.” (person no3, 1:38 – 1:50)	Mirror images vs. reflection of light (Optics)

Deep Structure	"You have an inertia that has to be stopped immediately…This means a certain energy that has to be conducted somewhere. (Regarding the car this means…)" (person no1, 4:40 – 5:03)	Instability as a safety feature (Mechanics)

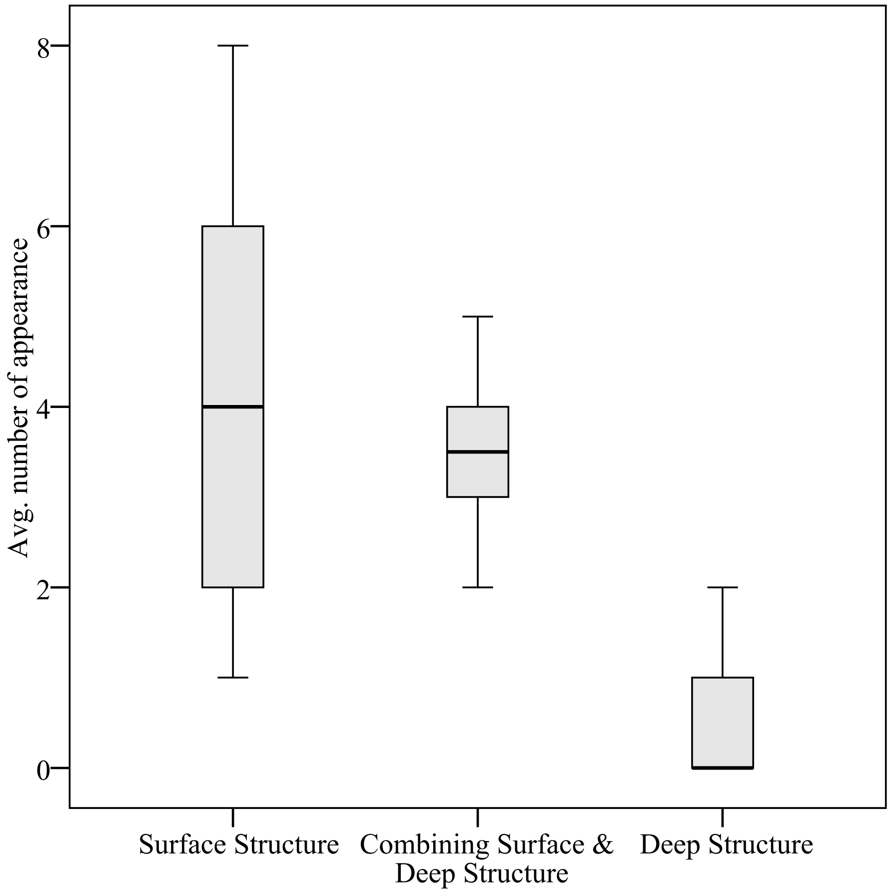

Figure 4. Variable "Base of physics statement". Distributions cannot be considered as equal (Friedman-Test: .001). Difference comes from: 'SS' - 'DS' & 'CS' - 'DS', (Post-Hoc-Test (LSD): .002 & <.001)

However, Figure 5 shows that students are capable of arguing in different structural areas during one single problem solving process (person no1, mechanics context).

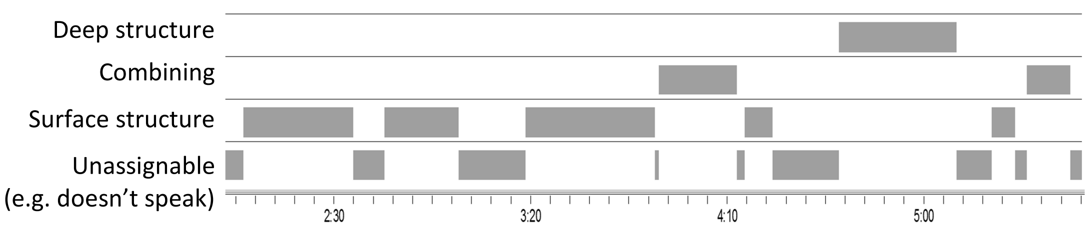

Figure 5. Appearance of different structural areas within one problem solving process.

Considering the variable "Quality of solution" with reference to the variable "base of physics statement" (Figure 6) gives us deeper insights on the impact of the learners' capability to overcome the surface structure. It seems that - even though the total amount of nonconstructive statements is still higher - the number of constructive statements increases if students manage to leave the surface structure towards the deep structure while at the same time the number of nonconstructive statements decreases.

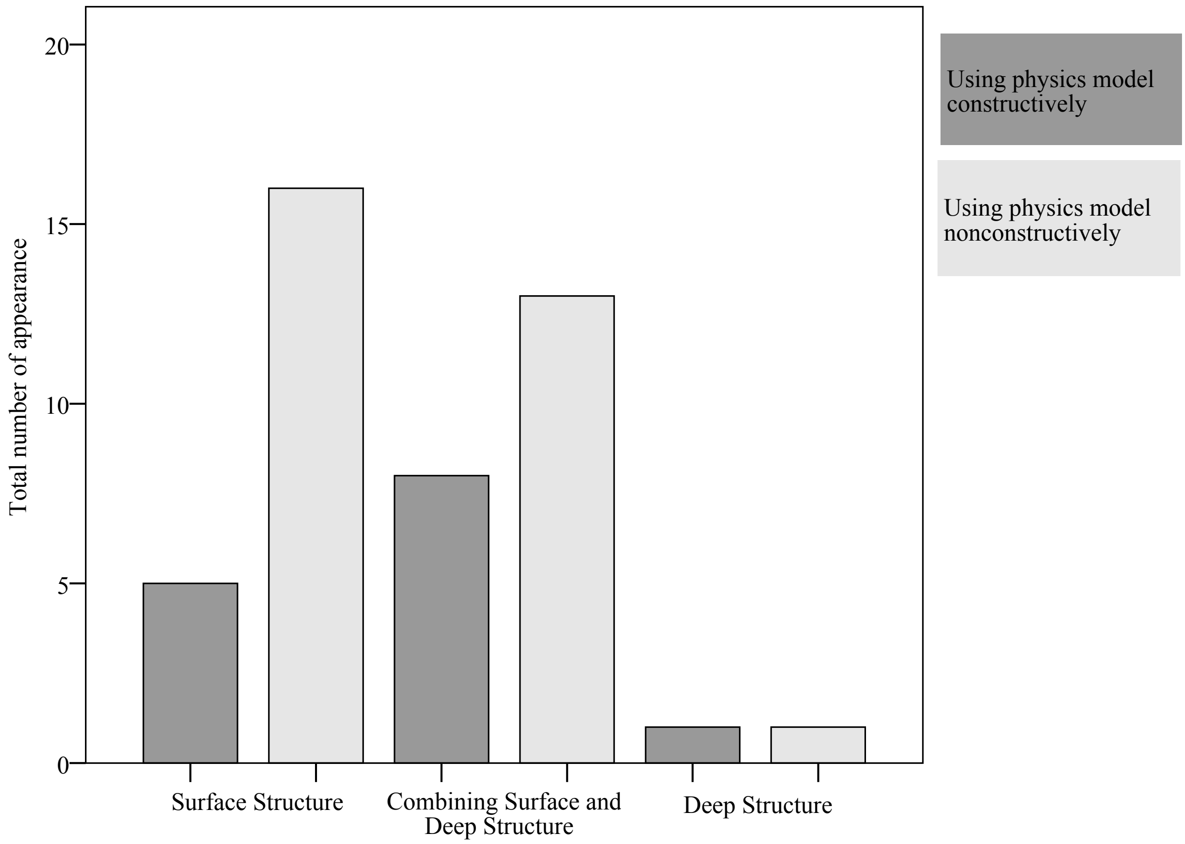

Figure 6. Combined variables “Quality of solution” & “Base of physics statement”. Distributions cannot be considered as equal (Friedman-Test: .033). Difference comes from: 'ConCS' - 'ConDS', 'NConSS' - 'NConDS', 'NConCS' - 'NConDS', 'ConDS' - 'NConSS', 'ConDS' - 'NConCS' (Post-Hoc-Test (LSD): .045, .022, 044, .030, .044).

These results indicate that learners spend most of the time doing proposals for solution. As a result, they try to apply physics models (deep structure) while at the same time they can hardly overcome the surface structure of the context. They also try to link elements from the surface structure and the deep structure, which has opposed effects: Although the amount of nonconstructive statements is still higher, the difference between the number of constructive and nonconstructive statements however decreases from both sides compared to statements only based on surface structure.

OUTLOOK

It might be assumed that it would be of central importance for the students in the study to overcome the surface structure of a context-based task to succeed. Unfortunately they tend to consider the relations between elements of this surface structure to be analogical to elements of the deep structure and therefore apply physics models nonconstructively. The reason may be a misconception of the role of models in physics, as they are often introduced as a kind of analogic translation of a given situation into physics. As the ability to form situation models can be seen as a part of modeling (Leiss, Schukajlow, Blum, Messner & Pekrun 2010), this indicates that for context-based tasks students need help with the comprehension of the problem situation, e.g. via identifying key features of the surface structure that affect how students link it with the deep structure. Based on the current study, one of the key features of contexts might be their *transparency*, which considers the amount of links between surface and deep structure, for example by using physics terms and principles or by choosing topics with more or less similarities between surface and deep structure, as mentioned in Table 2.

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INVESTIGATING MST CURRICULUM EXPERIENCED BY ELEVEN-YEAR-OLD POLISH AND ITALIAN PUPILS

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Abstract: In SECURE project, three different types of questionnaires have been designed for 8, 11 and 13 years old pupils' and their teachers, to collect research data, analyze it and provide recommendations that could initiate a debate on the development and implementation of the curricula of mathematics, science and technology (MST) at European level. Questionnaires are structured with multiple-choice questions and open questions. The number and the type of the items proposed have been adjusted to the age (for learners) or to the subject matter (for teachers) in a way that guarantees the feasibility to fill in all the items in at most one hour. The questionnaires were analyzed and the significant emerging elements were discussed combining the acquired data with relevant information derived from the analysis of the official MST curricula documents. In this contribution a part of the study concerning comparison between Italian and Polish MST curricula experienced by 11 years old pupils is provided with respect to rational, aims and objectives, content, learning activities, teacher role, materials and resources, grouping, location, time, assessment and motivation.

Keywords: curriculum, student interest, teacher thinking

THEORETICAL FRAMEWORK

Research on transnational education surveys has got a long history. Starting from the results of the International Association for the Evaluation of Educational Achievement (IEA) and following previous studies (Heyneman&Stephen, 2004), several recommendations have been issued for the planning of balanced, fruitful survey. Mainly of those related to the procedures and the sampling methods of such work (Cochran, 1977) and to the attention that must be devoted to the framework and to non-sampling errors in the analysis (Lessler,1992).

In a view of performing a cross-country analysis of the curricula, the definition of 'curriculum' itself has different meanings in different contexts of the educational research (Beauchamp, 1986; Walker, 2003). There are few substantive distinctions between those meanings (Clements, 2007). To have a global vision of the curriculum, the analysis of the official national documents is not enough, but the investigation of the implemented and perceived curriculum has to be done (Cochran, 1977).

To emphasize this aspect van den Akker (2003) proposed representing the curriculum as a spider web in which the main subjects and aspects of the curriculum are visualized and the curricular research takes place at different levels. Rationale, aims and objectives, content, learning activities, teacher role, materials and resources, grouping, location, time, and assessment are the main items taken into account in this approach. Within this framework, it is therefore necessary to develop questionnaires and interviews aimed to investigate all the aspects of the curricular spider web at the level of teachers and students (Kuiper et al. Kuiper, Folmer, Ottevanger and Bruning, 2011).

RESEARCH QUESTIONS

The questionnaires developed in the study, were aimed to investigate the elements of the curriculum spider web as perceived by teachers and students. In particular, for the learner questionnaires, five main aspects of the curricular spider web were addressed: learning activities, time, materials assessment and location, and an additional item, “attitude and motivation” was added to research. For each of those aspects, pupils’ answers have been analyzed to investigate their particular perception in ten European countries, taking part in the research and to compare them on a cross-country level. In this contribution, the results for Italian and Polish 11 years old learners are contrasted and compared.

Therefore in the above-mentioned group the research questions have been posed as following:

RQ1.Are students interested and motivated to study mathematics, science and technology (MST)?

RQ2.Which are the learning activities most used in schools?

RQ3.How much time do pupils spend on MST?

RQ4.Which are the learning materials that pupils use in schools?

RQ5.How pupils are assessed?

RQ6.Where do the lessons take place?

INSTRUMENTS AND METHODS

Three different types of questionnaires have been developed to investigate teachers’ and the students’ perceptions of the curriculum: two for students and one for teachers. All of the questionnaires are structured with multiple-choice questions and a few open questions. Questionnaires are composed in sections in accordance to the elements of the curricular spider web.

The questionnaire for the 8 year old students contains 96 multiple-choice questions and one open question, questionnaire for 11 and 13 years old combines 108 multiple-choice questions and 7 open questions and the two questionnaires for teachers have altogether 155 and 138 items for Mathematics and Science/Technology, respectively.

The questionnaire for the 11 years old pupils is structured with 15 items on motivation, 27 on learning activities, 21 on materials and resources, 12 on location, 6 on time, 27 on assessment, and 6 open questions concerning learning activities and one open question regarding additional students’ comments. The number and the type of the items have been adjusted to enable to fill in the entire questionnaire in at most one hour. Student questionnaires were completed in the classroom, while teachers could also fill them in at home. In the framework of the pilot study of the SECURE project a questionnaire for the 5 year old pupils was also implemented in Italy, however skipped later on in the main study.

SAMPLE

All over Europe, 1425 teachers' and 8198 pupils' questionnaires were collected (2666 of 8 years old, 2797 of 11 and 2735 of 13) during the school year 2011-2012. In this paper, the analysis of the Italian and Polish data of the 11 years old pupils is provided and discussed. The choice to address this particular age was driven by the consideration that 11 years old represent a pivotal age around which pupils move from primary to secondary education and start to raise the pupils' autonomy and critical thinking. Those two particular countries were chosen for the comparison as having specific situation of implementing not one core curriculum, but either following different core curricula at different ages (Poland) or having three different core curricula to be chosen from by decision of a school (Italy). Among ten countries under research, those two seem also to be quite similar as concerning the cultural background and approach to tradition (i.e. also traditional view of teaching and upbringing).

RESULTS AND DATA ANALYSIS

Data analysis as regards the distribution of the students' replies in each country was done by elaborating the entire collection of questionnaires, discussing significant elements and combining the acquired data with the information coming out of the analysis of the official documents and the data interviews. As example, in Fig.1 one of those graphs is reported.

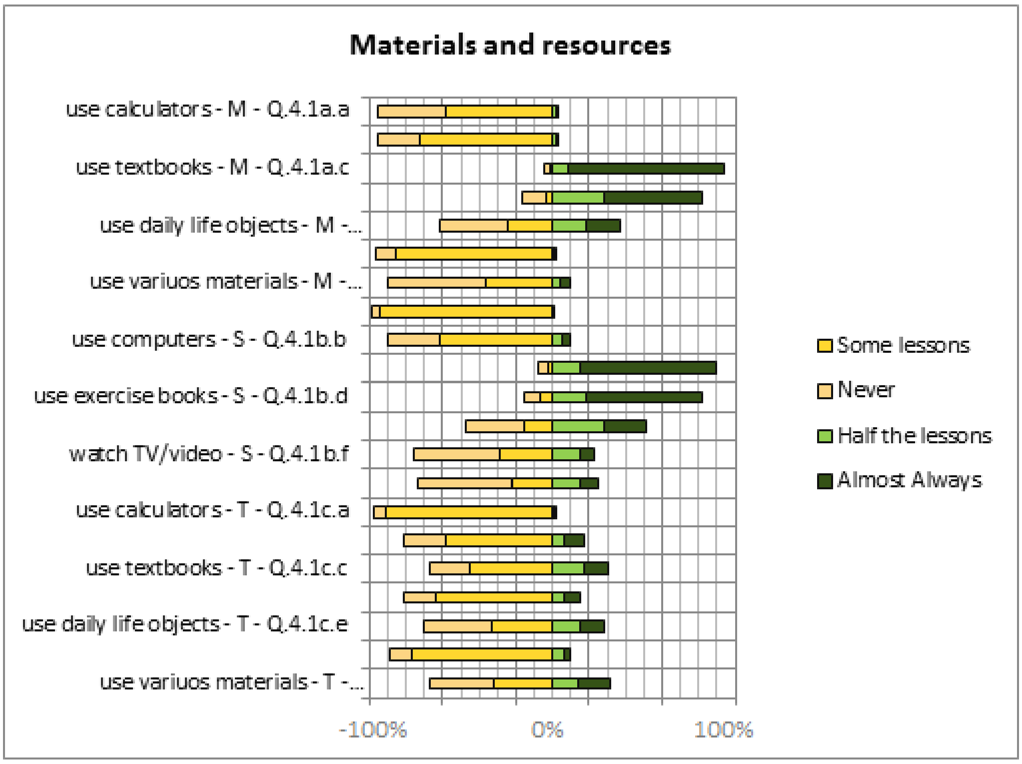

Figure 1. Exemplary results are obtained on 'Materials and resources' items for 11yo learners in Poland.

From the analysis of those graphs, the following considerations emerge for each one of the involved countries.

As concerning learners' attitude towards MST subjects, in Poland, students like MST because of topics, activities and teachers. During MST lessons, students mostly listen to the teacher's explanation and work on their own. Half of the students, in at least half of the lessons had to memorize how to answer questions, both in M and S, and 40% of students do the same in T. Practical activities are more done in ST than in M, however, half of the students do practical activities rarely or never. Work in small groups is more relevant in S and T (18% and 20%, respectively) than for M (10%). For materials and resources (cf. Fig.1), a vast majority does not use calculators and only less than 17% use computers in at least half of their lessons. Exercise books and textbooks are used in MS by 82% and 94%, respectively while in T by 14% of pupils. The use of everyday life objects in half of the lessons of MST is reported, respectively, by 36%, 52% and 28%. The main way of assessment in M are unexpected tests, in S - planned tests, projects and oral tests and in T - assignments. In MS most of the pupils do not go to different rooms dedicated to the subjects. Whilst for T the use of a specific room is reported by less than one-third of students. The majority of all MST lessons are provided inside the classroom. Apart from Technology, most of the students agreed they spent a lot of time on MST in school (M50%, S58%, T37%) and on homework (M49%, S53%, T27%).

In Italy, students like MST with no significant differences between the reasons (topics, activities, teacher), while MS have a higher level of agreement (M70%-79%,S77%-84%) than Technology (57%-64%). With a threshold on "half of the lessons", a mixed picture for the different activities is observed: the prevalent one is "listen to teacher's explanation" (M89%,S81%,T77%), followed by "work on one's own" (M68%,S61%,T73%). "Memorize how to answer" is also relevant (M52%,S50%,T41%), while in T, it is exceeded by "do practical activities" (60%). "Work in small groups on a problem" has a very low percentage of agreement (M10%,S14%,T10%). Calculators, computers and video have a very low or null impact (~10%). For MS the most frequently used methods of assessment are planned tests (57%, 57%) and oral tests (57%, 62%). Textbooks are used at least in half of the lessons (M89%,S93%,T66%). Exercise books are frequently used in MS (M59%,S61%), while in T exercise books are used only by 18%, surpassed by various and daily-life materials (60%,27%). The majority of the lessons are provided inside the classroom (M99%,S83%,T84%). MS are considered as time demanding (75%, 65%), while for T, there is no clear indication (50%).

A comparative analysis between the two countries has been conducted by confronting the normalized distributions of the pupils' answers for each item, using two different representations: a histogram and a radial graph. In the latter, the indicator is obtained assigning to each possible answer ('never', 'few', 'some', 'almost always') a weight and thus calculating the weighted mean of the replies on those weights. In Fig.2 and Fig.3 exemplary graphs of the comparison between the distributions of student answers to questions on attitude towards mathematics and science subjects are shown with the use of histograms.

In both countries, Poland and Italy, mathematics is not liked more than the other subjects, but the contents and the learning of mathematics are enjoyed by more of the half of the pupils, with a greater appreciation in Italy (cf. Fig.2). Science is liked by most of the pupils in Italy and Poland equally (cf. Fig.3).

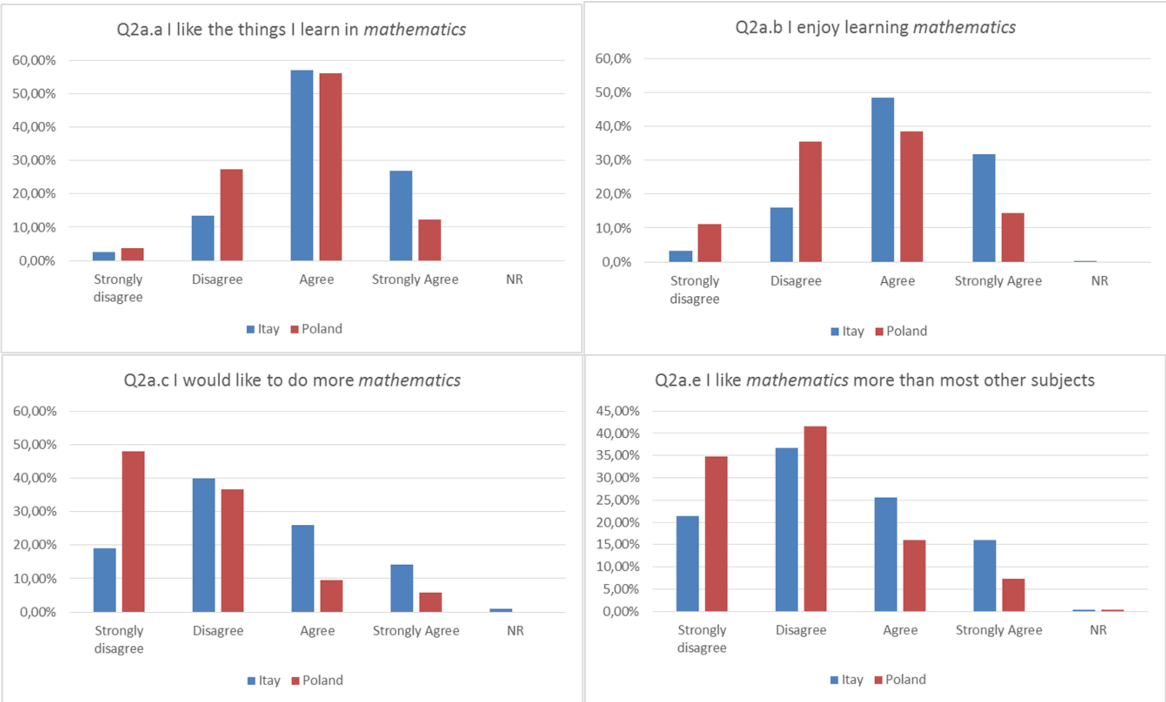

Figure 2. Graphs on comparison between the distributions of the student replies to items concerning attitude towards mathematics subject

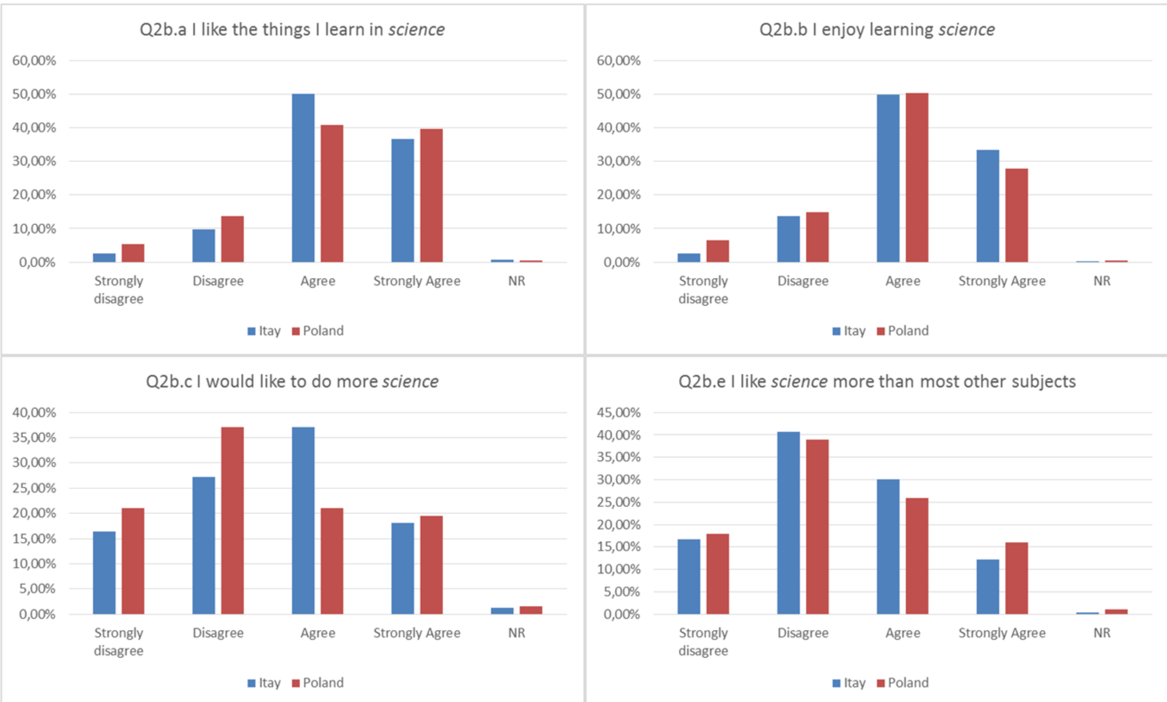

Figure 3. Exemplary graphs on comparison between the distributions of the student replies to items concerning attitude towards science subject

Concerning MST, the ranking of the most appreciated subjects differs from Italy to Poland. In Italy, the most appreciated subject is S (80.3%), followed by M (70.5%) and then T (57.1%). In Poland, although the most appreciated subject is also S (76.3%), Technology (64.1%) is ahead of Mathematics (57.6%). In addition, looking at the strong positive replies, it emerges that they are more relevant to S in IT than in PL while, vice versa, they are given more frequently in PL, than in IT as concern T.

The main activities done in both during the M class are teacher-centered lectures and work alone. In Italy, the teacher-centered lecture is used more often than in PL, where the work alone is more used. Occasionally, a practical work and students' presentation of their work are proposed in Italy and Poland, respectively. Small group work is rarely chosen as the classroom activity. Also for S, the most common activities are teacher-centered lectures and working alone. There are small differences between Poland and Italy: in the former, there is more work done alone than in the latter, where the lectures are more teacher-centered. Presentation of the results is more used in Italy than in Poland, where a small group work is done more often. Practical activities are done equally frequently in both countries. In T classes, working alone and memorizing are used equally often in both countries, while teacher-centered lecture, a practical work and presentation of the students' own results are done more often in Italy. During the T classes more small group work is reported in Poland than in Italy.

For each subject a characteristic distribution of the learning activities emerges, but there are also common elements among the subjects. In Italy, a small group work is almost never used at all. Teacher-centered lectures and working alone are the most frequently proposed activities. Memorizing is a shared and common activity implemented for all of the subjects. In Poland, in addition to the teacher-centered lectures and working alone there is more focus on practical activities.

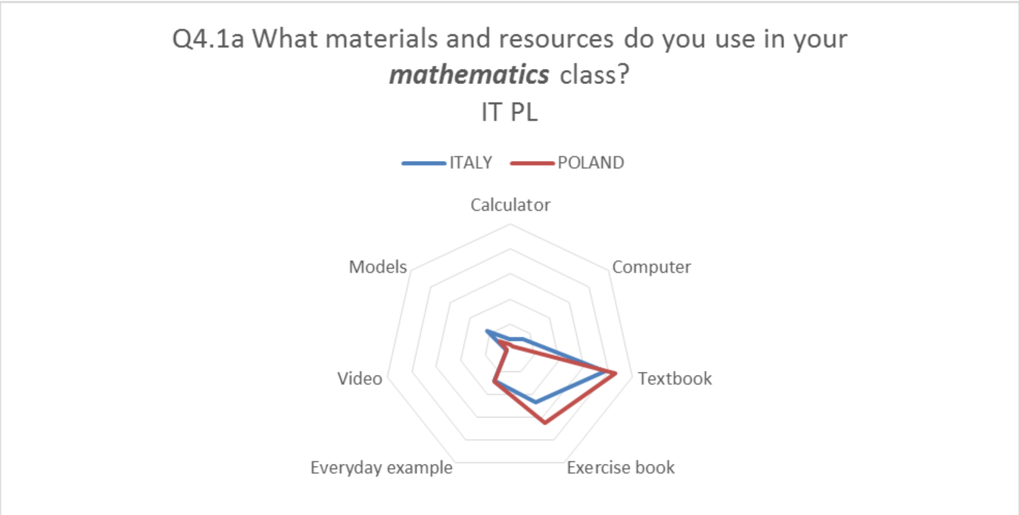

Figure 4. Exemplary graph on comparison between the distributions of the student replies to items concerning use of materials and resources in mathematics subject in Italy and Poland

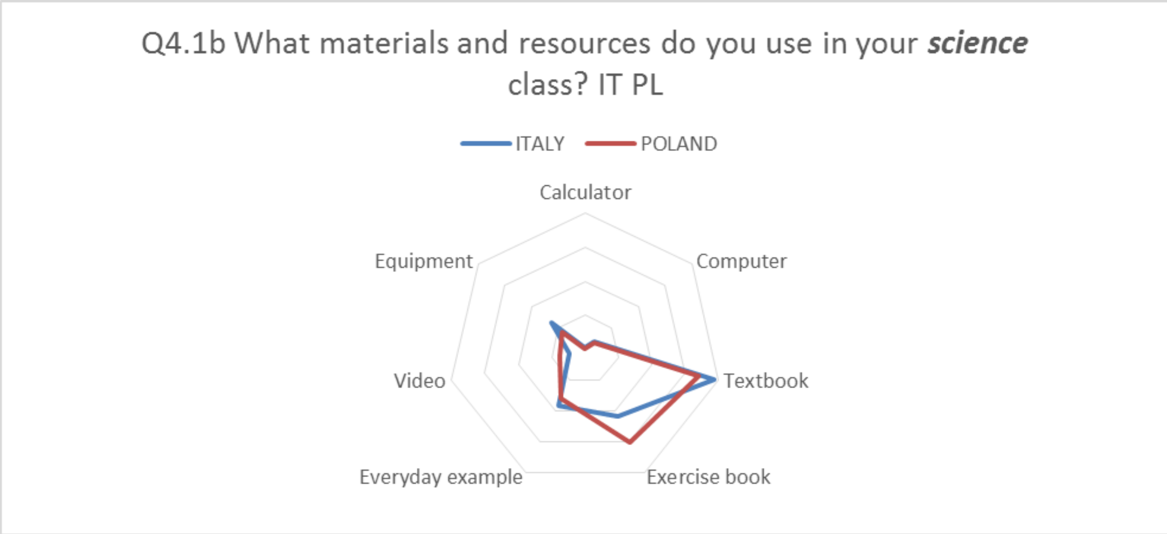

Figure 5. Exemplary graph on comparison between the distributions of the student replies to items concerning use of materials and resources in science subject in Italy and Poland.

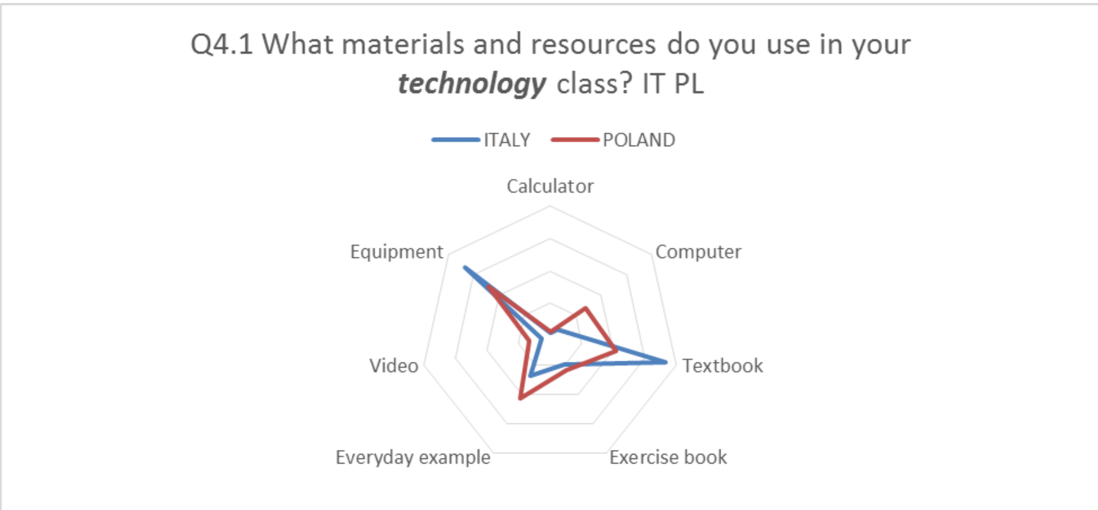

Figure 6. Exemplary graph on comparison between the distributions of the student replies to items concerning use of materials and resources in technology subject in Italy and Poland.

As regards learning materials, there is a high similarity between Poland and Italy in M (cf. Fig.4): calculator, computer and video are never used, everyday examples are used sometimes, textbooks and exercises book are used almost all the time. In S (cf. Fig.5), textbook is the most common material used in both countries, while exercise book is used more frequently in Poland than in Italy. The use of everyday objects is comparable between the two countries, while the use of equipment is more common in Italy even if it is occasional. Calculators and computers are almost never used during S lessons. In T (cf. Fig.6), the distributions between the countries are quite different: in Italy, textbook and equipment are the most often used materials, while in Poland those materials are accompanied by the use of computers and a more extensive use of everyday objects.

In both countries, M lessons usually take place in the non-specific classroom, with the exception of some cases in which M is taught in devoted classes, mainly in Poland. Situation in S is similar to M, but there is a small increase of the percentage of students who's lectures are held in a devoted room, mainly in Italy. In Italy and Poland the classroom is the main location for T, and in both countries, the percentage related to the devoted classrooms is increased with respect to S and M. In particular, in PL this case is more relevant.

Italian students recognize M and S as more time consuming than the Polish ones, but the time spent doing Mathematics at school is longer than the one devoted for S, while T is considered less time-consuming, especially in Poland.

Italy and Poland have a lot in common with respect to the use of written tests in M, but they differ as concern the second main type of assessment. In Italy, it is the oral interview, while for Poland it is an unexpected test. In S a diversity of ways, in which the teachers assess the students work is observed in Poland, while in Italy it emerges that the central role of the written test and the oral interviews prevails. In Poland, the assessment of projects and tasks are relevant, while in Italy several strategies are frequently used (with the exception of the unexpected test and the evaluation of students presentation).

DISCUSSION AND CONCLUSION

A big amount of analogies and differences emerge from the comparison of the results obtained from questionnaires of 11 years old learners in Italy and Poland. The analysis enables to sketch a general picture of MST education at that age in both countries. In particular as concern M, Italian 11 years old students describe it as mainly held in classrooms, using textbooks, or working sometimes alone, mostly listening to the teacher that is able to transmit the passion for math. In Poland, M is done in classrooms, using textbooks and exercise book, working alone and listening to the teacher.

In Italy, S is liked by pupils for what they learn and for the activities held in class; S lessons are mainly held in the classroom, with prevalent use of the textbook and listening to the teacher's explanation. In Poland, S lectures are also held in the classroom, using textbooks, doing exercises, listening to the teacher and working alone.

In Italy, T is mainly done in the classroom with several type of activities: listening to the teacher, working alone, doing practical works and using textbooks. In Poland, it is done both in non-specific classroom or in a devoted room, working alone or listening to the teacher.

It can be summed-up that despite different curricula, MST education has got a lot in common in Poland and Italy, showing a picture of more passive and traditional teaching, with not much emphasis given to practical work and use of other materials than text books. Furthermore, assessment strategies are also quite similar in both countries, with huge attention paid to written and oral tests. Although the investigation of reasons for such similarities is not in the scope of the current research and needs further studies, the authors would seek for possible explanation among common, traditional approaches to education and upbringing of young generations in both countries.

ACKNOWLEDGEMENT

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IDENTIFYING MISSING TYPES OF NORDIC RESEARCH IN SCIENCE EDUCATION

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Abstract: In order to get comprehensive picture of science education research and specifically identify overlooked research topics in this field, a new way to categorise research papers was developed. The new categorisation system is based on the didactic triangle, a theoretical model describing the elements of teaching-studying-learning processes, which we have extended in our work. We started with the analysis of in total 19 physics and chemistry education papers in two annual Finnish conference series revealing that students' attitudes, understandings and their learning styles, as well as teachers' pedagogical activities were well investigated areas, whereas less emphasis was put on society level studies in this data set. With the 84 papers published in NorDiNa (2005-2012) we had an opportunity to extend the view to a wider field of research in the Nordic countries, where for instance the society level studies were more frequent. Our analysis demonstrates that the developed categorisation system could be used to trace the differences and missing types of research foci in different publication forums. Moreover, the new categorisation system also supports meta-level analysis of published research papers and thus contributes to the discussion about the goals and the present state of science education research.

Keywords: science education, meta-analyse, didactic triangle, paper categorisation, new research topics

BACKGROUND

There are obvious problems in science education, especially related to the popularity of studying science. Altogether, there is a need to improve science education, to enhance the recruitment, motivation, and engagement of students. This is naturally the goal of applied educational research. The number of science education research papers seems to increase annually. Authorities such as European Commission and the national academies and boards of education plan and execute research strategies and framework curricula that contribute to the trends and topics the researchers follow and take under investigation.

However, too rarely we pause in order to elaborate whether or not the different educational areas are researched in sufficient extent. Our experience suggests that crucial improvements cannot be gained by changing some details in the educational process but we have to gain a holistic understanding. Our current research is an attempt to identify and define such areas that have been bypassed in the field of science education research and thus to provide a tool for identifying valuable new research questions.

Previous interesting approaches to categorise science education research papers have been based on papers published in several scientific journals over ten years (Tsai & Wen, 2005; Lee, Wu, & Tsai, 2009; Tsai, Wu, Lin, & Liang, 2011). We note that the above studies include an analysis on what educational level (from preschool to university/graduate level) the papers concern. We decided to add the dimension presenting the scope of the research, i.e., whether it concerns course, organization, society, or international level issues. This provides a more sophisticated and holistic way in our analysis.

Characteristic of the previous studies is that they are based on data-driven analysis of a pool of papers. Therefore, it is not possible to identify categories that do not exist in that pool. While we are looking for a holistic view, we base our categorisation on a theoretical model, which suggests that certain categories should exist (which can be empty in the analysed data pool). Our analysis is based on Herbart's didactic triangle (*cf*. Peterssen et al., 1989), which describes three main elements of a didactic system (teacher/student/content) and their interrelations. It has been developed further by adding the relation between the teacher and the students' studying and learning processes (arrow A in Figure 1), which can be seen as scaffolding and which reflects the didactical teacher-student relation (Kansanen, 2003; Kansanen & Meri, 1999). Other developments have been suggested, for example, by Toom (2006) who developed the model to describe teacher's tacit pedagogical knowing. Bergamin (2006), on the other hand added a community node to the original triangle transforming it thus to a tetrahedron which allows thinking about the instructional phenomena at larger context. In addition, Goodchild and Sriraman (2012) summarize how the didactic triangle has been developed further and applied it in the area of mathematics education.

The starting point of the present project was the doctoral thesis work by Kinnunen (2009) where the Kansanen's version of the triangle (Kansanen, 2003; Kansanen & Meri, 1999) was extended by adding a relation reflecting student's feedback on teacher's pedagogical actions (arrow B, Figure 1). In addition, the triangle was put into a larger context, where also the organisational and society level activities were taken into consideration. This widened the applicability of the didactic triangle as a base for categorising research since we are no more confined to an individual teacher or a single classroom. There is also an obvious need to include the relation of science to society in the analysis as there is even a trend to include these relations in the Nature of Science concept – teaching and learning about science and society has been discussed in the relation of nature of science already over several decades (see e.g. Ziman, 1980; Aikenhead & Ryan, 1992). More detailed description of the development of the multi-layered didactic structure is published in Kinnunen (2009).

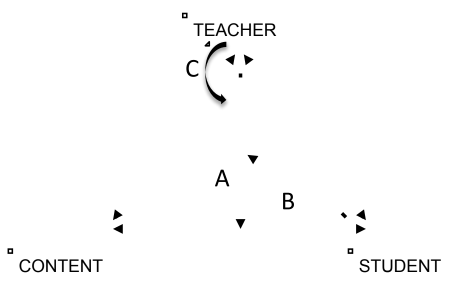

Figure 1. Didactic triangle

In the current study we use the version of the multi-layered didactic structure where an additional relation describing teacher's own reflections on the pedagogical actions (arrow C, Figure 1) is also visible (Kinnunen, Lampiselkä, Malmi, & Meisalo, 2013; Kinnunen & Malmi, 2013). We also extend the existing multi-layered didactic structure by adding the international level (Figure 2), as it is obvious how to include this global level with corner concepts 1) mankind or international organisations like UNESCO, OECD/CERI, etc. 2) citizens of nations, and 3) international recommendations for goals/contents.

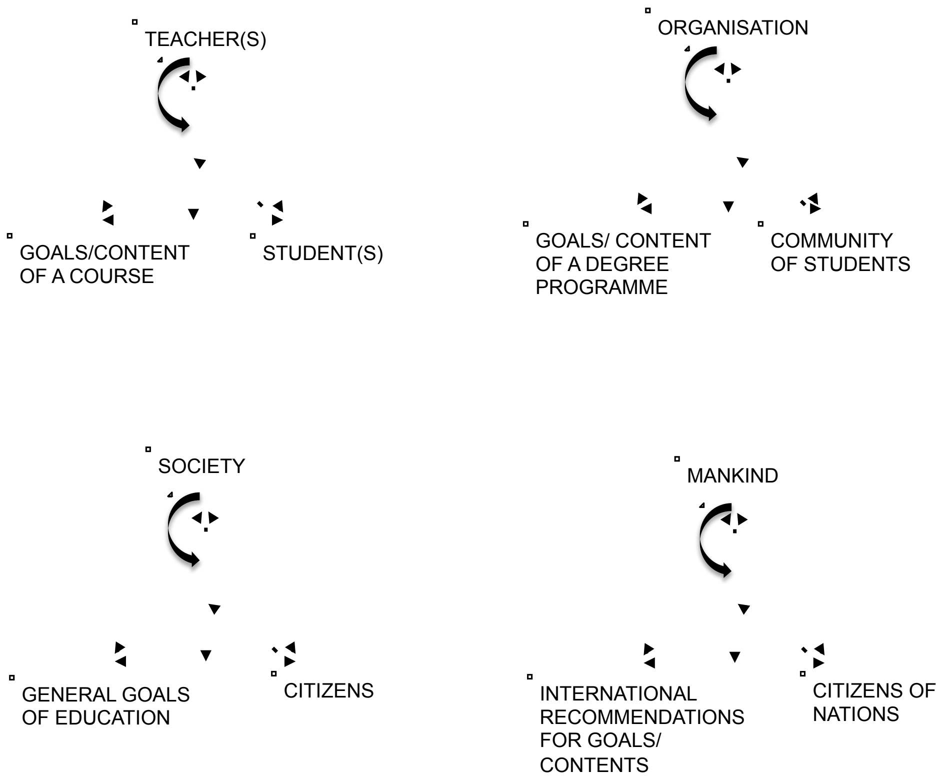

Figure 2. Four levels of the multi-layered didactic structure: course, organization, society, and international levels.

METHOD AND DATA POOL

The eight main categories we use in this paper are derived from the multi-layered didactic structure (Figure 1). The first three categories (see Table 1) are derived from the three main elements of the instructional process, visually expressed as the three vertices of the triangle (teacher, student, goals/contents). The categories four to eight are derived from the relations between the vertices or the vertex and another relation (the arrows in Figure 1). Each category consists of four levels (the individual, organization, society, and international levels). We do not present or justify our categories in more detail here while the origins are discussed thoroughly in the monograph by Kinnunen (2009) and in Kinnunen, Meisalo, and Malmi (2010).

The new categorisation system has been successfully applied to analysing international computing education research papers (Kinnunen et al., 2010), engineering education research papers (Kinnunen & Malmi, 2013) as well as science education papers in Finland (Kinnunen, Lampiselkä, Malmi, & Meisalo, 2013). In this paper, we present our work where we extended the latter analysis by looking also at science education papers in the Nordic countries. Thus, the data pool for this research consists of peer reviewed research papers published in the proceedings of the Annual Symposia of the Finnish Mathematics and Science Education Research Association (FMSERA) over years 2009 – 2010, proceedings of the Annual Symposia of the Finnish Subject Didactics Research years 2008 and 2010 (no papers fitting our criteria were published here in 2009), and research papers on chemistry and physics education in NorDiNa journal (2005-2012).

Both FMSERA and Annual Symposia of the Finnish Subject Didactics Research are annually organized national conferences. Presentations of papers are accepted in Finnish, Swedish, or English. The conferences are targeted mainly for researchers, but participants include also schoolteachers in the areas of the conference. We may interpret, however, that the peer-reviewed papers in the Conference Proceedings are written primarily for the researcher community. The NorDiNa journal defines its focus and scope, as follows:

> *NorDiNa is a Nordic journal of science education publishing scientific articles in the field of science education; both research based and reflective perspectives. Articles on related topics such as technology and geography are also welcome. In addition to scientific articles we publish descriptions of curriculum development, ongoing projects and short abstracts of dissertations in the field. Contributions are in English as well as in Swedish, Danish and Norwegian. All articles have an English abstract and title regardless of the article's language.*[1]

NorDiNa accepts papers from all countries. However, most articles in our NorDiNa data pool origin from Nordic countries, and thus reflect the Nordic population of researchers.

To be more exact, our analysis took account of papers that focused on education in physics, chemistry or integrated natural sciences, whereas papers focusing on biology, geography or mathematics education were left out at this stage of the research. Papers on technology education were included if they were explicitly focusing on chemical or physical technology; otherwise the papers were regarded as out of scope. We made the decision to focus on physics, chemistry and integrated natural sciences based on our own professional interest and expertise of our research group.

Primarily, we approached the analysed material deductively but inductive content analysis type reading was used also (Patton, 2002). The categorisation system has its origin in the didactic triangle and the categories were predetermined based on theory and while reading the journal articles we tried to match each paper into pre-existing categories. However, we found out that not all research papers fitted in the predetermined categories. Some papers were simply excluded from the data pool as mentioned above and some other papers led to the decision that refinement in the categorisation scheme was needed. For example, the resolution of the category 7 was improved when a new subcategory was added in it. Also the whole categorisation system was improved when we added a new analysis layer (the international level) to the typology. Hence, the reading and analysing procedure included both deductive and inductive approaches of content analysis. One could regard our method as abductive content analysis method, but we think that in abductive content analysis method the researcher should use both the deductive and the inductive approaches more or less equally. This is not the case in our study. We used mainly deductive content analysis method with small but important inductive content analysis approach involved. Therefore we separate our analysis method from the abductive method and regard it as majorly deductive, to lesser extent inductive method.

In praxis, the four authors of this paper read each of the papers individually and categorised them according to the typology. Our goal in the content analysis was to aim at understanding the research holistically, not just sorting the articles by the abstract or the research questions. This meant that our analysis was not based merely on the content of the study design chapter but on the more holistic understanding of the entire article all the way from the objectives of the study to the results and discussions of the study. When analysing the papers we made notes on 1) the pedagogical aspects the paper focused on. The paper may focus on one or more pedagogical aspects at the same time. In some cases, some categories were deemed minor (side focus), if their role in the paper was smallish. 2) We also made notes whether the paper discussed course, teaching organization, or society level issues or if it was on the international level. 3) Finally, we also identified on which educational level(s) the paper focused on. We identified the following levels: preschool, primary, secondary, tertiary, and other in which we classified papers concerning professional development, informal learning and doctoral training. For instance, the study by Lavonen et al. (2005) looked at which physics contents and contexts lower secondary pupils find interesting. This study focuses on pupils' interest and attitude towards content and goals and can thus be placed in category 5.1. Respondents were a representative sample of a certain age cohort in lowed secondary school in Finland and therefore the results can be placed to the society level.

The team categorised the papers reading them first individually and assigning them preliminarily to different categories. However, the individually made categorisations were tentative and we used them as a starting point for collegial discussion during which we compared the outcomes and discussed carefully the possible disagreements until full agreement was reached for each paper.

RESULTS

In the Finnish conference papers (N=19) we found 40 foci (32 main foci, 8 side foci). In average the papers had 2.1 foci (min=1, max=4, SD=1.6). The spectrum of the pedagogical foci in the Finnish conference papers on different categories and educational levels is shown in Table 1. The table highlights what the researchers have found particularly interesting and worth studying in Finland on these forums. The sample is small, but we can clearly make some observations. The main foci of the research papers in the data are students' understanding and attitudes (Category 5.1), results on students' actions (Category 5.3), and teachers' pedagogical actions (Category 7.3). Table 1 also shows the aspects of the instructional process that are overlooked. For instance, there were no studies that focus on the relationships between, for example, a community of students and the teaching organization. There were neither any studies on teachers' conceptions of students' understanding of the goals and contents of the course (Category 7.1). Overall, Table 1 shows that most studies focus on the course and the organization levels whereas society level studies are rare.

In NorDiNa papers we found altogether 160 pedagogical foci (135 main foci, 25 side foci) in the analysed 84 papers. On average, the papers had 1.9 foci (min=1, max=5, SD=0.99). The distribution of foci between different pedagogical aspects is summarized in Table 2. Many publications report a study that was done at the teaching organization level, which is clearly different from the Finnish conference data. Studies that were done at a course/classroom level were also relatively frequent. There were also some society level studies, and only few studies that discussed the pedagogical phenomena at the international level mainly comparing findings from different Nordic countries. We interpret these findings that authors of papers in our data pool (teachers and researchers) are primarily interested in the developments and improvements of the educational environment on the local level rather than in the broader national or society frame.

Content and goals were studied reasonably often (category 1). Researchers' interest towards students-and-teachers-related aspects varied. Students' perceptions and attitudes towards contents and goals (category 5.1), students' actions to achieve the goals (category 5.2), and the learning outcomes (category 5.3) were frequently studied pedagogical aspects. There is not much difference with the Finnish data. At the same time, students' characteristics (category 2) and students' perceptions and opinions on the pedagogical interventions (category 8) were less studied areas. In other words, the researchers have paid a lot of effort to find out what contents should be taught and how the students have perceived these contents from the attitude or the substance point of view.

Table 1

Spectrum of chemistry and physics education research articles in Finnish conference proceedings. There were no international level publications in this data set. Frequencies in parentheses refer to side foci.

Categories	Course	Organization	Society	Total
1. Goals and content	2	-	1	3
2. Student(s)/community of students/ citizens of a nation	(1)	2	1	3(1)
3. Teacher(s)/organization/society-level educational bodies	-	1	-	1
4. Relation between student(s)/community of students/citizens and teacher(s)/organization /society-level educational bodies	-	-	-	0
5. Relation between student(s) and goals and content				
5.1 The understanding of and attitude about goals and content that the student(s)/community of students/citizens have	2	3	1	6
5.2 The actions (e.g. studying) the student(s)/ community of students/citizens do to achieve the goals	-	1	-	1
5.3 The results of the action of the student(s)/community of students/citizens	4(1)	2	-	6(1)
6.Relation between teacher(s)/organization /society and goals/content	-	1	-	1
7. Relation between teacher(s) and studying				
7.1 The conceptions of teacher(s)/organization/ society of students' understanding /attitude on goals/content.	-	-	-	0
7.2 The conceptions of teacher(s)/organization /society of students' actions towards achieving goals (e.g., studying)	-	-	-	0
7.3 Pedagogical activities of teacher(s)/ organization/society	5	3(1)	(1)	8(2)
7.4 Reflections of teacher(s)/organization /society on their own pedagogical actions	-	2(1)	-	2(1)
8. Relation between student(s)/community of students/citizens and teacher's/organization's /society's pedagogical means to enhance learning	1(1)	(1)	(1)	1(3)
Total	14(3)	15(3)	3(2)	32(8)

Table 2.

Distribution of chemistry and physics education research articles in NorDiNa (2005-2012). Frequencies in parentheses refer to side foci.

Categories	Course	Organization	Society	International	Total
1	1	8(3)	8(2)	2	19(5)
2	1	2(1)	2	1	6(1)
3	-	2	-	-	2
4	1	1	1	-	3
5.1	5(1)	14	5(1)	1	25(2)
5.2	6	6(1)	-	-	12(1)
5.3	7(1)	3	2	2	14(1)
6	-	4(1)	-	-	4(1)
7.1	-	1	-	-	1
7.2	1	-	-	-	1
7.3	9(2)	14(4)	4(2)	-	27(8)
7.4	4	11(3)	-	-	15(3)
8	1(1)	4(2)	1	-	6(3)
Total	36(5)	70(15)	23(5)	6	135(25)

In NorDiNa papers teachers' pedagogical interventions (category 7.3) was a popular focus like in the Finnish data, but here also the teachers' reflections (category 7.4) were studied much. Teachers' characteristics (category 3), teachers' perceptions/opinions/understanding of the contents and goals (category 6), teachers' perceptions' of students' understanding of the contents and/or goals (category 7.1), and teachers' perceptions of students' actions towards achieving the goals (category 7.2) were much less studied aspects. Students' and teachers' perceptions of each other (category 4) appeared also as one of the less interesting aspects of the instructional process.

DISCUSSION AND CONCLUSIONS

The research shows the benefit of taking the multi-layered didactic structure as a starting point for the development of the categorisation system. It helps researchers to discern the various aspects of the instructional process and to analyse which aspects are less studied. The original categorisation scheme was improved during the process, differences and similarities among different categories became more evident, and finally, the whole scheme became more refined. In conclusion, the majorly deductive partly inductive content analysis type reading (Patton, 2002) combined with the developed categorisation system and peer discussions seemed functional and produced meaningful categorisations. We conclude that the developed typology was successfully applied to analyse two different sets of data, and we expect that it can be used to analyse research papers in many other contexts, too.

The small share of society level studies is noteworthy. Is it possibly regarded as an uninteresting research theme for science education or is it regarded something, which cannot be changed? It might also be that authors choose other publication venues for society level studies, we can find number of such cases easily. Moreover, teachers' reflections towards their own teaching and students' feedback on it are poorly investigated at all levels and clearly more research in this field is needed.

The results also illustrate the potential of the used categorisation system to reveal differences of publication venues. Most publications in Finnish national level conferences (FMSERA and Annual Symposia of the Finnish Subject Didactics Research) discuss teaching organization or course level aspects of the instructional process reflecting perhaps that those conferences are clearly national conferences. These conferences are also popular among researchers new to the field or researchers who wish to inform science teachers about their findings. It is also understandable that the conference data reflect more the interests of researchers in the beginning of their careers and they have more narrow interest profiles. Thus the popularity of course and organization level foci is understandable. On the other hand, foci in NorDiNa data are distributed more broadly also on society and international levels reflecting perhaps also broader, and international, audience of the journal.

The use of the developed categorisation system will continue and next we are aiming at publishing our work in the NorDiNa journal in more detail. Our data pool consists of articles published in this particular journal and we hope that our analysis would help both the journal editorial board in their work and especially the Nordic researchers might find interesting our findings of the categorisation. Our next extension might be that we include biology oriented didactical articles to the data pool. One of the reasons for this is that in many Nordic countries biology is taught together with physics and chemistry as an integrated subject depending on the educational level. Also we are aiming at applying our instrument to international level journals, such as International Journal of Science Education, and international level conferences, such as the European Science Education Research Association conference publications in order to get more comprehensive view of the distribution of the research foci in science education.

NorDiNa journal publishes articles in English, Swedish, Danish, and Norwegian. Roughly estimated half of the articles are published in English whereas articles written in Swedish, Norwegian and Danish language together comprise the other half. The members of our research group are native Finnish speakers but with a good competence in reading Swedish and English language. Written Norwegian and Danish resemble Swedish to the degree that it is possible to understand them rather well if one is fluent in Swedish[2]. One of strengths of our research methodology is that all final decisions concerning the categorisations were based on discussions and mutual understanding. This diminishes the possibility to language-oriented misinterpretations and increases the validity of the decision made. However, we see that some sort of international collaboration would increase the validity of the methodology. Therefore, we encourage our Nordic and all other colleagues to use the developed analysing instrument in order to test whether or not they as native speakers will end up with same results that we have made.

NOTES

[1]Endnote. http://www.naturfag.no/tidsskrift/vis.html?tid=1519975

[2]Endnote. However, we acknowledge the possibility that we have not reached some fine nuances in the articles written in non-native languages to us, especially in Norwegian or Danish language.

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