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