Enhancing Innovation and Creativity in Science Teaching
STENCIL Annual Report n.3
This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

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ACKNOWLEDGEMENTS
We would like to thank all teachers, educators and researchers for sharing their experience and supporting this publication.

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INTRODUCTION

Developed within the frame of the STENCIL NETWORK, this book aims to supplement the contents of the STENCIL Annual Reports n.1 and n.2, by discussing current research initiatives and innovative practices, under the scope of making explicit practitioners’ voice to the policy and researchers’ calls for innovation and creativity in science teaching.

The first STENCIL Annual Report addressed science education from the perspective of national policies and reform frameworks and orientations, complemented with expert positions and best practices on the themes: teacher training, collaborative approaches, and new pedagogical approaches, key competences development and diversity. The second STENCIL Annual Report provided practical content for teachers, by making visible the current research endeavours towards change on the themes of teacher training, ICT and new technologies, equality.

The orientation of the Annual Report n.3 is guided by the outcomes of the analysis of the STENCIL catalogue and stakeholders questionnaires, which provided feedback on teachers’ interests and needs, as well as identified critical problems and gaps in introducing innovation and creativity in classrooms. As reported in STENCIL Guidelines for teaching and learning science in a creative way,

‘Research in Science Education has produced plenty of examples of good practices focused on innovation, but their impact on school teaching at large scale is still very problematic. Initiatives and activities that can bridge the gap between research and school practice should be encouraged.’

(Recommendation 1, ‘Guidelines for teaching and learning science in a creative way’)

In the view of the above recommendation, this book is developed under the ambitious aim of contributing towards bridging the gap between research and school practice: it aims to provide a ground for science teachers’ reflective practice, as a prerequisite of actual engagement in implementing innovation and creativity in the classroom settings.

Effective self-reflection is considered as a key component in the process of successful implementation of innovative and creative initiatives in science teaching. It is an iterative process involving teachers creating meaning around their teaching practices, improving the understanding of their teaching activities and - in this way - introducing innovation and creativity in the educational settings. Under this frame of mind, this book aims at providing a stimulus for science teachers’ reflective practice, by focusing on current research issues in thematic areas pertaining to everyday school practice and which are of great interest to practitioners. These are presented in the form of expert positions and teachers’ reflections and feedbacks,
complemented with best practices targeting to promote innovation and creativity in classrooms.

The book draws contributions from a selected group of professionals on thematic areas guided by teachers’ interests and needs, as evident from the analysis of the STENCIL catalogue and stakeholders questionnaires. Some of the main outcomes of this analysis that provided the impetus of the major themes addressed in the document are the following:

‘IBL (Inquiry Based Learning) methodology is considered one of the main carriers of innovation in science education. But the width of IBL potential seems still far from the school s and teachers’ potential. Good practices focused on IBL should be disseminated and researchers in collaboration with teachers should be encouraged to deeply investigate the factors that still hinder the IBL spread.’
(Recommendation 2, ‘Guidelines for teaching and learning science in a creative way’)

‘Although ICT is widely promoted by central authorities, large implementation gap remains. Activities and projects that aim to revise traditional curricula should be boosted and teachers should be encouraged to explore ICT tools and be free to change their school practices consequently.’
(Recommendation 3, ‘Guidelines for teaching and learning science in a creative way’)

‘The quality of education is greatly influenced by the quality of teachers and their skills. Effective and sustainable communities of practice are recommended to be designed with specific and shared educational aims.’
(Recommendation 4, ‘Guidelines for teaching and learning science in a creative way’)

‘The width of the innovative potential of the recommended methodologies and issues shows to what extent the complex process of science education innovation requires an extraordinary engagement and participation of the teachers.’
(Conclusions: The teacher of the future, ‘Guidelines for teaching and learning science in a creative way’)

‘The social impact of science due to the so called “gender & minority” issue is not yet sufficiently acknowledged. Initiatives and actions aimed to spread the perception of how and why the gender and minority issue affects on the social impact of science and, vice versa, how science teaching, even implicitly, impacts on the social issue gender & minority.’
In the view of the above-mentioned outcomes and recommendations, STENCIL Annual Report n.3 highlights Inquiry Based Learning (IBL), as a methodology for achieving broader educational aims and as a teaching tool that can contribute to the improvement of the educational performance for the individual learner and the system as the whole. The document also discusses ICT based teaching, both under the scope of promoting equity and as a tool for improving understanding of scientific concepts and processes. Special emphasis is given to the dimension of teacher training and professional development, as it is a key factor in any effort towards the propagation of innovation and creativity in the educational settings.

The book is structured in three parts, those being:

**Part A: Innovating Science Education – Knowledge sharing between researchers and practitioners**
Under the scope that innovative materials and examples need to show not only how to implement new methodologies, but also why and for what, this part addresses the following questions: Innovating science education: towards what, by what, by whom; these questions determine accordingly the three sections of this part:

**Section I: Aims of science education for the future**
Experts’ contributions and practitioners’ feedback address the fields of: Inquiry Based Learning (IBL) in relation of the broader educational aims it seeks to achieve; Information and Communication Technology (ICT) under the scope of promoting equity; Science Education and the World of Work.

**Section II: Methods and tools of science education for the future**
Addressed are the themes of: Inquiry Based Learning (IBL), Tools, Environment and Resources; ‘Traditional’ scientific laboratories vs. virtual ones, discussed by researchers and teachers.

**Section III: Teacher training towards creativity**
Highlighted are expert positions and teachers’ reflections on the themes: ‘alternative’ teacher training programmes; competences of the teachers for the future.

**Part B: Innovating Science Education in Practice – Current creative initiatives**
Best practices targeting to promote innovation and creativity in classrooms are presented, under the scope of promoting teachers self-reflection for successful implementation: the Inquiry Learning concept AuRELIA; ACTIVE SCIENCE™, an innovative tool for promoting scientific education and citizenship; the Physics Club, in which teachers gain practical experience on Inquiry-Based Learning and students
take the role of scientists; the Fibonacci project, aiming at teachers’ professional development on Inquiry Based Learning (IBL); “Investissements d’avenir” and project of the Academy of Sciences, an in-service science and mathematics teacher training programme, focusing on: the relationship with the scientific community and an opening to the world of research and a pedagogy based on inquiry and interdisciplinary.

**Part C: A step towards bridging the gap between research and practice**
The book concludes with a section, in which the outcomes of the experts’ positions, the current initiatives towards innovation and creativity and the teachers’ reflections on the issues are comparably viewed, under the scope of contributing towards bridging the gap between research and school practice.
Part A: Innovating Science Education – Knowledge Sharing between Researchers and Practitioners

This part of the Annual Report n.3 focuses on current research issues on thematic areas pertaining to everyday school practice and which are of great interest of teachers – as evident from the analysis of the STENCIL catalogue and stakeholders questionnaire. These are presented in the form of expert positions and teachers’ reflections and feedback.

Section I addresses the question: Innovating science education towards what?, with the objective to provide a stimulus for reflection on the aims of science education for the future. In the first paper in this section, Foteini Chaimala discusses how Inquiry Based Learning (IBL) methodology comes to support broader educational aims, in relation both to the individual learner and to the society. Following this, Cathrine Tømte challenges our views on Information Communication Technology (ICT), gender and education, by suggesting that the male domination on the entire ICT field is not the case anymore; as such, novel perspectives are needed in order to explore in which ways the gender issue appears in youngsters’ use of and attitudes towards ICT. Last but not least, Stanko Blatnik highlights the dimension of the world of work, discussing whether there should be and how there could be a connection between science education and the industry.

Section II focuses on the methods and tools of science education for the future, by addressing the question: Innovating science education by what?. First, Alexandra Okada contributes in this section, by presenting Inquiry Based Learning (IBL) tools, web-based environments and resources and by discussing the key features, the way they work and the pedagogical approach for IBL. Then, Dimitris Stavrou takes the lead and presents the Microcomputer-Based laboratory (MBL) tools, which have become increasingly popular for the real-time collection, display and analysis of data in the laboratory. Two experimental devices - called respectively as “traditional” and “microcomputer-based” chaotic pendulum are comparably discussed, in order to make these educational advantages of MBL transparent.

Section III addresses the question: Innovating science education by whom, emphasising the dimension of teacher training and professional development towards creativity. Stefan Zehetmeier presents the “Innovations Make Schools Top”
(IMST) project, aiming at establishing a culture of innovation in Austrian schools by proposing action research as a stimulus for teachers to reflect on their professional development. Following this, G-L Baron contributes with an essay on the dimension of competences of the teachers for the future, providing ground for reflection on the changing role of teachers in the view of the technological advances and possible evolutions in the next 20 years.

Each paper is accompanied with practitioners’ reflections and comments on the authors’ positions, with the aim to make evident their voice to the policy and researchers’ calls for innovation and creativity in science teaching.
SECTION I: AIMS OF SCIENCE EDUCATION FOR THE FUTURE

INQUIRY BASED LEARNING IN SCIENCE EDUCATION: FOR WHOM AND FOR WHAT?

EXPERT CONTRIBUTION: DR FOTEINI CHAIMALA (RESEARCHER, ERE GROUP, IACM / FORTH, GREECE)

During the last decade, a consensus has emerged that Inquiry Based Learning (IBL) is a promising teaching and learning methodology for school science. Theoretical positions, current educational policy demands and empirical evidence form a convincing body of arguments in favour of the promotion of IBL in science education (Bell et al., 2010). Why students—though besides scientist, should be engaged in scientific inquiry? Which broader educational aims does IBL seek to address?

As calls for IBL to take a central place in science instruction increase, answers to these questions become important and relevant not only to educational theorists, researchers and policy makers, but also to teachers, the mediators and supporters of innovation endeavours in everyday practice. This paper aims at providing a ground for reflection for science educators, in terms of the links between the purposes of science teaching and IBL methodology. For pursuing this aim, this paper starts with presenting the broader purposes of school science; it then focuses on providing the main characteristics of IBL in science education; finally, it concludes with some remarks on how IBL methodology comes to support the broader purposes for teaching science.

Why do we teach science for?

“Confusion of goals and perfection of means seems, in my opinion, to characterize our age.”

Albert Einstein
Science refers to ‘a system of acquiring knowledge based on the scientific method, as well as to the organized body of knowledge gained through such research’ (EC, 2007). In a more descriptive statement, the term ‘science’ reflects: a) the collection of discrete disciplines with clearly-defined bodies of knowledge; b) the methods and processes of exploring and extending knowledge; c) the people who, using these processes, extend the boundaries of knowledge. These three elements of science (body of knowledge, methods and processes, people) have been evident in curricular documents in science education in the last decades. However, there are differences in the emphasis that has been put each time, according to the broader educational aims that science education should pursue.

Before eighties - when the purpose of science education was mainly to recruit future scientists - an emphasis was put on content knowledge based on teaching of definitions and on experiments which illustrated foregone conclusions (Black, 1993). Mainly after the nineteen’s a growing concern with environmental and socio-scientific issues and with the moral responsibilities of scientists (Hunt, 1988) led to curriculum reforms that gave emphasis to the processes, methods and skills of science, while the first ideas of science for decision-making and for scientific knowledge necessary to fulfil civic responsibilities emerged. Nowadays, a consensus has emerged that science should be a compulsory school subject and that an education in science (with all three content emphasis evident) is important for all school students: not only the minority of those who will be the next-generation of scientists, but mainly the majority who will follow non-scientific careers (Osborne & Dillon, 2008).

Regardless of the student focus groups, there are at least two dimensions in terms of why science should be a compulsory school subject, emerging in the nineties (the

“"The primary goal of science education across EU should be to educate students both about the major explanations of the material world that science offers and about the way science works. Science courses whose basic aim is to provide a foundational education for future scientists and engineers should be optional."

era of ‘debates in priorities’) and still being a definition of the science curriculum in many countries in recent times: the one focuses on the macro-level, arguing for the importance of promoting ‘public understanding of science’ from a societal point of view; the other focuses in the micro-level, where the plea is for ‘personal development of the pupils’.

Public understanding of science: In the question ‘why public understanding of science should be promoted’, different answers and arguments can be found in the literature. Millar (1996) has grouped them into five distinctive categories:

<table>
<thead>
<tr>
<th>The economic argument</th>
<th>There is a connection between the levels of public understanding of science and the nation’s economic wealth.</th>
</tr>
</thead>
<tbody>
<tr>
<td>The utility argument</td>
<td>An understanding of science and technology is practical useful, especially to anyone living in a scientifically and technologically sophisticated society.</td>
</tr>
<tr>
<td>The democratic argument</td>
<td>An understanding of science is necessary, if any individual is to participate in discussion and decision-making about issues with a scientific component.</td>
</tr>
<tr>
<td>The social argument</td>
<td>It is important to maintain links between science and the wider society. Improved public understanding will lead to greater support for science and technology.</td>
</tr>
<tr>
<td>The cultural argument</td>
<td>Science and technology is the major achievement of our culture and that all young people should be enabled to understand and to appreciate it.</td>
</tr>
</tbody>
</table>

Personal development of the pupils: Ratcliffe (1998) argues that the development of the individual pupil is equally important.

<table>
<thead>
<tr>
<th>Main purposes of science education</th>
<th>Subsidiary purposes of science education</th>
<th>Content emphasis</th>
</tr>
</thead>
</table>
| **Intellectual development of the pupils** | Acquisition of content knowledge
Understanding of key concepts of science | Knowledge |
|------------------------------------------|---------------------------------------------------------------------------------|-----------|
| **Development of analytical skills** (critical way of thinking, curiosity, creativity, imagination, skills of questioning and explaining, decision-making) | Use of scientific methods of observation, investigation, interpretation and prediction | Processes
People |
| **Development of practical skills** (observational, experimental skills) | Practice in the laboratories of some standard scientific procedures involving technical equipment | Processes
Knowledge |
| **Development of values and social skills** (communication skills, engagement in debates) | Acquisition of knowledge about the historic and cultural contexts
Acquisition of knowledge about environmental and social applications of science | People
Knowledge |

**Inquiry Based Learning in Science Education**

“I never teach my pupils. I only attempt to provide the conditions in which they can learn”.

Albert Einstein

It is difficult –if not impossible- to give a commonly accepted definition for Inquiry Based Learning; however, some common ground among different definitions exists. Scardamalia & Bereiter (1991) provide an interdisciplinary definition, by describing inquiry as an unpredictable, holistic process of creative development of ideas within a community of learners. For the domain of science learning, Quintana et al. (2004, p. 341) define inquiry as “the process of posing questions and investigating them with empirical data, either through direct manipulation of variables via experiments or by constructing comparisons using existing data sets”. Similarly, Linn, Davis and Bell

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Scientific inquiry is more complex than popular conceptions would have it. It is, for instance, a more subtle and demanding process than the naive idea of ‘making a great many careful observations and then organizing them.’ It is far more flexible than the rigid sequence of steps commonly depicted in textbooks as the scientific method.

AAAS, 2009
(2004) define inquiry as the intentional process of diagnosing problems, critiquing experiments and distinguishing alternatives, planning investigations, research conjectures, searching information, constructing models, debating with peers and forming coherent arguments.

Bell et al. (2010), synthesized various approaches found in the literature and came up with a list of main categories – inquiry processes that characterize IBL in science.

<table>
<thead>
<tr>
<th>Main inquiry processes</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orientating and asking questions</td>
<td>Students make observations or gaze at scientific phenomena that catch their interest or arouse their curiosity. Ideally, they develop questions by themselves.</td>
</tr>
<tr>
<td>Hypothesis generation</td>
<td>It is the formulation of relations between variables.</td>
</tr>
<tr>
<td>Planning</td>
<td>It involves the design of an experiment to test the hypothesis and the selection of appropriate measuring instruments for deciding upon the validity of the hypothesis. Planning also incorporates the use of suitable meta-cognitive strategies.</td>
</tr>
<tr>
<td>Investigation</td>
<td>It includes the use of tools to collect information and data, the implementation of experiments, and the organisation of the data pool.</td>
</tr>
<tr>
<td>Analysis/interpretation</td>
<td>It is the basis of empirical claims and arguments for the proposition of a model.</td>
</tr>
<tr>
<td>Model</td>
<td>Students learn to explore, create, test, revise, and use externalised scientific models that may express their own internalised mental models.</td>
</tr>
<tr>
<td>Conclusion/evaluation</td>
<td>Students extract the results from their inquiry.</td>
</tr>
<tr>
<td>Communication</td>
<td>Students learn how to make claims on the basis of data and to provide reasons why the data support their claims. While communicating, the learners are also forced to reflect their own work.</td>
</tr>
<tr>
<td>Prediction</td>
<td>It is a statement about the value(s) of one or more dependent variables under the influence of one or more independent variables.</td>
</tr>
</tbody>
</table>

Recently, within the weSPOT project\(^1\), an IBL pedagogical model has been proposed, which moves on from other simplistic cyclical IBL models found in the literature. This model is more elaborate regarding the sub-phases, providing a detailed

\(^1\) weSPOT (Working Environment with Social and Personal Open Tools for Inquiry Based Learning) is an EC-funded Research Project under the Grant Agreement no. 318499 of ICT FP7 Programme in Technology Enhanced Learning. For more information on the project: [www.wespot-project.eu](http://www.wespot-project.eu)
A description of things that teachers and students should consider when conducting inquiry (Protopsaltis, Seitlinger & Chaimala, 2013).

As it can be viewed in Figure 1 above, the weSPOT IBL model consists of six phases, placed within the context, that mirror the phases that researchers need to go through in order to conduct research. Each phase consists of a number of activities ranging from five to nine. A key feature of the weSPOT IBL model places reflection at the centre of each inquiry phase, as it views reflection as an integrated process throughout the inquiry activities. The different phases of the model are interconnected, meaning that learners and/or teachers can start their scientific inquiry at any phase, depending on the focus of the curriculum, or even the nature of the specific inquiry. The weSPOT model provides the flexibility to support the different levels of inquiry in terms of students’ autonomy from confirmation inquiry (where the teacher has the absolute control over every phase) to open inquiry (where students make decisions throughout the process). Thus the weSPOT model offers the flexibility for tailored and adapted scientific inquiry, depending on the needs of the curriculum and the expertise and knowledge of the learners.
How IBL comes to support the purposes of school science?

“It is the supreme art of the teacher to awaken joy in creative expression and knowledge. The important thing is not to stop questing. Curiosity has its own reason for existing.”

Albert Einstein

Inquiry Based Learning (IBL) has the potential to provide for the students both as individuals and as members of the society. In regard to the personal development of pupils, it could support the main purposes of science education as exemplified previously in this paper:

<table>
<thead>
<tr>
<th>Main purposes of science education (personal development of the pupils)</th>
<th>How IBL methodology could contribute?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intellectual development</td>
<td>The call for IBL is based on the conviction that science learning is more than memorizing scientific facts and information, but rather about understanding and applying scientific facts and concepts.</td>
</tr>
<tr>
<td>Development of analytical skills</td>
<td>The use of the scientific methods of questioning, observing, investigating, interpreting and predicting is at the heart of IBL method. These activities are linked to skills and competences like critical way of thinking, curiosity, creativity, imagination, skills of questioning and explaining, decision-making.</td>
</tr>
<tr>
<td>Development of practical skills</td>
<td>IBL mirrors the phases that researchers need to go through in order to conduct research. It often incorporates practice in the labs in relation to scientific procedures, activities linked to observational and experimental skills and competences.</td>
</tr>
<tr>
<td>Development of values and social skills</td>
<td>Through IBL students engage in debates, reason and communicate procedures and outcomes. As such, they come in acquaintance with science not as a value-free static body of knowledge, but as a social process and endeavour.</td>
</tr>
</tbody>
</table>

From a broader societal point of view, on the other hand, IBL has the potential to address the main arguments for why public understanding of science should be promoted:
Public understanding of science | How IBL methodology could contribute?
--- | ---
The economic argument | Provides means to increase interest in science, builds skills essential for careers *in* science (future scientists) and careers *from* science (the extensive range of potential careers that the study of science affords)
The utility argument | Promotes understanding of and in science (knowledge, processes and people) which is essential for scientific literacy in a scientifically and technologically sophisticated society
The democratic argument | Cultivates students in the process of discussion, tolerance, reasoning, decision making
The social argument | Focuses on the process of communication, presents science as an integrated part of the society, leading to greater support for science and technology
The cultural argument | Enables to understand science as an endeavour and achievement of our culture

What is the relevance of the above to teachers’ everyday practice? Educators in their everyday practice are called to implement teaching methodologies for achieving specific goals, often relating to the specific contents of the formal curriculum. In doing so, it is often the case that the focus remains on “the trees”, while the big picture of “the forest” remains invisible. By focusing on the “trees” (specific learning outcomes in each lesson), the big picture of why we teach science is often neglected, as well as the process of reflecting on how the teaching methodologies come to support broader educational visions. In the everyday practice, we often neglect that at the end of the day science education is an act *for* and *towards* the pupils; it is a part of education, which according to a definition is

‘the formal part of what adults provide to their society’s children to equip them [...] in the world in which they will find themselves as adults’ (Claxton, 1997, p.76).

This concern for the children, both as individuals and as members of the society, during the act of teaching science is essential and reflection on how our teaching methods address this concern helps towards achieving broader educational aims.

**References**


We found the document Inquiry Based Learning in Science Education: For whom and for what, interesting and useful in our work in school.

We strongly agree that Inquiry Based Learning (IBL) is a promising teaching and learning methodology for school science. However, in this moment it is not widely use in the schools in Slovenia. It is used mostly in programmes, which are not part of formal education, as for example Young Researcher for Development of Šaleška Valley, in which many pupils and high school and university students are working on research projects (in last 30 years in framework of this project 2200 young researchers implemented 1100 projects). The work of researcher was supported by 1139 mentors. Young researchers – participants of programme are profoundly engaged in the scientific inquiry. Although results of this programme are outstanding, there is no transfer of this good practice in the formal education.

We believe that articles like this can significantly influence on and trigger more intensive use of Inquiry Based Learning, as promising teaching and learning methodology for school science.

Especially important parts of article are Public understanding of science and personal development of pupils. In this moment science is not very popular in Slovenia, there are a lot of pseudoscience and non-sceptical thinking, and it is very important to develop use of scientific methods and critical thinking as soon as possible, starting from elementary school. The argument from article “that an education in science (with all three content emphasis evident) is important for all school students: not only the minority of those, who will be the next-generation of scientists, but mainly the majority who will follow non-scientific careers” is exactly what we need in our schools.

The described IBL model developed in the project WeSPOT is interesting and in our opinion could be used in schools as teaching and learning methodology.

Of course the implementation of IBL particularly of weSPOT model requires additional efforts and resources (education, training, support of management), however the long-term benefits of its implementation will be significant.

Although the article will help teacher reflect on and implement innovation in everyday teaching practice, there are some important elements, which have to be taken in account, when we are going to implementation of IBL in school, namely:

- The curiosity of students is important for successful IBL implementation. How to motivate students to become curious especially in science is not a simple task. Especially when science is not as popular as it was in 1950ties.
Present students are more interested in technology – maybe technology applications offer an opportunity to facilitate IBL methodology.

- Teachers are still most important player in educational process. How to motivate them for use of IBL is another not simple task. And there is no unique solution.

Positive solution of above described problems will certainly provide successful implementation of Inquiry Based Learning at schools.
**Equity and Science Education: Challenging our views on ICT, gender and education**

**Expert Contribution: Cathrine Tømte (Research Professor, Dr. Art, Nordic Institute for Studies in Innovation, Research and Education, NIFU, Norway)**

**Challenging our views on ICT, gender and education**

The overall picture of the situation of gender and Information and Communication Technology (ICT) has so far been that men have been dominating and left the women behind. This has also been the point of departure for policymakers in their efforts to make plans and activities in the field (Abbiss, 2008). But, as will be shown, this male domination on the entire ICT field is not the case anymore. On the contrary, the situation is far more complex. When looking at younger generations, the picture appear to be more nuanced; both boys and girls seem to be involved and interested in using different tools of ICT, both at school and elsewhere (CERI, 2010). Moreover, along with the new generation, there is the emergence of the new social media, in which girls seem to be highly involved. Based on this, we have to explore in which ways the gender issue appears in youngsters’ use of and attitudes towards ICT and how they perform and interact as producers and consumers of digital content. This new insight of a complex picture needs to be taken into consideration for policymakers, schools/ educational institutions and in research.

**Main indicators on girls’ and boys’ familiarity with ICT**

The production and use of knowledge by using advanced ICTs is increasingly important as the basis of what is often coined as “the new knowledge economy”, which can be framed as a response to increasing global competition among countries and regions drawing on knowledge as the main asset. To ensure that society and individuals are included in this development, the notion of “digital inclusion” has been suggested in order to enhance social, political and economic inclusion to all social marginalized groups, in which gender has been embedded.

Available statistical information on access and use of the Internet reveals the existence of a digital gender gap, even if there have been positive developments regarding access of the Internet; gender differences are decreasing in most OECD countries (European Commission, 2010). However, there are still differences between males and females on the amount of time spent online and on their computer skills and preferences towards ICT. Notwithstanding, the gender gap appears to be lower when comparing young males and females to older males and females (ibid).

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2 A previous and more elaborating version of the paper is available at [http://www.idunn.no/ts/dk/2011/special_issue/art06](http://www.idunn.no/ts/dk/2011/special_issue/art06)
When there is evidence to suggest a gender specific difference on attitudes towards ICT, in which boys reveal more confidence than girls, we do not know at what age this gender based difference on attitudes starts; several studies confirm no gender specific differences on younger students.

The experience with ICT from an out of school context, most likely at home, influence the younger children’s’ attitudes and expectations on ICT. This is echoed in their expectations on ICT for pedagogical purposes at school. In this case, it is suggested that:

- Computer gaming can generate a self-efficacy with technology, which can increase attainment in other aspects of use (Kennewell & Morgan, 2006).
- Boys are most likely to be well experienced in the use of videogames for entertainment purposes at a very early age (Colley 2003; Kent & Facer, 2004).
- The use of computer games in schools seems to have a positive impact on engagement, and, in particular, on school drop outs, who very often happen to be boys (Kirriemuir, 2004).

For older children research confirms gender based differences related to ICT. What seems to be a turning point is when students are reaching the age of 11-12, at this stage some gender specific differences appear in their preferences, skills and attitudes towards ICT. There are various ways on how this is to be revealed. Still, we might interpret these developments as to correspond with the fact that it is normally at this age boys and girls are entering the puberty, in which gender identity represents a central aspect. The gender specific differences can be summarized in that girls recognize their importance for work, while boys are more concerned with playing games or representing a leisure-oriented approach towards ICT.

Moving over higher education, there is a gender gap in most OECD countries. Despite an impressive increase in female participation in higher education; girls are approaching 60% of university student population (Hegna, 2005; Nordahl, 2007), gender segregation in regard to choice of education and career is still strong (Støren & Arnesen, 2007; Hill, 2010). Women remain relatively absent from fields like computer science, software development and the design of ICT products in most western countries. Moreover, male dominance is also observed in the field of ICT education and training, like in science and technology-related degrees and in computing related fields of education (Hill, 2010; Prpic, 2009; European Commission, 2010).

The highest female rates in occupations that use ICT, occur in office or clerical types of occupations, which traditionally have not been considered as advanced use of ICT or even what counts as ICT specialists. Following this, the share of female employees, in a more narrow definition of ICT skilled employment, as ICT specialists, appear to be very low and is even declining or stagnated in some OECD-countries (van Welsum, 2007; European Commission, 2010).
As shown, gender specific preferences towards ICT emerge mainly as kids grow older. This calls upon to relate the phenomena and the evolvement of stereotypes to explanations connected to socialization-processes on gender, and to some extent, also biological explanations (children turning into puberty). One possible approach is to empirically nuance the picture on the stereotypes, without taking for granted that only one dichotomy will emerge. For example, using multiple profiles as a more precise way to understand how people, men and women, use ICT. The work carried out in the PISA and ICT 2006 report (CERI, 2010), for instance, provides a set of detailed insights for a set of nine selected profiles. The profiles both confirm the existence of gender stereotypical use of ICT across most OECD countries but also reveal the existence of various groups of students, both males and females, who are identified in the profiles and who fall in-between the polarizations. This way the set of profiles show evidence that multiple sets of preferences towards ICT exist, both between boys and girls, as well as between different groups of girls and different groups of boys.

Spheres of influences of youngsters’ own perceptions of ICT

Until now, we have seen some evidence about several differences between girls and boys in relation to ICT. This second part provides a theoretical and explanatory framework about how society (or community) generates these differences between boys and girls in relation to ICT.

Most boys and girls hold on to different ICT tools and applications. They also relate themselves differently towards what constitutes technology and they talk about it differently (Carr, 2005; Enochsson, 2005; Heemskerk, Brink, Volman, & ten Dam, 2005; Tønnessen, 2007). This constitutes a gender issue, which is influenced by social norms on what constitutes to be male and female behaviour. It is equally believed that young people’s gendered identities have an impact on future educational and career patterns, particularly in relation to science and technology; the two most crucial areas for knowledge economies (Vekiri, 2008, Geneve, 2009; Hill, 2010). In other words, youngsters’ ICT preferences and patterns of use are influenced by socialization processes. To illustrate this, the “Sphere of influence”-model, here presented in Figure 1, (Geneve, 2009) is useful; it shows how various environmental aspects form a person’s lifecycle and affect choices of education and professions;

Figure 1: The “Sphere of Influence” model: Influences on educational careers and pathways

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3 Moreover, the gendering process of individuals is also related to biological issues. However, this dimension would need a much broader approach that this paper might give, which is why it is set aside.
The model was developed to work as a framework to explore the complex socially situated participation of women in the ICT industry. It suggested that influences are manifested in the environment as 1) cultural phenomena, formed by historical, socio-cultural, economic, legal and political influences. These macro level distal cultural norms are mediated by the 2) media in its various forms such as literature, television and via technologies such as the internet. Furthermore, proximal influences such as 4) resources including learning resources, or simply access to technology, can be an influence. The 3) social category encompasses socialization agents where mechanisms, such as family, institution, workplace and communities of practice, may influence the individual (Geneve, 2009). The model also visualizes the various levels of influences and how these are interconnected. This way, the model also serves to illustrate how our understandings of gender and in particular how gender relates to ICT, might have affected boys and girls differently, from their childhood to work life.

The community represents children and youngsters’ closest contexts; parents and family, peers and the school community are present from the earliest start and are central in the process of shaping and influence the young ones perception of the world in its broadest sense and their surroundings in a narrow sense. Parents, peers and schools might represent various values and perceptions, even when co-located in the same national and cultural area. Socio-economical differences might also be a critical dimension in this regard. For example, immigrant children might be exposed to cross-cultural set of values; where those communicated from the family differ from those from the school and the local municipalities. These aspects are important to bear in mind, when diving into the different segments of the
community. Parents have influence on children and young peoples’ attitudes towards and use of ICT, both

- in terms of encouraging ICT use, for instance in homework,
- by communicating their own perspectives of gender and ICT, and -
- by behaving as gendered persons themselves.

Parents' socio-economic status also influences children's access and use of ICT at home and their schoolwork (Livingstone, 2005; OECD, 2007). Another interesting aspect is on parents’ influence on children’s’ and youngsters self-efficacy towards ICT. Parental support and, to some extent, also peer support are the most important variables for both boys’ and girls’ self-efficacy and value beliefs towards computers (Vekiri, 2008). In addition, the expectations that parents communicate to their children can have long-term consequences as they have a strong effect on children’s future self-efficacy beliefs, academic choices and career plans (ibid).

The role of school and teachers

We are of course aware of the teachers’ role within education, what we do not know so much is if their gender has any kind of impact on the learners and their approach to ICT. Another central perspective is whether teachers and schools are aware of their own often outdated perspectives on gender and how these might be communicated to the students. The existing curriculum on ICT might also function as an effective tool to prevent girls from choosing ICT related subjects. Moreover, teacher’s gender does matter when it comes to their appearance as good role models, for example when including

- A student-centred pedagogical approach (Vekiri, 2009) and -
- Computer experience of female teachers in order to raise their self-efficacy towards ICT (Meelissen, 2008).

In some cases, both students and teachers appear to reproduce outdated understandings of gender; in schools where teachers and schools had implemented strategies to attract more girls to ICT education, these strategies often reinforced the stereotyped notions of gender (Lynch, 2007). To change, researchers therefore suggest that:

- Teachers and teacher trainers should pay attention to their students’ awareness of gender differences in computer attitudes and computer use of primary school children (Volman & Van Eck, 2001; Smeets, 2005; Kennewell & Morgan, 2006; Meelissen, 2008).
- Teachers and teacher trainers should also focus on gender differences in self-confidence in ICT use of future teachers (Volman & Van Eck, 2001; Smeets, 2005; Kennewell & Morgan, 2006; Meelissen, 2008).
• Teachers and teacher trainers should also recognize that boys and girls often talk about/use the language differently when talking about ICT (Enochsson, 2005).

• Change the curriculum, which often has been identified as traditionally male oriented fields of interests (Colley, 2003; Lynch, 2007).

• Change the pedagogical practice related to ICT to become more exciting; misconceptions on the existing practice have an impact on youngsters’ expectations of future studies on the subject (Colley, 2003; Lynch, 2007; Anderson, 2007).

• Younger students would benefit from more support for their lower skill levels since this can help offset any gender differences in the experience brought to the classroom from the home environment.

• Young students, and particularly boys, are heavily exposed to the excitement of computer games. This makes it a risk that more mundane tasks appear more boring in comparison (Colley, 2003).

Another statement on teacher’s role in relation to the gender issue has been that this is most likely connected to wider contexts, such as socio-cultural environments. For example, findings from the SITES 2006 study, which focuses on pedagogy and ICT use in schools around the world in math and science, concludes, that despite more systems having higher percentages of ICT-using male teachers for both teacher populations, the gender imbalance is probably not due to gender specific differences in the pedagogical adoption of ICT. In this case, researchers stress that any such difference is more likely to relate to social, historical, cultural and other contextual differences between male and female teachers in the specific education systems (Law, 2008). An extra perspective is the misconceptions on how teachers and students perceive their own ICT skills and competences (Arnseth, 2007). These discrepancies and lack of a shared understanding of terminology between teachers and learners might influence the learning situation.

Young people consider the Internet as a highly important arena for socializing (Ito, 2008) and during the last years there has been an increasing use of so-called content creating activities on the Internet. Web resources like YouTube, Flickr, MySpace, Facebook and Wikipedia are engaging to young people. These content creating activities have been framed in the concept called Web 2.0 or social media. Moreover, these activities appear to attract boys and girls differently. These variations somehow indicate to us the complexity of the gender issue, in which there ought to be important variations of practicing gender between the cultures and nations, and which gives us some indications of the heterogeneity of young people. Most of the activities connected to these resources are being done outside a school context; most likely at home.

Concluding remarks

There is evidence to suggest the existence of gender specific preferences and patterns of use towards ICT and that these are emerging as children grow older. This
can even be framed as stereotypes of boys and girls’ behaviour. Still, as shown, even if the existence of stereotypes is confirmed, research also shows us the existence of variations across these stereotypes. The user profiles elaborated from the PISA 2006 data represent one example in this case. Moreover, girls’ interests of and activities within social networking indicates a considerable interest in ICT, which might lead to more frequent use of other various ICT tool in the future. However, we do not know if this trend leads to more females becoming ICT specialists or professionals. Nevertheless, one possible approach might be to include both boys’ and girls’ various interests and user patterns towards ICT in future perspectives both in teaching, research and policymaking on what represent ICT. As long as males’ use of ICT still seems to represent the norm, this might indicate a certain challenge.

References


CERI, OECD. (2010). Are the New Millennium Learners Making the Grade? Technology use and educational performance in PISA. Paris: CERI.


At the beginning of the school year a survey among teachers on ICT in several Bulgarian schools was organized and conducted. They discussed the report “Challenging our views on ICT, gender and education” of Professor Dr. Cathrine Tømte research about problems related to the education of girls in ICT and their possible future career in this field. Based on their experience teachers came to the following conclusions:

- They agree with the opinion of the author that there is no significant difference in the ICT-teaching of boys and girls in elementary school. Students prefer to play games and this enables teachers to use educational games in teaching mathematics and natural sciences. For example, high school students from School-Brezovo and School of Mathematics Plovdiv who learn specialized ICT, develop learning games for students from elementary school. These games are created to meet pupils’ needs and characteristics. Observations confirm that the boys stay longer at the computer to play.

- For girls 12 to 16 years there has been increasing interest in the Internet and social networks. The interests of boys still are directed mainly to computer games. Teachers use this fact to put group tasks that need to be addressed to cooperation between students as using social networking and communication in real time. In this group, girls learn better the study material in ICT than boys, but boys demonstrate greater creativity and have more knowledge related to the more widespread use of these technologies.

- In high school boys and girls showing almost equal interest in ICT training. The boys prefer mobile technology and programming. The girls prefer computer graphics, design, animation and prepress. The majority of the teachers prepare students for competition in ICT at the national level. According to the general opinion of teachers boys do better with web development, while girls prefer visual event-programming. However, at the national ICT competitions and Olympiads the boys are significantly more than girls. Exception to the general rule is the students from SOU-Brezovo where the girls, who participate in national ICT competitions and Olympiad, are more than boys (about 80%).

- In universities, the number of boys and girls is almost equal. The trend in secondary education is: girls prefer more the applications of computer science, while boys programming. Observations of teachers from Plovdiv University "Paisii Hilendarski" confirm the general trend. According to them, the girls learn better and achieve better results, but the boys perform better in software companies after they complete their studies.
• When choosing professions boys prefer programming, and girls to become teachers, work in software companies (i.e. designers), create learning resources or perform clerical jobs.

• The influence of the family in determining children's attitudes towards ICT is essential. Stereotypes are constructed from an early age. There are difficulties in choosing children to deal with ICT when families are not motivated. Most serious is the problem with minorities.

• Most teachers in Bulgaria are women. Students tend to study ICT better when they are trained from male teachers. Particularly obvious is this trend for boys who feel that their competence is more important than knowledge of female teachers. The fact is that boys and girls speak different languages when using ICT. It has been observed that boys use more frequently than girls terms and words that are specifically used in social networks contexts. Teachers use the official terminology. This often leads to misunderstandings.

The problem of gender equality and trends in ICT learning of boys and girls is common to all European countries. The opinion of Bulgarian teachers largely supports the findings of the article of Dr. Cathrine Tømte. They believe that it takes a lot of research in this direction.
Introduction

I started my professional career as a physics teacher at the University of Tuzla. After 16 years I left teaching and begun to work in industry. It was stressful because I worked in a different environment that demanded different skills and knowledge (which I did not acquire during my formal education – studying physics as the most interesting science in 1960s).

I will explain these differences on a concrete example. A couple of weeks ago I had a meeting with a scientist who had the idea to make a new type of therapeutic device and with a group of engineers who had to develop the product starting from that idea. The meeting was productive and the engineers understood what needed to be done, so the meeting closed after one hour. On our way home (I was in the engineers group), we stopped for a glass of beer and started to discuss how to make the product and several questions were raised:

- Which material shall we use?
- How to design the housing for the device?
- We need the tool for housing – how much will it cost?
- Who will make the model of housing?
- Shall we use rapid prototyping?
- Which company will make the electronics?
- Who will assemble the device?
- What about intellectual property?
- Shall we submit patent application?
- In which countries do we have to protect the invention?
- Shall we build and protect the trademark?
- What will the total cost for the device be?
- What price can we set for the market?
- How to sell the product?

We spent almost three hours discussing the topics but we did not come to the final solution, so we defined the time and topics for our next meeting and delegated the tasks which had to be carried out until that meeting.

Everything was clear from the scientific point of view (which physical phenomena will be used, which characteristics the device had to feature). Even the prototype could be built easily by using standard components available on the market. The large scale production of the device generated several issues which in most cases were not part of the curricula in formal educational institutions. Why did this happen?
Science Education and the world of work: should there be a connection?

The main aim of most science courses on all levels of formal education is to teach about the phenomena under consideration - why they emerge and perhaps to learn about some practical applications in that field. However, that practical example is usually described on a very general level. For example, let’s look at X-rays. We know why they occur, how they were discovered and that they can be applied in medicine, material science and so on. However, further considerations are usually left out and teachers never ask their students to develop their own x-ray device. This is the main reason why we are not fully qualified to work in the field from which we graduated. This is also why industry experts say that people coming from the university do not have necessary skills and knowledge for their workplace. For some reason, we are more interested in learning than in innovations of products, services, etc. But if the industry wants to survive, it has to design new products which will be competitive on the global market.

This problem is perhaps best explained by Edward de Bono [E. de Bono 1997] in his article published in the Guardian, titled AWAY WITH THE GANG OF THREE. Here are some quotes from this article:

“We do not make very full value of the opportunities provided by technology because we prefer critical to constructive thinking, argument to design...

Traditionally, we have solved problems by analysing them and seeking to identify, and then removing, the cause of the problem. Often this works, but at other times there are too many causes to remove or we cannot remove the cause because it is human nature. The ceasefire in Northern Ireland was squandered because the Government could not design any constructive way forward. That is mostly a design problem, but it is not getting any design attention. Argument will never solve the problem...

Most of the world’s major problems (poverty, crime, conflict, pollution, etc.) will not be solved by yet more analysis and yet more information. We need to design ways forward - leaving the cause in place. Unfortunately, the traditions of education and the thinking culture of society make no provision for “design” - we see it as applying only to buildings, furniture and Christmas cards. This is a fundamental weakness, derived from the last Renaissance, which never encouraged innovation or design but believed that truth was enough...

It is truly astonishing that Western culture has never developed an idiom of "constructive" thinking. We have the absurdity of "argument" as our basic idiom. We worship the nonsense of "debate". Each side claims the truth
and seeks to attack the other claim. This way we are supposed to arrive at the truth through triumph or synthesis....

Students in Britain know most of the names of Henry VIII’s wives, the date of the Treaty of Utrecht and even the shape of a Roman legionnaire’s sandals. But they have not the faintest idea how the corner shop works or how society works in general. They have no idea of how value is created in society....

In OECD countries, an average of 24 percent of the time in school is spent on mathematics. Of the mathematics taught, probably less than five percent is of use in life to most students....”

Although de Bono is predominantly concerned with social sciences, I am sure that we need to teach more about design in technical sciences as well. If during my study I had to design a new kind of device, whose operation is based on known physical principles, I would more clearly understand the physical principles themselves. At the same time, I would learn a lot about the process of product development by starting from those physical principles. What I would learn could be very useful later, if I were to go to industry to conduct new experiments in physical institutes or to teach general physics to the students of Engineering.

If we look at education from the industrial point of view, there is one significant problem which was also initially well considered by de Bono in the same article: “In education we are concerned with literacy and numeracy. That leaves out the most important aspect of all, which I call "operacy". The skills of action are every bit as important as the skills of knowing. We neglect them completely and turn out students who have little to contribute to society.”

What does “operacy” stand for and why do we need it? It is not enough to have good ideas to develop a new product or to solve a problem that may occur in any segment of some industrial process. We have to prepare to become active and to know how to perform planned activities in an efficient way. And again there is no “operacy” in formal education systems.

Being part of formal educational system for years, I understand quite well that it is not easy to involve “design” and “operacy” in curricula everywhere. It will ask better and different prepared teachers, who will have to make much more efforts teaching “design and operacy” then to teach standard well-known topics, which do not demand for creativity and finding way in unknown land. However, the institutions which will integrate the above topics will have significant competitive advantages compared to more classical institutions.

**Science teaching and the world of work: how could there be a connection?**

There are several things which have to be improved for teaching science, if we want to prepare students for successful industrial career. Let’s shortly describe some of them:
- **Rule of thumbs**, defined as “a principle with broad application that is not intended to be strictly accurate or reliable for every situation” (Wikipedia [http://en.wikipedia.org/wiki/Rule_of_thumb](http://en.wikipedia.org/wiki/Rule_of_thumb)). In industry, it is very important to be able to make some estimation by using simple rules. This helps to understand the problem and to discuss it while looking for its resolutions (because we do not have time to prepare and make exact solutions). It has to be practiced by giving some very practical exercises, such as how long we can survive in the classroom without fresh air. Think about that problem and try to make some simplifications on how to calculate and which data are necessary to find approximate solutions.

- **Teamwork**: how to work together, communicate, listen, solve conflicts and problems, deal with failures, etc. All this is necessary and usually not taught. Although it does not have too much to do with science education on the first sight, if you look at the history of science, you can see that, as Drucker said “only exchange of knowledge can generate new knowledge”. It is easy to develop teamwork culture in school; you only have to organize a group which will try to solve a problem. Monitoring and providing the group with advice will enhance the development of skills necessary for efficient teamwork.

- **Creativity**: In the world of global competition, only those organizations which release and use creativity potential of their employees will be successful. In accordance with R. Florida [Florida 2003], all people are creative; however, we have to build the conditions that will allow them to use their creativity. There is a need to teach pupils and students to use some methods for creativity development (mind maps, brainstorming...) and to provide them with conditions for presenting their creativity.

- **Intellectual property**: is extremely important but it is almost never taught in school. Trying to find solution to a simple problem and then to protect invention with patent application could be fun and students could learn a lot. It is a way for applying some scientific principles for finding solutions to real problems.

- **Ethics**: Almost all main problems of modern world are connected with ethics. Pollution, child labour, gender discrimination, etc. All these topics can be solved by using ethics. Science could not develop without ethics – we cannot cheat when we present our scientific results because the falseness of the results will become visible sooner or later. So involving ethics in science education could help us resolve serious problems on the long-term basis.

### Some final remarks

In the end, I would like to quote my favourite author Alvin Toffler [A. Toffler], a famous futurist with a very radical view on education. In an interview, he said that we have to destroy public education system: “In our book *Revolutionary Wealth*, we play a game. We say, imagine that you’re a policeman, and you’ve got a radar gun,
and you're measuring the speed of cars going by. Each car represents an American institution. The first one car is going by at 100 miles per hour. It's called business. Businesses have to change at 100 miles per hour because if they don't, they die. Competition just puts them out of the game. So they're travelling very, very fast.

Then another car comes. And it's going 10 miles per hour. That's the public education system. Schools are supposed to be preparing kids for the business world of tomorrow, to take jobs, to make our economy functional. The schools are changing, if anything, at 10 miles per hour. So, how do you match an economy that requires 100 miles per hour with an institution like public education? Could this be done by a system that changes, if at all, at 10 miles per hour?"

I know that we will not destroy the system of public education. However, if we look at the trends, the students that graduate now will have to work until 2063. Which skills, knowledge and competences will they need in the middle of 21st century???

Perhaps the best answer to this question would be to use the experience I gained while giving lectures at West Valley College in Silicon Valley. Each year, the Digital Media department organized a late dinner with the representatives of industries future employee of Digital Media students. In a relaxed atmosphere the teachers and industry representatives discussed about the developments and new trends in industry. It is a simple way to establish better communication between the teachers and industry. Such meetings are also not very expensive and complicated to organize.

References


The article Science Education and the World of Work is interesting and useful for both partners: companies and education.

As people responsible for operation and high performance of small companies and active in the field of High-Tech, we agree that there is a big gap between what students learn at university and the solving of concrete problems in the real world of work. We could argue this position with several examples from our working experience. Usually, the graduated students come with a lot of theoretical knowledge; however, they have very little experience in the process of solving problems, which appeared in everyday work in companies.

We believe that there is no or very weak connection between educational institutions (especially universities) and companies. We strongly supported the idea of common informal meetings of representatives of university and companies with an aim to improve educational process and provide students with necessary practical knowledge and skills. This will make students get employed more easily, and will provide them with good background for professional career.

However, we think that there is quite a lot of space to improve educational process as follows:

- To organize a course (in the final year of the study), in which students will work on a project determined by companies. It has to be typical problem for that branch of industry, and students will have to work in environment, which is identical or at least very similar to the environments in the world of work. Such courses are relatively simple to establish and will significantly improve the quality of education and reduce the gap between education and real world of work.

- Companies have to try to involve the students in early years of study in participation in their project. This asks for additional efforts of company’s staff; however, the long-term benefits will be very high. Students will get experience, and the employee will provide their human resources necessary for successful operation. We know some examples, in which companies started to work with students from high school and become very successful. However, this is not a common practice in Slovenia.

- The professionals from world of work have to be involved in the educational process; vice versa, the teachers from educational institutions have to be involved in world of work. Such exchange will significantly improve both: educational process and operation of companies.
We agree that the innovation and intellectual property rights are very important topics usually not covered in formal education. We think that realization of concept of “knowledge triangle” which is defined as:

*Research, education and innovation are three central and strongly interdependent drivers of the knowledge-based society. Together they are referred to as the “knowledge triangle”. To realize ERA, research needs to develop strong links with education and innovation.*

This is the right direction for stronger cooperation between educational, research institutions and companies.

Last but not least we would like to state that we like very much the concept of design and operacy (both invented by de Bono), as described in the article. We believe that using and developing these two concepts in education, significant improvements in the knowledge, skills, and mindset of the students could be achieved.

We are aware of the fact that people from industry are busy, have no time to think about improvement of education, but on long-term the return of investment in efforts described above will be significant.
During the last two decades, many software tools and virtual learning environments were developed for promoting inquiry based learning. Most of them, however, have not been updated since their projects were completed or their funding finished.

<table>
<thead>
<tr>
<th>Period</th>
<th>Active?</th>
<th>Tool</th>
<th>More information</th>
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<tbody>
<tr>
<td>1996 – 2012</td>
<td>yes</td>
<td>WISE = Web-based inquiry</td>
<td>WISE, a free on-line science learning environment for students in grades 4-12 created by a large team from the University of California, Berkeley.</td>
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<td></td>
<td></td>
<td>science environment</td>
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<tr>
<td>1998</td>
<td>No, last update 1998</td>
<td>GenScope learning environment</td>
<td>GenScope is a learning environment that uses the computer to provide an alternative to text-based science education. It provides teachers and learners with a new tool that enables students to investigate scientific and mathematical concepts through direct manipulation and experimentation.</td>
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<tr>
<td>2001 – 2010</td>
<td>No, last update 2010</td>
<td>The Progress Portfolio</td>
<td>The Progress Portfolio is software that helps students conduct long-term inquiry projects on computers (e.g. visualization projects, web-based inquiry projects, explorations with CD-ROMs, simulations, digital libraries, etc.). It allows students to document and reflect on their work using an integrated suite of screen capture, annotation, organization, and presentation tools. In addition, teachers can use the Progress Portfolio to guide students in their work through the design of prompts and templates that encourage students to think about key issues as they work. It is used by SIBLE: Supportive Inquiry-Based Learning Environment Project.</td>
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<tr>
<td>1995 – 2002</td>
<td>No, last update 2002</td>
<td>BGuILE = Biology Guided</td>
<td>BGuILE, learning environments bring scientific inquiry into middle school science and high school biology classrooms. The</td>
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<tr>
<td>Inquiry Learning Environment</td>
<td>environments consist of computer-based scenarios and associated classroom activities in which students conduct authentic scientific investigations.</td>
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<td><strong>2007 – 2010</strong></td>
<td><strong>nQuire</strong></td>
<td>The nQuire software enables students guided by teachers to design and run science inquiries at school, at home, or outdoors on mobile devices. Teachers can choose from a set of ready made inquiries for their students, modifying them as they need, or creating their own new inquiries. They can also monitor their students’ progress through inquiries, and give them access to new parts as they complete each stage.</td>
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<tr>
<td><strong>2008 – 2011</strong></td>
<td><strong>SCY – Science created by You</strong></td>
<td>Science Created by You (SCY) is a project on learning in science and technology domains. SCY uses a pedagogical approach that centres on products, called “emerging learning objects” (ELOs), that are created by students. Students work individually and collaboratively in SCY-Lab (the general SCY learning environment) on “missions” that are guided by socio-scientific questions</td>
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<tr>
<td><strong>2008</strong></td>
<td><strong>LETS GO</strong></td>
<td>LETS GO frames its vision of “open inquiry” as the opportunity to catalyse and sustain global learning using mobile science collaborators that provide open software tools and resources, and online participation frameworks for learner project collaboration, mobile media and data capture, analysis, reflection and publishing.</td>
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<tr>
<td><strong>2013 – 2015</strong></td>
<td><strong>weSPOT</strong></td>
<td>The weSPOT project aims to propagate scientific inquiry as the approach for science learning and teaching in combination with today’s curricula and teaching practices. weSPOT is currently developing a “Working Environment with Social, Personal and Open Technologies” that supports users (from 12 to 25) to develop their inquiry based learning skills.</td>
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**What is WISE?**

WISE - Web-based Inquiry Science Environment was developed in 1997 by Berkeley University supported by the National Science Foundation. WISE is a virtual learning environment for designing, developing, and implementing science inquiry activities collaboratively. Its participants comprise a growing community of more than 15,000 science teachers, researchers, and curriculum designers, as well as more than 100,000 students around the world. Its main objectives are to investigate and provide:

1. Effective designs for inquiry activities and assessments.
2. Technology supports for students and teachers.
3. Authoring partnerships to create a library of inquiry projects.
4. Professional development programmes to enable a wide audience of teachers to succeed with inquiry and technology.

**What are its key features?**

WISE ([http://wise.berkeley.edu/](http://wise.berkeley.edu/)) is entirely browser-based; it does not require the installation of any software. Users only need access to a computer with an Internet connection, with no required software other than the Web browser. It provides an
easy-to-use interface for online discussions, visual graphical representations, reflective notes, interactive simulations and assessments. It also offers a library of inquiry projects with an increasing variety of science topics and range of student age groups.

WISE is Free and Open Source. It is available for anyone with a computer and internet connection. It is driven by a growing community of teachers, researchers, and software developers, who are continually expanding and improving the system. The WISE project library is also result of collaboration among teachers, researchers and experts. It focuses on bringing science inquiry into diverse learning settings: classrooms, museums, home-school environments.

**How does it work?**

Students can create and save their work on the central project server hosted by Berkeley University that enable their accounts be coordinated with teacher’s accounts. Users can access their work as well as the library of curriculum projects from any computer on the Internet. Teachers can choose from in the WISE Teacher’s Portal, a set of materials including a detailed lesson plan with assessments grounded on to the AAAS National standards. Teachers can manage their student accounts, grade and monitor student work as well as provide formative feedback during an inquiry based learning project.

Students can develop their inquiry projects through four steps:

1. Prediction, Observation, Explanation, and Reflection: Students register their predictions, include their observations with data collected, and integrate their evidence to describe explanations and changes to their predictions.
2. Critique and Feedback: Students define criteria to evaluate different claims in terms purpose and sources of evidence. Based on these criteria, they review the work of their peers by writing critical responses.
3. Science Narratives: Students then prepare coherent narratives based on the feedback received.
4. Challenge Questions: Students evaluate the quality of different scientific explanations and are redirected to relevant activities to improve their understanding.

**What is its pedagogical approach for IBL?**

WISE pedagogical approach is to emphases collaborative inquiry, engaging students to both self-monitoring and collaborative reflection. It also help teachers develop a sense of ownership, by providing opportunities for them to reuse, readapt or recreate new projects. Some pedagogical principals are:

1. Making Science Accessible
   - Project builds on student ideas and scientific knowledge framework to model the inquiry process
Students can connect project to personally relevant questions on topics of standards-based curricula

Making Thinking Visible
- Students explore and create personal representations to express their ideas
- Students can access and review multiple representations incorporated into assessments
- Activity promotes learning through representations as well as illustrates the process of inquiry

2. Learning From Others
- Students exchange ideas and learn from each other
- Peers have productive interactions to develop understanding
- Groups of learners develop shared criteria for scientific discourse
- Learners have the opportunity to share their findings after generating their own ideas

3. Promoting Autonomy and Lifelong Learning
- Project engages students in meaningful reflection as critics of diverse scientific information
- Project helps students understand and generalize the inquiry process to diverse science projects
- Project provides opportunities for learning and applying context-embedded content knowledge

Where to find more information?

There are many IBL tools—but most of them are not available for installation, last update is more than 10 years ago.
What is SCY?

SCY – Science Created by You was developed by a consortium of 12 countries under coordination of Universiteit Twente, supported by the European Commission from March 2008 to February 2012. SCY is a system for students between 12-18 years developing their constructive and productive learning of science and technology. SCY offers some missions which require a combination of knowledge from different content areas (e.g., physics, mathematics, biology, as well as social sciences). Students perform several types of learning activities: experiment, game, share, explain, design, etc.

The configuration of SCY-Lab is adaptive to the actual learning situation and may provide advice to students on appropriate learning activities, resources, tools and scaffolds, or peer students who can support the learning process. In the course of the project, a total of four SCY missions were developed: "the design of a CO2-friendly house", "creating a healthy pizza", "determining water quality", and "forensic DNA".
What are its key features?

SCY (http://www.scy-net.eu/) is based on ‘emerging learning objects’ (ELOs) that are created by students individually or collaboratively in SCY-Lab, which is the general SCY learning environment on ‘missions’.

The SCY approach is enabled by the innovative architecture of SCY-Lab that supports the creation, manipulation, and sharing of ELOs (models, data sets, designs, plans, etc.). The central unit in the SCY architecture is a broker that configures SCY-Lab to unfolding learning processes and activities. For this it uses information from pedagogical agents that exploit techniques of educational data mining to monitor information in the SCY repository that stores the ELOs as well as domain information, the log-files of student behaviour, and the recorded chats between students.

How does it work?


The SCY-Lab digital learning environment provides the look and feel of a computer desktop. However the Using SCY-Lab, the student can navigate through a mission, open assignments, browse through previously made ELOs. For that, they can use these following tools to make new ELOs, communicate with fellow students and customize their workspace:

- SCY-Interview: helps learners to design a good interview.
- SCY-Feedback: is a peer assessment tool with which students can easily ask for and provide feedback on ELOs as they are being developed in a Mission.
- SCY-Data: enables students to process and visualize numerical data sets.
- SCY-Experimental Design: allows learners to write down experimental procedure as task trees.
- SCY-Lighter: is a Mozilla Firefox Add-on for collecting relevant information on the web and saving it into the SCY-Lab.
- SCY-Mapper: makes concept-maps representing ideas as nodes and the relationship between these ideas as links.
- SCY-ePortfolio: is used to build a mission portfolio to be assessed by the teacher.
- SCY-Assessment: is a tool with which teachers assess submitted Portfolios (summative assessment).
- SCY-Text: is a simple text editor integrated into SCY-Lab.
- SCY-Uploader: enables students to import external files into SCY-Lab as ELOS (e.g. word documents).
- SCY-Dynamics: is a modelling tool that helps create and simulate graph-based models of complex problems and phenomena.
• SCY-Tagging: is a co-operative tagging tool used by students to tag ELOs in SCY-Lab.
• SCY-Chat: allows learners to communicate with each other in SCY-Lab and thereby collaborate on ELOs.
• SCY-Search: enables students to search the collection of ELOs to find relevant work by themselves or by other learners.
• SCY-Draw: Allow learners to create simple drawings, with elementary drawing capabilities: shapes, freehand drawings, importing images.
• SCY-Simulator: is a multi-purpose simulation tool that is able to show and run simulations.
• SCY-Datacollector: is a means for learners to collect numerical and multimedia data in the field with their mobile devices (based on the Android platform) and store the collections as ELOs.
• SCY-Formauthor is fully integrated into SCY-Lab and can be used to create forms for data collecting activities.
• Teacher tool: SCY-Authoring offers the teacher the ability to fine-tune a mission and obtain a real-time overview of activity in SCY-Lab.

What is its pedagogical approach for IBL?

SCY uses a flexible and adaptive pedagogical approach to learning based on "emerging learning objects" (ELOs) that are created by learners. The basic ideas behind constructionism focuses on learning by creating knowledge, this construction takes place when students are engaged in building objects SCY’s ELOs such as models, concept maps, artefacts, data sets, hypotheses, tables, summaries, reports, plans and lists of learning goals.

In SCY-Lab (the SCY learning system) students work individually and collaboratively on "missions" which are guided by a general socio-scientific question (for example "how can we produce healthier milk?") and fulfilling the mission requires a combination of knowledge from different domains (e.g., physics and mathematics, or biology and engineering).

While on a SCY-mission, students perform several types of learning actions that can be characterised as productive (experiment, game, share, explain, design, etc.), students encounter multiple resources, they collaborate with varying coalitions of peers, and they use changing constellations of tools and scaffolds (e.g., to design a plan, to state a hypothesis etc.). The configuration of SCY-Lab is adaptive to the actual learning situation, advising students on appropriate learning actions, resources, tools and scaffolds, or peer learners that can support the learning process.

Where to find more information?

• Slotta, J.D., Schanze, S., & Pinkwart, N. (2010). Guest Editors’ Introduction. Special Issue: International Perspectives On Inquiry And
The weSPOT project, supported by the European Commission from 2012-2015, aims to propagate scientific inquiry as the approach for science learning and teaching in combination with today’s curricula and teaching practices.
In inquiry-based learning co-learners take the role of explorers and scientists and are motivated by their personal curiosity, guided by self-reflection, and develop knowledge personal and collaborative sense-making and reasoning.

What are its key features?

weSPOT will create a “Working Environment with Social, Personal and Open Technologies” that supports users (from 12 to 25) to develop their inquiry based learning skills by means of:

- a European reference model for inquiry skills and inquiry workflows,
- a diagnostic instrument for measuring inquiry skills,
- smart support tools for orchestrating inquiry workflows including mobile apps, learning analytics support, and social collaboration on scientific inquiry,
- social media integration and viral marketing of scientific inquiry linked to school legacy systems and an open badge system.

Eight primary test-beds in a European wide approach in 8 European member states

1. **Food:** Examples of plastics contaminating food have been reported with most plastic types. Different countries might have different problems and solutions. Learners involved in this scenario will be acting as chemical engineers and food scientists.

2. **Biodiversity:** Biodiversity is increasingly recognized as critical to human life. Species are more threatened than ever by human activities like urbanization, climate change, deforestation, agricultural expansion, overexploitation of marine ecosystems. To explore these issues, students will investigate different habitats and carry out fieldwork research. Their inquiry projects could be related to breeding programme for endangered species, bird populations in a garden, bug populations in a flower bed, fauna in a pond-ecosystem, other food webs or succession.

3. **Earthquake:** Students will download and format near real-time and historical earthquake data and seismogram displays from various sources (e.g. FORTH’s own seismological station, U.S. Geological Survey, Institute of Geodynamics - National Observatory of Athens). Students will create spreadsheets and graphs to explore earthquake magnitude, wave amplitude, energy release, frequency occurrence and location. In a more advanced scenario students could do GIS Mapping and Analysis using free GIS Software.

4. **Sea:** High school students go on ½ year trip across the Atlantic Ocean, on their journey; they have normal class and run the clipper. In addition they explore their environment (water, air, physics on board, astronomy...) in personal projects.

5. **Energy:** Using discussion students should identify disadvantages of the current building from the energy-efficiency point of view. They should try
to predict (providing evidence) future energy problems. Forming teams, they will work on developing reasonable ideas for future energy-efficient buildings. Some guidelines to them: What type of new materials for new energy efficient building components with reduced embodied energy to use. What technologies will ensure a high quality indoor environment, keeping in mind Ecology.

6. **School:** The student should provide research on expected changes in the future school. Possible directions: dropping and new courses; the future classroom – real or virtual; new ICTs in education; the role of the teacher; students relationships; new educational approaches; formal vs. informal learning, the role of lifelong learning etc. Proposing innovative learning activities, preparing students for new jobs.

7. **Innovation:** The students will reflect their learning environment (or other environments) to determine some of the most pertinent problems, obstacles, “things they do not like”, etc. With the help of a teacher those points will then be contemplated form the viewpoint of what out of that could be changed and what (unfortunately) could not be changed.

8. **Economy:** In recent published Economic Complexity Atlas Slovenia is the tenth country with high Economic Complexity Index (ECI), and Bosnia is ranked on 8th place as country which has large ECI and small GDP (so it is expected that it will develop fast in next period). It would be interesting to research how these facts can be used for faster economic and social developments.

**How does it work?**

weSPOT aims for five main products: a) diagnostic instrument for inquiry skills b) inquiry reference model c) Inquiry workflow services for shared workflow definitions d) mobile clients for inquiry support e) collaboration clients and reflection clients inquiry analytics.

weSPOT will provide students with the ability to build their own inquiry-based learning environment, enriched with social and collaborative features. Smart support tools will be offered for orchestrating inquiry workflows, including mobile apps, learning analytics support, and social collaboration on scientific inquiry. These offerings will allow students to filter inquiry resources and tools according to their own needs and preferences. Students will be able interact to with their peers in order to reflect on their inquiry workflows, receive and provide feedback, mentor each other, thus forming meaningful social connections that will help and motivate them in their learning. From a learner’s perspective, this approach will offer them access to personalized bundles of inquiry resources augmented with social media, which they will be able to manage and control from within their personal learning space. Inquiry workflows can be described by graphical representations, whose aim is to help users visualize and orchestrate their inquiry projects. These representations are a key to personal as well as social inquiry based learning. Learners can link diverse steps of their investigation and represent their scientific
reasoning by integrating graphically their questions, hypothesis, concepts, arguments and data. Inquiry workflows play an important role as visual strategy and mediating tools in scientific reasoning.

It should be noted though, that there is a significant distinction between the user-centric approach of the Web 2.0 paradigm and the learner-centric approach of weSPOT. This is because a social learning environment is not a just a fun place to hang out with friends, but predominantly a place where learning takes place and it does not take place by chance but because specific pedagogies and learning principles are integrated in the environment.

What is its pedagogical approach for IBL?

The weSPOT’s model aims to provide teachers and learners with the support and the technology tools, so as learners become able to find the optimal level of inquiry to match their needs and be facilitated in the transition from passive towards active learning.

weSPOT will employ a learner-centric approach in secondary and higher education that will enable students to:

- Personalize their inquiry-based learning environment.
- Build, share and enact inquiry workflows individually and/or collaboratively with their peers.

The project focuses on inquiry-based learning with a theoretically sound and technology supported personal inquiry approach, supporting four levels of inquiry based learning:

- **confirmation**: students are provided with the question and procedure (method) as well as the results, which are known in advance
- **structured**: the learning goal is to introduce students to the experience of conducting investigations or practicing a specific inquiry skill, such as collecting and analyzing data
- **guided**: the question and procedure are still provided by the teacher. Students, however, generate an explanation supported by the evidence they have collected
- **open**: students have the opportunity to act like scientists, deriving questions, designing and carrying out investigations as well as communicating their results

Where to find more information?

- Mikroyannidis et al. (2013, in press) weSPOT: A Personal and Social Approach to Inquiry-Based Learning, Journal of Universal Computer Science Special Issue on Cloud Education Environments.
Teachers Response on Inquiry Based Learning Tools, Environments and Resources

CONTRIBUTION: ANNALISE DUCA, KERRY FREEMAN (ACROSSLIMITS, MALTA)

The paper by Alexandra Okada named “Inquiry based learning Tools, Environments and Resources” has been distributed amongst European and Maltese teachers to express and reflect on particular tools highlighted in the mentioned paper.

The tools that the mentioned teachers had to reflect upon were:

- WISE
- SCY – Science created by You
- weSPOT

(IBL) and learning tools – Teachers View

With regards IBL and learning tools, this approach is widely being used in classrooms by teachers. They believe that such method motivates and keeps students attention for longer periods of time. It helps pupils to associate science facts with real life. Such method also allows pupils to talk more about their science perceptions.

Apart from the positive feedback, teachers also expressed that the national curricula need to be less content based and focus more on the inquiry based method in science.

WISE

When asked about the pedagogical approach implied by the tool WISE the teachers expressed that the tool has the following characteristics:

- Easy to use
- Visually attractive
- Useful examples that can be easily used in class
- Allows communication between teacher with other professions and students
- The use of multiple choice helps low achievers as they provide them with a choice to choose the right answer.

Teachers believe that this tool can be easily applicable to their schools and classrooms however believe that usually they take parts of it and conform to their teaching requirements while also making sure that they suit the topics and the pupils' ability.

The general feedback about this tool are positive and teachers are willing to implement it as part of their teaching methods since they mostly believe that students have a positive response to new and exciting learning experiences.
**SCY – Science**

This project had some negative views since the website is not user-friendly and too difficult to navigate to find the material needed. Concept of this project is well received however it might need further work to reach teachers and implement this in their classroom.

Teachers also stated that this tool is good for students that are over the age of 16 especially when one finds that most pupils had little or no support in doing practical work previous while in primary level and early secondary years.

**weSPOT**

The weSPOT project seemed to have grabbed the interest of the teachers and they believe that it can be beneficial in their teaching while another positive outcome is that it links to everyday world problems to the classroom topics. Further comments included that this tool should be more teacher friendly since not every teacher is computer oriented.

Teachers believe that part of this project can be incorporated in classroom since it promotes scientific disciplines but not as a whole as usually this takes a lot of time while also still having to make sure that the syllabus is all covered.

As a general conclusion, teachers try different software and tools that are available online, always keeping in mind their students’ abilities and the school curriculum.
There is a general agreement that experiments are significant means to foster learning of science content, experimental skills and methods of science inquiry (Duit & Tesch 2010; Lunetta, Hofstein & Clough, 2007). There is also evidence that using appropriate technologies in the school laboratory can enhance learning. Microcomputer-Based laboratory (MBL) tools have become increasingly popular for the real-time collection, display and analysis of data in the laboratory (e.g. Thornton 1987; Sokoloff, Laws & Thornton 2007). MBL tools consist of electronic sensors, a microcomputer interface, and software for data collection and analysis. In a Microcomputer-Based Laboratory students conduct “real” experiments –not simulated ones- using various sensors (e.g. motion, voltage, temperature, light intensity) connected to a computer via an interface.

The main educational advantage of using MBL may be considered the real-time display of experimental results and graphs thus facilitating direct connection between the real experiment and its representation in real-time plots. Since data are quickly taken and displayed, students can easily examine the consequences of a large number of changes in experimental conditions during a short period of time. Students can for example see a cooling curve displayed instantly when a temperature sensor is plunged into ice water, or they can use a microphone to see how a sound pressure versus time plot changes as one of them is singing. The students can spend a large portion of their laboratory time observing physical phenomena and interpreting, discussing and analysing data with their peers.

In order to make these educational advantages of MBL transparent two experimental devices –called respectively as “traditional” and “microcomputer-based” chaotic pendulum – will be presented in the following. The two devices have been used to teach basic ideas of deterministic chaotic systems, in particular the impossibility to make long-term predictions despite the deterministic laws governing them. In principle, the future development of these systems is completely determined by the past. However, in practice, due to their “sensitivity” to small changes of the initial conditions and subtle disturbances occurring in the process, their behaviour, even though based on deterministic laws, is unpredictable in the long term. It appears that the interplay of deterministic laws governing the systems and random disturbances play a key role in explaining the observed complex behaviour (for details see Stavrou & Duit 2013; Stavrou, Assimopoulos & Skordoulis, 2013).

**“Traditional” Chaotic Pendulum**

The “traditional” chaotic pendulum basically consists of a spherical pendulum that swings above three magnets arranged as shown in Figure 1. When the iron bob is
released from a certain spot, its motion is random, and it finally ends above one of the magnets. If the experiment is carried out several times, the resulting paths vary and the pendulum bob comes to rest above different magnets. As a result, it is unpredictable above which magnet the pendulum finally comes to a rest.

Although the motion of the pendulum is unpredictable, it is governed by deterministic laws. Due to certain zones of unstable equilibrium between the three magnets (see Figure 4), small differences in the starting conditions and small external influences during the motion play a significant role in the process. In some way, these small deviations and disturbances ‘determine’ which path the pendulum will follow and finally above which magnet it will come to rest. The small deviations and disturbances are random and affect the pendulum’s motion in an unpredictable way.

**Microcomputer-Based Chaotic Pendulum**

As an example of a Microcomputer-Based Chaotic Pendulum a commercial chaotic pendulum system (Figure 2) manufactured by PASCO (www.pasco.com) interconnected with a data acquisition interface is presented. By varying a suitable parameter the progression from predictable harmonic motion to chaotic motion is possible. The behaviour of the pendulum can be explored in two ways: (a) by observation of the motion of the disc pendulum; and (b) by a real time plot of the angular position of the disc as a function of time.
(Figure 3 lower graph) and of the angular velocity as a function of the displacement angle of the oscillation (Figures 3 upper graph) on a computer monitor using data collection and analysis software (DataStudio by PASCO).

**Teaching and Learning Activities**

In the “traditional” chaotic pendulum the motion of the pendulum could be observed only during the real time motion. On the contrary, the motion of the microcomputer-based pendulum could be observed not only in real time but also by its representation by a real time plot. In both cases an irregular motion is displayed, which indicate a kind of randomness generated though by deterministic rules.

In an experimental research design the “traditional” chaotic pendulum has been used with thirty 11th-grade students and the microcomputer-based chaotic pendulum with eighteen pre-service teachers. The two groups showed no significant differences in their pre-instructional knowledge about aspects of deterministic chaotic systems. Thus the starting point of the two groups is quite similar.

The learners used the possibility to determine the deterministic or random nature of a process by the comparison of the development by repeating the process under exactly the same conditions several times. That means that, if in each repetition the development of the processes and the final outcomes were identical or only slightly different, students considered a deterministic process; if they were significantly different, they considered a random behaviour.

In the case of the “traditional” chaotic pendulum repeating though frequently the experiment there is no way to recognize that some characteristics remain the same and some differ. Therefore, students had to proceed to the difficult, as it turned out, task, of the detailed analysis of the motion in order to identify the deterministic

![Figure 3. Chaotic Motion: Angular position vs. time (lower graph) & Angular velocity vs. displacement angle (upper graph)](image-url)
base of the process (e.g. the forces between the magnets and the iron bob) and the role of the small deviations and disturbances. To explore the reasons for the differences occurring in the outcomes when repeating the experiment substantial guidance has proven essential. For example a graph with the potential of the chaotic pendulum (Figure 4) and the ridge analogy (Figure 5) were offered. The graph of Figure 4 illustrates that there are ‘lines’ where the iron bob is attracted by equally strong forces from the right and left magnets. To understand the role of these ‘lines’ and the role of small random factors in causing the unpredictable behaviour of the chaotic pendulum, the ridge analogy (Figure 5) was introduced. The behaviour of a ball approaching a ridge was compared with the lines of equal forces to the right and left (lines of unstable equilibrium) in the chaotic pendulum. Only then students were able to develop an explanation about the behaviour of the chaotic pendulum. In other words, the characteristics of the experiment did not facilitate the understanding of the intended ideas.

**Figure 4. The potential of the chaotic pendulum**

**Figure 5. The ridge analogy**

In the “micro-computer based” chaotic pendulum on the other hand, the learners could observe the motion of the disk in real time and also its representation by a real time plot (Figure 3). Different runs of the experiment can be displayed in the same screen (Figure 6). Thus they had the opportunity to study the behaviour of the motion using the real time plots. This fact facilitated their explanations as the deterministic base could be observed, for example, by the similar form occurring in a repetition of the experiment comparing the graphs \( \omega = \omega(\phi) \) (Figure 6, upper graph). Therefore, the similar form in the graph was strong enough evidence for the students to accept a deterministic behaviour in the chaotic motion of the pendulum. When the learners consider the graph of \( \phi = \phi(t) \) (Figure 6, lower graph) they realize that it is not possible to make a prediction about the motion of the disc. So they conclude that it is possible to have deterministic laws without predictability. In other words, the possibilities provided by the microcomputer-based chaotic pendulum facilitate the understanding of the intended ideas.
Concluding Remarks

In the demonstrated example it seems that the direct connection between the real experiment and its representation in a real-time plot facilitate students understanding of the chaotic pendulum motion. But this conclusion has to be regarded with caution in order to avoid overgeneralizations. When carrying out experiments in the classroom we have always to keep in mind that experimental results cannot speak by themselves. That means, “...diligently and beautifully designed experiments do not necessarily result into the outcomes expected – they need to be staged adequately in such a way that hands & minds on actually may occur” (Duit & Tesch, 2010; p.26).

**Figure 6. Chaotic motion: Graph comparison for two runs of the experiment**

References


Lunetta V.N., Hofstein A. & Clough M., (2007), Learning and teaching in the school science laboratory: an analysis of research, theory, and practice, In N. Lederman and S. Abel (Eds.), Handbook of research on science education. (pp. 393-441), Mahwah, NJ: Lawrence Erlbaum.


Many teachers have already heard about MBL, but they haven’t experience in using it. In fact, till recently, these tools were too expensive for schools, and only in the recent years they have become accessible in terms of cost.

Teachers have appreciated the fact that in the article, “real computer experiments” are well distinguished from the “simulated” ones. In the teachers’ opinion, in fact, using PC simulations at schools doesn’t allow students to clearly perceive the “reality” of the physics experiments, but often leads them to confuse the experiment with a videogame.

On the contrary MBL (Microcomputer Based Laboratory), by linking the PC to a “real situation”, helps students to bridge the gap between virtual and real worlds, and to investigate the real physics world.

MBL makes teachers thinking at the popular concept of internet of things”, one definition of which is: A global network infrastructure, linking physical and virtual objects through the exploitation of data capture and communication capabilities (e.g. household electrical appliances, light bulbs, etc.)

From a logistic point of view, using MBL doesn’t have specific requirements; in some case a re-organization of the lab room is needed: in fact in some schools physics and ICT labs are located in two different rooms. In order to use MBL there are two possible procedures:

1) To introduce net book in the physic lab and to connect them with the data acquisition interface
2) To bring either physical objects for measurement and computers in the same room / lab.

In case 1) there are some additional costs to equip the physics lab with ICT tools; in case 2) only 1 lab could be used (which seems to be easier for small schools).

A cheaper solution is to equip only the teacher desk with a PC for data acquisition, linked to a projector. This solution has the disadvantage of reducing the active involvement of the students who are allowed “only” to follow the teacher’s operations. In such a case the teacher could give students the data of the experiment to be elaborated at a later stage, in the ICT lab or at home.

In terms of costs, MBL could replace more expensive equipment: especially if a school is undertaking the labs modernization, MBL can be used as a cheaper solution with respect to the classical instruments. On the contrary for schools already fully equipped, to buy MBL could represent an additional cost.

In terms of teaching aspects of MBL, teachers agree on the expert’s position. The following remarks on the teaching aspects have been made:
a) who’s the experiment for? The target beneficiaries of the experiment described in the article are not clearly described;

b) the experiment is too difficult with regards to the students’ competences of an Italian scientific high school

c) the article seems to describe a phenomenon rather than an experiment. It might be an issue in understanding it, by teachers from different countries: What Italian teachers mean by “experiment” is: a practice that links lab activities and data analysis. What is described in the article seems to refer be more similar to a natural sciences lab activity, where observation plays a role more relevant than analysis. This could be due to different teaching practices used in different countries.

More specific remarks have been done by math’s teachers.

The “chaos theory” is a fascinating subject for students, with hard mathematical implications, which are not easy to deal with. On the opinion of the respondent teachers, it is important to make the students able to “write and solve” equations, as well as to understand the chaotic character of the system from the solutions.

In the article the problem is proposed in a way that (Italian) high school students, not being able to work and solve the related equations, can only observe the evolution of the system, without understanding the underlying equations. The problem should be set up on an easier system, with equation that can be solved by students.

In conclusion: teachers recognize and appreciate the teaching possibilities offered by MBL, but they think it should be for experiments more appropriate to their teaching practice.
SECTION III: TEACHER TRAINING TOWARDS CREATIVITY

ACTION RESEARCH AS A STIMULUS FOR TEACHERS TO REFLECT ON THEIR PROFESSIONAL DEVELOPMENT

EXPERT CONTRIBUTION: Stefan Zehetmeier (Assistant Professor, University of Klagenfurt, Austria)

Introduction

In Austria, a nation-wide teacher professional development programme, which is based on the ideas of action research, was launched 15 years ago: the IMST project. Since then, this programme has undergone several modifications and adaptations and is still persisting. The aim of IMST is to establish a culture of innovation and to strengthen the teaching of mathematics, natural sciences, and related subjects in Austrian schools. (See e.g., Krainer, Hanfstingl, & Zehetmeier; 2009).

This contribution aims at introducing the IMST project’s genesis, providing its developmental stages and describing its current project status.

The starting situation in 1995

The initial impulse for the IMST ("Innovations Make Schools Top") project in Austria came from the 1995 TIMSS achievement study (Third International Mathematics and Science Study). In Austria, as in many other countries, international comparative studies like TIMSS and PISA (Programme for International Student Assessment) had a considerable influence on the national educational policy. Austria participated in all three cohorts (primary, middle and high school) of the TIMSS achievement study. Whereas the results concerning the primary and the middle school were rather promising, the results of the Austrian high school students (grades 9 to 12 or 13) in the TIMSS advanced mathematics and physics achievement test were dissatisfactory. The ranking lists showed Austria as the last (advanced mathematics) and the last but one (advanced physics) of 16 nations (e.g., Mullis et al. 1998, p. 129, p. 189). As a reaction to these results, the IMST project was implemented in three steps:

- The IMST research project (1998-1999) was designed to analyse the situation of upper secondary mathematics and science teaching in Austria and to work out suggestions for its further development.
- The IMST² development project (2000-2004) focused on upper secondary level in response to the problems and findings described.
- The IMST³ support system (in three stages 2004-2006, 2007-2009, 2010-2012; a fourth stage 2013-2015 just started) started to implement parts of the strategy plan; among others, by continuously broadening the focus to all school levels and subjects.
The IMST research project

The IMST research project (1998-1999) was set up to analyse the TIMSS results in the upper secondary level and relate the findings to the whole educational system. The project identified a complex picture of diverse problematic influences on the status and quality of mathematics and science teaching:

For example, Austrian students showed poor results in particular with regard to items which refer to higher levels of thinking. In their response to the item in the TIMSS-questionnaire concerning reasoning tasks in lessons, less than a third of Austrian students felt that they are involved in reasoning tasks in most or every mathematics lesson(s), resulting in the last but one place in the international ranking of 16 nations. In physics the corresponding figure was half of the students, with Austria in last place.

Moreover, mathematics education and related research was seen as poorly anchored at Austrian teacher education institutions. In chemistry education, for example, no university had a university professor for that scientific domain. Subject experts dominated university teacher education, other teacher education institutions showed a lack of research in mathematics education. The collaboration with educational sciences and schools was –with exception of a few cases– underdeveloped. A competence centre like the Freudenthal Institute at the University of Utrecht in The Netherlands or the Institute for Science Education at the University of Kiel in Germany did not exist.

In sum, the overall findings showed a picture of a fragmentary educational system of lone fighters with a high level of (individual) autonomy and action, however, there was little evidence of reflection and networking (Krainer et al., 2002).

The analysis project highlighted possible implications: Improvements could be achieved if both pupils’ sophisticated skills and autonomy would be enhanced. These issues should be accompanied by professional development programmes for teachers, which should focus particularly on reflection of teachers’ own practice, on networking with colleagues and on the support by academics. In sum, this could lead to the development from a rather fragmented system towards a "learning system" (see, e.g., Krainer et al., 2002)

The IMST² development project

The IMST research project (see above) led to the IMST² development project (2000-2004). This project (Krainer et al., 2002) focused on the upper secondary school level and involved the subjects: biology, chemistry, mathematics, and physics. It adopted teachers’ enhanced reflection and networking as the basic intervention strategies. The theoretical framework builds on the ideas of action research (e.g., Stenhouse, 1975; Altrichter, Posch, & Somekh, 1993), constructivism (e.g., von Glasersfeld, 1991; Ernest, 1994) and systemic approaches to educational change and system theory (e.g., Fullan, 1993; Willke, 1999).
The main objectives of this project were

- to initiate, promote and make innovations visible, to analyse and to disseminate innovations, with the emphasis on generating “good practice” concepts and on supporting teachers in further developing their teaching;
- to take part in setting up a support system for the further development of school practice in MINT subjects, in particular by encouraging practice-oriented, scientifically grounded subject didactics.

In order to take systemic steps to overcome the fragmentary educational system, the approach of a “learning system” (Krainer et al., 2002) was taken. It adopted enhanced reflection and networking as the basic intervention strategy to initiate and promote innovations at schools. In particular, IMST regarded action research as a key, following Elliott (1991, p. 69), defining action research as “the study of a social situation with a view to improving the quality of action within it”.

Besides stressing the dimensions of reflection and networking, “innovation” and “work with teams” were two additional features. Teachers and schools defined their own starting point for innovations and were individually supported by researchers and project facilitators. The IMST² intervention built on teachers’ strengths and aimed at making their work visible (e.g., by publishing teachers’ annual project reports on a website). Thus, teachers and schools retained ownership of their innovations. Another important feature of IMST² was the emphasis on supporting teams of teacher colleagues from a school.

In the years 2000–2004, IMST² supported each school-year about 50 innovative projects at Austrian upper secondary schools. The participation was voluntary and gave teachers and schools a choice among four priority programmes (Basic education; School development; Teaching and learning processes; Practice-oriented research: Students’ independent learning) according to the challenges sifted out in the above mentioned research project. The priority programmes supported initiatives at schools that planned and evaluated corresponding teaching units and worked out innovative concepts.

In general, teachers in all four priority programmes were supported by staff members of IMST. On average, teachers within a priority programme and their staff members met two times a year. In addition, communication also happened via phone or e-mail, and staff members organised individual meetings with their teachers at their school in order to collect or discuss data. The priority programmes can be regarded as small professional communities that not only supported each participant to proceed with his or her own project but also generated a deeper understanding of the critical reflection of one’s own teaching, by means of actions research methods (see e.g., Zehetmeier, 2010).

The IMST3 support system

The succeeding IMST3 support system stands for the consistent pursuit of the second objective of the IMST² project (see above). It provided seven key measures
(M1 – M7, see below), which are designed to support a high quality of instruction and are focusing on various levels of the educational system: local, regional, and national. The measures are presented below:

At the local level (schools):

- **(M1) Upgrading the role of local subject coordinators**

  Subject teams within schools need to be established in a systematic way throughout the country. The coordinator for such a team needs to be properly qualified for the task and to be given an appropriate status at his or her school. By the end of 2012, M1 has been repeatedly included in government plans; however, it still awaits implementation.

At the regional level (federal states):

- **(M2) Upgrading the role of regional subject coordinators**

  The federal states have regional subject coordinators, however, with highly diverse tasks and responsibilities. There is a need for unifying and precisely specifying these tasks nation-wide. M1 and M2 were suggested to form a flexible system of subject-related education managers at local and regional level, thus generating a kind of middle management helping to optimize the communication and information processes between the local, the regional and the national education system. M2 started in the years 2006-2008 with a pilot-project (about 90 teacher leaders graduated). It was extended and combined with another two-year professional development programme organized by the AAU (Alpen-Adria-Universität Klagenfurt, Austria), starting 2012 with more than 150 teachers.

- **(M3) Setting up regional centres for subject didactics and school development**

  Regional centres need to be established with a view to generating synergy effects that benefit both research in subject didactics and school practice. These regional centres should have overarching responsibilities and work in close contact with corresponding national centres (see M5). M3 has been implemented, starting in 2007. By the end of 2012, 19 Regional centres had been established. It is planned to increase its number in the IMST period 2013-2015.

- **(M4) Setting up new or upgrading existing regional networks**

  Regional networks of teachers and schools enable the economical use of available human and material resources. Beyond this, the establishment of such networks is expected to facilitate the setting of regional subject-related or cross-subject goals which direct the support in the teaching of MINT. M4 has been implemented: In all nine federal states, regional networks have been set up to support the regional educational structures, starting with the first regional network in the federal state of Styria in 2003. Moreover, support was provided by setting up five district networks.

At the national level (Austrian Educational System):
• (M5) Setting up national centres for subject didactics

The national centres for subject didactics should, among others, be engaged in the planning, implementation and evaluation of innovative research and development projects; they provide support for classroom teaching and monitor national developments and international programmes. M5 has been implemented: Austrian Educational Competence Centres (AECC) –with subject didactics centres for biology, chemistry, German language, mathematics, and science– have been put in place, starting 2005.

• (M6) Setting up a Fund for teachers

In order to effectively stimulate innovations in the teaching of MINT as well as in teacher education, a Fund needs to be set up. The Fund should provide financial and organizational support to school development initiatives as well as to school-related research on subject didactics. M6 was implemented in the form of a “Fund for Instructional and School Development” for teachers in 2007.

• (M7) Operative steering of IMST3

The goal of the Centre of Instructional and School development (IUS) at the AAU is to be engaged in research, development and consultation at all three levels of the school system, namely teaching, individual schools as organisations, and the educational system at large. This centre was founded in 2004.

On-going Project Stage

Throughout all phases of IMST, the project is accompanied by a website (which includes, for example, all documents written by staff members and teachers), an annual conference (recently comprising four days) and a quarterly newsletter (with about 15,000 exemplars printed). By the end of the school year 2011/12 1,091 innovative teaching projects were carried out within the IMST project. In the school year 2012/13 there were 107 further projects promoted by IMST. Approximately 1,800 teachers were actively involved in the project which reached roughly 40,000 pupils.

For 2013-2015, the ministry expressed its intention to continue IMST. The overall goal is setting up and strengthening a culture of innovations in schools and classrooms, and anchoring this culture within the Austrian educational system.

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This response seeks to provide a clearer understanding of the perceptions of teachers and teacher trainers working in Turkey, both in state schools and private ones on Alternative Teacher Training Methodologies. Presented are the positions from a set of five teachers as these emerged from the consultative process applied. These address several crucial issues, such as: on knowing how to teach; the uncertainties of teaching; real teaching; the future of teaching; alternative outlooks on teaching. Discussed are teacher student relations, problems teachers face, and competing academic traditions.

Gonca Öngel (teacher at a state school): We need to make sure that all teachers – new recruits as well as those already in classrooms – are well-trained, have access to ongoing training and are treated as professionals – with decent pay and conditions. Without trained teachers for all, education for all will never be a reality. Teacher education refers to the policies and procedures designed to equip prospective teachers with the knowledge, attitudes, behaviours and skills they require to perform their tasks effectively in the classroom, school and wider community. Continuous professional development is really important. Because the community that teachers are preparing young people to enter is changing so rapidly, and because the teaching skills required are evolving likewise, no initial course of teacher education can be sufficient to prepare a teacher for a career of 30 or 40 years. Continuous Professional Development (CPD) is the process by which teachers (like other professionals) reflect upon their competences, maintain them up to date, and develop them further. Continuous professional development should be spread over time, be collaborative, use active learning, be delivered to groups of teachers include periods of practice, coaching, and follow-up promote reflective practice encourage experimentation, and respond to teachers’ needs.

Sevinç Özdemir (teacher and a policy maker at a state school): As we all have most probably experienced, a skill can mainly be developed through its systematic practice, and as in many other professions, teachers starting their career face circumstances they have never heard or thought of before. Thus entering the field of teaching can many times be very frustrating. To help the teacher cope with such situations, every teacher in Turkey in his/her first year of teaching is appointed to a mentor teacher from among the teachers of the school with the task of guiding the new teacher. The load of work of the mentor, however, prevents him/her most of the time from paying the necessary attention to the new beginner’s needs. It can also be argued whether the mentor him/herself is competent enough for this role as s/he is educated as a teacher but not a mentor who needs to be proficient in the training of teachers. Delivering teacher in-service training seminars is another alternative for new beginning as well as experienced teachers to learn, refresh or develop their knowledge and teaching skills. However, not all teachers have the
opportunity to attend these programmes. The lack of follow-up seminars is another constraining factor. Taking into account the drawbacks and ineffectiveness of the above mentioned approaches, I believe that a system that promotes the mentoring of the teacher on the spot, needs to be considered thoroughly. The presence of proficient teacher trainers in schools can be a very effective and promising praxis in the training and development of teachers. It’s obvious that by observing teachers in their classes and providing them with one to one feedback and a systematic guidance for more effective teaching can eliminate an important deficit in the training of teachers. The education of teacher trainers on the other hand needs to be considered by universities as a separate area defined anew for these trainers need to be equipped with the teaching methods and techniques which serve all disciplines taught at school.

Özlem Sağlık (teacher trainer at a private school): Teacher training sessions are usually perceived as either a long lecture or a stand-up show, swinging at the edges of extremes. While the latter is an attraction centre for most; the long lecture does not sound very interesting no matter how educative it is: Which, then results in the decrease of the number of the participants. As a trainer, I believe, a successful training session is a mixture of both theory and practice. Neither long monologue-like lectures nor very enjoyable activities and jokes can solely help one to improve themselves in teaching. A successful session must have theoretical input as well as certain practical activities ready to use in the classroom –right after the session. Without knowing the necessary background information and the conceptual orientation behind all those fancy techniques, it does not seem very likely to establish a well-balanced classroom atmosphere. A teacher trainer differs from a lecturer in that a trainer must plant seeds in the participants’ minds as well as giving them flowers.

Hüseyin Uraz (teacher at a state school): Not only does teaching or learning matter, but learning to teach and teaching to learn should also be taken into consideration as it is unrealistic that one without another can progress. It is a common belief that teachers tend to teach in the way they are taught. Thus, in teacher training programmes what we say or explain is not important, but how we give the message is the only thing that matters. For example, when it is explained or presented in front of slides how students can be activated and encouraged to take part in activities, it doesn’t matter how well it is explained, the only message that participants receive is teacher-centred education and long teacher talk time. In other words, teachers tend to treat students in the way they are treated in training sessions. Therefore, a fruitful training session should be participant centred; sharing ideas to each other and learning by doing should be essential.
Technologies and teachers: some predictions may come true

A preliminary warning is in order: the future will last a long time and many things will happen in it. So it is important to precise which future is under scrutiny. In fact, 3 types of temporality may be considered. The first one is proximal. Here, things are easy: nothing new will probably happen in education in the next few years: educational systems evolve very slowly.

A second type of temporality is easy to dispose with: the very distant future. Prediction is possible, but risky. Of course, in the past, some visionaries have done great work. For example, in late XIXth century, French author Albert Robida, in a book entitled *La vie électrique* (*The electric life*) (1892), imagined, for the XXth century, a device named telephonoscope, which allowed for distance education. In the following illustration, a young lady follows distance courses in order to become an engineer. This anticipation is impressive (using the still new telephonic technology to also transmit images). On the other hand, of course, many science-fiction predictions did not come true; but, after all, does it really matters?

The last category is the most interesting and the most difficult: medium range anticipation. It is this one I'll try to deal with in this synthetic paper, relying on a project led in France in 2010: PREA2K30⁴. This project has focussed on the issue of which research about education and learning should be launched now in order to prepare for 2030. To achieve this, the research consortium has identified a series of variables (e.g. technology, research, curricula...), considered for each of them both weak signal and massive tendencies, taking into account what happens in the global world where we are living (Redecker et al. 2010) and produced macro-scenarios (Baron & Burkhardt 2011).

What I present here is a reflection also marked by my own situation: I'm a French researcher in education; I know better what has happened in the domain of French speaking countries. But, what has been observed in these countries is probably similar to what happens elsewhere. The main difference is not so much linked with the language but rather lies between rich and poor countries. Those latter still have a weak and expensive internet infrastructure and must cope with many problems; But they are very creative. Quite a lot of work is available on the use of “older” technologies like radio, that also allow for creativity and efficiency (Awokou 2007).

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⁴ [http://prea2k30.scicog.fr/]
Continuity or disruption?

(Christensen et al. 2008) claim that we shall shortly experiment a disruption in school systems, due to the expansion of technologies, allowing students to study partially online, at their own pace, what they like. Other authors like (Collins & Halverson 2009), without going that far, remark that, on the long run, many changes in the finalities and the modalities of education have occurred, that now education must be rethought in the new context marked by pervasive technologies changing interactions between learners and teachers.

A crucial issue is the evolution of teacher roles and responsibilities in this context. Will they really become something akin to coaches, not obliged any longer to teach in an old fashion way? What will be their expertise and responsibilities regarding subject matters? Which kind of new freedom can they conquer? Or perhaps will they be obliged to become auxiliaries of a technological system they do not master? Or are we in a situation that will not change much, technological innovations being strongly limited by the structure of school systems: As Larry Cuban remarked, between the classroom and the technology, the winner is the classroom, with a singularity for primary education, more permeable to technological innovation (Cuban 1993)? Or perhaps shall we finally see what Ivan Illich predicted in 1971, a de-schooled society, with teachers having a very different status (Illich 1971)?

Research has amply documented that technology is manifold and that only what is sufficiently in phase with the system can spread. For example, in education, presentation devices, compatible with frontal teaching, have quickly become commonplace and are now quite naturalized.

Their contribution may be high, since teachers, when connected to the internet may improvise and adapt to the students’ interests. It may also be rather modest, when teachers just follow their slides in their primitive order. The same happens with
Interactive whiteboards (IWB). Some innovative teachers have invented very creative ways to use them. But, after a promising start, will IWB fulfil the expectations of their first promoters or will they be used to keep on doing classical things? An important idea, expressed by the French researcher Daniel Poisson long ago is that technologies are not automatically triggering new practice but that they often act as *amplifiers of existing practice* (Poisson 2003).

In order to be more precise, 3 main kinds of ICT use have to be distinguished. The first one is linked with educational technology, as a tool for teachers. The offer of resources is now very important and almost every vision of teaching and every situation can be matched with specific resources. But to what extent will it change teaching?

A second type of usage is linked with the instrumentation of learning rather than the instrumentation of teaching. One of the main innovations in the past 20 years has been the diffusion of specialized software tools offering powerful means to analyze data and, even to model and to describe data. The main applications have been in mathematics and science and known success, since curricula have often been modified to integrate them. Now, computer algebra systems, various computer simulations and computer assisted experimentation are quite commonplace. They may change the way contents are taught, provided teachers have received an education focussing on them.

Research led so far however suggests that changes are modest and occur more frequently when teachers are well trained and may rely on a community of peers. One of the major issues regarding letting students experiment is that teachers want, with good reasons, to prevent them for going too much astray, getting lost and perturbing the course. Hence, a tendency has been remarked from resource producers to propose environments guiding students quite strictly, which is contradictory with letting them experiment as they want.

In a sense, the situation appears to be rather stable: new technological possibilities keep on appearing and innovations show promising ways of improving education. But a sustainable innovation is an oxymoron and innovations either pass away without noise or distantly spawn new everyday practice that may apparently have little in common with the original innovation (Baron & Bruillard 2008). The key here is that, for innovations to know a real success beyond transient experimental conditions, a set of conditions have to be fulfilled: preliminary teacher education and professional development, an ample set of educational resources, coming either from a private market or from open sources, accompanying measures from authorities...

**Possible evolutions in the next 20 years**

The aforementioned Prea2K30 project (Baron & Burkhardt 2011), came up with 3 possible macro-scenarios for the 2030 horizon, the more probable in industrialized countries being perhaps the second.
The first one corresponds to the development of a global market of education, with a trend toward *McDonaldization*, as described by George Ritzer (Ritzer 1996). In this hypothesis, there would be growing contrasts and inequities between people according to their social milieu. The creativity of teachers would of course still exist, but with very different possibilities according to situations and available means.

The second macro scenario is also a continuous one, it is in a sense a technocratic scenario, with an important roles attributed to experts, a continuous quest for efficiency and a persistent duality, regarding educational resources, between what is being produced and exchanged within communities of teachers and a fragmented private market of educational resources.

In the third scenario, there would be an important commitment of policy-makers toward education and training, important national policies concerning research, and a dynamic involvement of practitioners for producing and exchanging resources.

Whatever scenario comes true, regarding secondary education, a few things seems highly plausible:

1. No global disruption is likely in the next 20 years, but inequalities may grow up, between school systems and between social milieus.
2. Situations will obviously vary according to countries and political and economic conditions.
3. Online resources are going to occupy a still greater place in the life of all actors of education, allowing for more collateral learning. But prescribing and organizing the study of valuable resources by students will remain the responsibility of teachers and occupy a greater place in their agenda.
4. Innovation will continue to exist and will hopefully be beneficial for the whole system.

The key, here, is the degree of autonomy that teachers can manage to conquer. They are professional and, united, may foster change. Two French researchers (Quentin & Bruillard 2013) have studied networks of teachers involved in the production of online resources. They distinguish between two main models of organization: the sandbox, where rules are flexible and where there is a great asymmetry between members and the hive, where restrictive rules are accepted “in the name of shared values” and where does exist a common commitment to producing resources according to fixed rules. The second model gives better results in terms of collective efficiency. As an example, authors analyze the case of the Sesamath association.

This association, founded by maths teachers in France⁵, has been promoting free software, free resources and public service since the beginning of the 2000, in order to help teach mathematics better. It has a strong vision of what should be done and has been inventing solutions with the Web and multimedia resources.

At some point, they decided to produce a mathematical textbook for 7th graders, both free on line and also available on paper for a fee. The extraordinary thing is

⁵  [http://www.sesamath.net](http://www.sesamath.net)
that this book became a best-seller (nearly 15% of the publishing market of mathematics in lower secondary schools textbooks) and that the association gained a strong influence, included at the political level, thus contributing to the promotion of creative ways of teaching mathematics. What this association will become in the forcoming years is however still open.

The future is not yet written down. Technologies have no intrinsic drive and scenarios of teacher alienation, being obliged to work under imposed leadership, are possible. However, recent history has shown that Internet can be used by teachers in a process of empowerment. This process is slow and based on the activity of communities of practice run by activists and supported by less involved colleagues. As Lave & Wenger claimed more than 20 years ago, legitimate peripheral participation in these communities is an excellent way of learning and empowering oneself (Lave & Wenger 1991). The activities of innovators cannot, of course, be sufficient to bring changes, but teacher agency is central. The hope is that decision-makers will understand the interest of innovations and support innovators without wholly denaturing their endeavour.

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Teachers Response on Competences of the teachers in the future

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First aspect: The role of teachers in the future

Frontal teaching is common in schools at the present time. But frontal teaching is not a priori bad teaching. It depends whether the learning process considers the way students are thinking, their previous knowledge and if all students know the objective of the lesson. Even in a lecture or in frontal teaching it is necessary to see the learning through the eyes of the students. Finally frontal teaching is only one of a huge amount of learning strategies teachers should handle with. Crucial is that teachers help their students to construct their own knowledge, independent of any method of instruction. Very important is the transparency of the learning process not only for the teacher but at first for the students. At every moment of the lesson each student must be able to answer the following questions: “Where am I going?” – “How am I going there?” – “What is the objective of the lesson?”

A better way of considering these basic requests on good practice in schools is indeed the changing of the role of teachers. But teachers remain the most important part of the learning process; they could not be replaced by computers.

Teachers should not longer be instructors but advisors and coaches, who organize the learning process in agreement with their students. In some way students should become their own teachers, they develop self-monitoring and self-evaluation. Teachers should provide their students with a lot of opportunities for developing and training learning strategies. Because we all learn so much from errors, they should be allowed and welcomed as an opportunity for learning and feedback.

These tasks should be kept in mind by adopting new technologies for teaching in the future. New technologies can only enrich the package of tools a teacher has. But they cannot substitute the role of a teacher completely. It is still up to the teacher to find an appropriate setup for the learning process, to outline a scheme, to put up scaffolding for the students.

This could be one of the most important changes in future schools.

Second aspect: Instrumentation of learning

Software tools offer powerful means for analyzing, modelling and describing data. But they cannot replace individual experience in working with data, doing own measurements and drawing graphs.

Even the labelling of axes must be done without any software. Software and the use of computers must not replace the learning of basic skills. We all learn by doing the work and not by clicking on a key.
But computers are unbeatable in researching of information, practicing and applying student’s knowledge. Repeating real experiments at home; changing parameters with the help of applets, these are some of the most important applications of IT.

Another good example is the mentioned IWBs. They can be a brilliant chance to bring transparency to the class and the learning process if they are really used as an interactive tool. They could function as a junction between the teacher, the students and their own devices, so the students can easily form virtual groups, present, and exchange ideas easily. Or from the downside they can be an additional “toy” for the teacher. Consequently, new technologies can only bring new tools to the teacher and the classroom. But HOW tools and techniques are used under appropriate circumstances is far more important than WHICH tools and techniques a teacher uses.

Third aspect: Interconnectivity

In the former paragraph IWBs were an example of interconnectivity in the classroom but interconnectivity in general will become more important. The teachers will and have to connect to the students by the means of the first paragraph to foster the learning process. Under the right circumstances technology may add the appropriate tools as described above.

But of course teacher by themselves can interconnect better and better. This could be in organized structures like Sesamath as described by the author, in structures provided by the state or publishing companies or in self-organizing structures like forums or bulletin boards over the internet. A good example for the latter is the German website 4Teachers (www.4teachers.de) where teachers voluntarily exchange materials and ideas for lessons. If preferred a more localized access is possible: Teachers (and students) of one school can interact and exchange via a moodle-website. Even social media may and will contribute.

So communication structures between teachers and between teachers and students will become more complex and versatile but less hierarchical as communication has to happen not only horizontally but also vertically in both directions.
PART B:
INNOVATING SCIENCE EDUCATION IN PRACTICE – CURRENT CREATIVE INITIATIVES

This part of the Annual Report n.3 focuses on best practices targeting to promote innovation and creativity in classrooms are presented, under the scope of stimulating teachers’ self-reflection for successful implementation.

First, the Inquiry Learning concept AuRELIA is presented. Based on an educational paradigm that obtains its evidence-based arguments from Self-Determination Theory, AuRELIA is a subject- and domain-independent concept for self-determined Inquiry Learning. It has emerged from the authors’ practice at lower secondary schools in science lessons with heterogeneous groups and it has been enriched with theory and evidence drawn out from several research projects. The initiative has already been successfully implemented into practical studies, as well as teacher education.

Second, one of the Winning Initiatives of the STENCIL 1st Call for Participants in 2012, ACTIVE SCIENCE™ is provided, as a recognized innovative tool for promoting scientific education and citizenship, addressed to high school students and teachers. It is part of the actions aimed at defining a new relationship between science and society, according to the goal of the so-called “University third mission”. The paper proposes some recommendations for those who are thinking at building their own Active Science™, while at the same time highlights some critical issues that have occurred during the implementation of the project in the last 4 years.

Third, The Physics Club is described, an initiative that has won a lot of important national awards in Germany. In this project students 10-19 years old act like scientists and work on interesting and up-to-date topics in physics, astronomy, biology, chemistry, IT, geophysics, while science teachers have the opportunity to practice Inquiry-Based teaching methodology. The paper discusses the impact of the project on teachers, schools and students, and provides results about the evaluation of the project regarding its influence on participants university carriers.

Then, the Fibonacci Project is presented under the scope of highlighting its impact on the professional development of teachers, on educational structures, on schools culture and on students. Suggestions for the successful transfer of the outcomes of the project are made, with the view of contributing towards sustainable development in learning and sustainable change in education.

Finally, “Investissements d’avenir” and project of the Academy of Sciences is provided. It is an in-service science and mathematics teacher training programme, with the training focus on: the relationship with the scientific community and an
opening to the world of research; a pedagogy based on inquiry and interdisciplinary; the practical implementation in class; the training of resource persons.
SELF-DETERMINED INQUIRY LEARNING - BRINGING REAL AUTONOMY INTO LEARNING ARRANGEMENTS
AN INTRODUCTION OF THE AuRELIA-CONCEPT

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Website: http://www.inquirylearning.eu (Inquiry Learning Research Homepage)

Johannes Reitinger introduced his Inquiry Learning concept AuRELIA to the participants of the STENCIL Conference at the SFN in Kassel on December 1st, 2012. Within the following article, he summarizes the theory as well as some practice-related outcomes of the concept.

Constructivism as well as Bildungstheorie proceed on the assumption that institutionalized learning en route to mature personality must not abstain from self-determination. Assuming further that human beings are generally equipped with a curious and inquiry-oriented mind, autonomous and exploratory action seems to be a human right and therefore an indispensable part of sustainable education at all.

This introductory paragraph denotes an educational paradigm that obtains its evidence-based arguments from Self-Determination-Theory, from current brain science, from epistemological reflections and from educational research, such as my research concerning the AuRELIA-Concept. AuRELIA stands for “Authentic Reflective Exploratory and Interaction Arrangements”. It is a subject- and domain-independent concept for self-determined Inquiry Learning. AuRELIA emerged from my practice at lower secondary schools in science lessons with heterogeneous groups. Meanwhile, I have underpinned the concept with theory and evidence drawn out from several research projects. At the University College of Teacher Education in Linz (http://www.phdl.at) this concept has already been successfully implemented into practical studies as well as teacher education.

The following explications glance at first at the conceptual architecture of AuRELIA. After this, some exemplary outcomes of practices are brought into discussion. Finally, a summary of research results may point out the concept’s potency.
The architecture of AuRELIA is characterized by seven action phases. These phases are:

- **Emergence** (encouraging interest, integrating the learners’ wants concerning content and method of learning).
- **Speculation** (connecting available knowledge and personal cognitive patterns, forming hypotheses).
- **Conception** (outlining an investigation strategy collaboratively with learners and coaches).
- **Investigation** (realizing the worked out conception, collecting information, conducting experiments).
- **Discovery** (editing and visualizing data, checking and reconstructing hypotheses).
- **Critical Phase** (discussing results, reflecting experienced processes, actualizing and evaluating developed personal contexts of meanings).
- **Transfer** (applying new insights and knowledge, publishing discoveries, opening externally by initiation of general discourses).

This phase structure derives from two existing concepts. These are the long-known action steps of John Dewey and the scientific-knowledge building process of Reinhard Demuth et al.

The sevenfold process-structure of AuRELIA is a closed structure. Nevertheless, within these phases we find widely opened phase-structures. Therefore, the question arises: How can a teacher or inquiry coach handle these open structures so that the autonomous actions within a phase won’t end up in randomness?

The following hints may be useful to give an answer to this question. I recommend to …

- … orient contents of Inquiry Learning lessons towards wishes, concerns and demands of the learners.
- … offer innovative learning environments. This may lead to a regulation by contexts.
- … transmit responsibilities to the learners. When inquiring their own questions they are intrinsically motivated and therefore eager to take tasks.
- … practice continuous reflection. They is a kind of viability check for all participants.
- … have available a wide personal repertoire of internalized educational techniques and micro methods. They will keep the teacher flexible during unpredictable lesson stages.

A further key element of AuRELIA is a cluster of six educational principles. Research evidence has drawn out that teacher’s recognition and contextual reflection of the principles a) trust, b) self-determination, c) safety, d) clearness, e) structuring and f) personalization during the outline, performance and reflection of Inquiry Learning projects have a positive influence on the outcome and the learners’ competence.
evolvement. Therefore, sensitiveness concerning these principles is one of my most important recommendations for teachers and inquiry coaches.

It is also worth mentioning that the AuRELIA-concept involves each of the six theory-based criteria of Inquiry Learning according to my Theory of Inquiry Learning Arrangement (TILA), published in 2013. These criteria are a) discovery interest, b) method affirmation, c) experience-based hypothesizing, d) authentic exploration, e) critical discourse and f) conclusion-based transfer. Therefore, AuRELIA is not just a practicable learning arrangement prototype but also – by unfolding the following inquiry-oriented dispositions and action domains – a theory-based concept:

- **Discovery interest:** Curiosity bases on the natural cognitive-emotional structure of human beings and is the impetus of autonomous action. People may be generally curious (curiosity as a disposition) or in particular situations (curiosity as a state). The emergence of curiosity in educational settings can be supported by consideration of pupils' wishes, concerns and demands. An authentically experienced exploration can only be achieved if discovery interest is given.

- **Method affirmation:** Learning by inquiry in a self-determined way cannot be ordered or simply commanded without a loss of authenticity. Thus, one requirement of Inquiry Learning Arrangements is that learners approve of this special kind of education. Agreements can be encouraged by a collaborative negotiation process that respects the learners' demands. Inquiry learning needs the approval on all hands.

- **Experience-based hypothesizing:** Based on a reflective attitude and linked to former individual experiences in Inquiry Learning Arrangements the learners construct assumptions and conceivable explanations. The estimation of possibilities by integrating implicit foreknowledge supports learners to evolve unrelated thoughts into meaningful configured patterns.

- **Authentic Exploration:** When learning by inquiry the location of viable exploratory paths is regulated by the learners and individually supported by the teacher. Considering evidence of autonomy research by John Reeve, it is important to maintain the following five elements: a) learners' curiosity, b) personalized intentions, c) flexibility of actions, d) challenging and meaningful learning contexts and f) demand-oriented learning environments.

- **Critical discourse:** Reflection is a very important part of Inquiry Learning processes. A multidimensional discourse should be oriented to a) a discussion of the output, b) a reflection of the learning process and c) an actualization and evaluation of developed personal contexts of meanings.

- **Conclusion-based transfer:** People want to disclose their own meaningful and novel discoveries. The application and externally opened communication of new experiences and knowledge are therefore obvious escorting and finalizing actions when performing authentic arrangements.
By summarizing these thoughts, we now arrive at a comprehensive definition of Inquiry Learning. In the author’s understanding Inquiry Learning is a both an autonomous and a structured process of personalized quest and discovery of novel experience and knowledge. It reaches from narrative explorations over systematic discoveries to methodical procedures characteristic for scientific research. The Inquiry Learning process is pillared by a) discovery interest and b) affirmation concerning the Inquiry Learning method. Further Inquiry Learning is typified by several inquiry-oriented action domains. These domains are represented by c) experience-based hypothesizing, d) authentic explorations, e) critical discourses and f) conclusion-based transfers.

Exemplary impressions and outcomes concerning AuRELIA: When proceeding AuRELIA with pupils, I often experience young curious learning people, who investigate autonomously far-reaching questions. In teacher education I mention students, who explore the pivotal contents of the curricula in self-determined ways powered by AuRELIA and our manifest conviction that humans are naturally curious and autonomy-oriented, to say it in the words of some important American researchers like Todd B. Kashdan or Edward L. Deci and Richard M. Ryan.
The following list shows a variety of exemplary impressions and outcomes collected within several AuRELIA-projects:

Once a group of young pupils in one of my classes wanted to know, how men’s body react on stressful emotions. This far-reaching research question was—at a first glance—unfeasible in self-determined experimental Inquiry Learning Arrangements, but we kept speculating. We then found a very cheap bio-feedback-equipment in the internet and installed a self-designed laboratory at the basement of our school. We examined pupils of a grade below concerning their physiological reactions (skin conductance level, pulse, temperature) while perceiving terrific images of ugly insects and arachnids. (The images emerged in an unexpected moment on a presentation screen.) The young researchers decided to divide the experimental-group into two subgroups. One subgroup was additionally stimulated with a special head massage tool. The recorded differences between the two subgroups were significant. What developed out of pupils’ very interesting research question was a two-group quasi-experimental treatment study (as we call such an approach in social-researches), discovered in a self-determined style by 12-years-old heterogeneous but curious youngsters.

To solve extraordinary inquiry questions many of my former pupils decided to make questionnaire-based field interviews. To give a demonstrative example, classmates of a secondary modern school wanted to investigate the scientific knowledge of ordinary citizen. They formed a list of different questions. One of the questions—indeed a tricky one—was. “What do you think when you read on a food pack: Contains E 300 – Ascorbic Acid?” What do you, dear reader, think? Well, an everyday thesis is, that the average consumer is of the opinion, that everything, that sounds like chemistry is categorical bad. My pupils wanted to reflect this thesis and
learned, that more people than expected could answer the tricky question. That was a surprising result, accompanied by a positive side effect. My students learned by themselves, that chemistry is not as black as sometimes painted. (Food additives are not generally critical. E300 for example is just vitamin C and therefore an essential substance for humans.)

Once, one of my teacher students, Susanne Oyrer, held a fivefold differentiated science project according to the conception of AuRELIA at one of our training schools. She treated personalized questions of her pupils like the following: “How can we make an electric motor with products from the supermarket? What is the best way to clean an oil-polluted water bird? Is it possible to hold fire in the hands? Can we boost a motorized bike with solar energy? How emerges weather?” You may look up the found answers in our students’ journal “Methodisches Entdecken” (http://www.inquirylearning.eu → Teaching Activities).

Sometimes I try Inquiry Learning with primary school kids. One interesting setting, I always remember was an examination of optimal conditions for a balloon rocket. During an experimental demonstration, the pupils wanted to know more about such conditions. I cancelled my pre-planned lesson outline, stopped demonstrating further experiments and gave some balloons, drinking straws and strings among the pupils. Organized in small groups they worked out more tested conditions, as I knew myself before coaching this workshop.

AuRELIA also works in teacher-education. To link students’ interests to curricular contents, I often stimulate their research questions with impressive curricular-referring picture-vignettes. After a picture-based stimulation of interests, I invite my students to outline individual questions, assumptions and strategies to explore their topics. I can’t remember one situation, the students didn’t accept my invitation.

...
Motivation Inventory (IMI, standardized scale). I learned that the estimations of all three variables are in the upper scale range at the same time.

My colleague Beatrix Hauer (University College of Teacher Education in Linz) investigated within her doctoral studies the influence of the concept on mathematical competence performance. She concludes that AuRELLIA is highly effective.

Very interesting to me is the finding that AuRELLIA also influences psychological traits. In teacher education, it was able to improve the inquiry habit of mind of self-determined Inquiry Learning participants significantly within a period of just two weeks.

Closing this brief introduction, I would like to address some words to the audience of the STENCIL Conference at the SFN in Kassel on December 1st, 2012. At this conference, I become acquainted with a lot of very ambitious and innovative students, teachers and researchers, all of them interested in evolving student-centred education and zest for science. This experience underpinned my hope that the paradigm of the self-determined learner has the potency to lead us to a promising future. Thank you very much!

References:


**ACTIVE SCIENCE™**

**CONTRIBUTION:** **ALESSIA DINO, ANDREA DE BORTOLI, GIOVANNI GALLO, GIANNI LATINI, ENRICO PREDAZZI (INTERUNIVERSITY CENTRE AGORÀ SCIENZA, ITALY)**

**Website:** [www.scienzattiva.eu](http://www.scienzattiva.eu)

One of the winners of the STENCIL 1st Call for Participants in 2012, **ACTIVE SCIENCE™** is a recognized innovative tool for promoting scientific education and citizenship, addressed to high school students and teachers. Designed by the InterUniversity Centre Agorà Scienza, it is part of the actions aimed at defining a new relationship between science and society, according to the goal of the so-called “University third mission”.

**The project**

Largely web-based, **ACTIVE SCIENCE™** makes use of deliberative democracy tools to address highly actual scientific and technological topics of great social impact. [www.scienzattiva.eu](http://www.scienzattiva.eu) is the virtual community where the main project phases take place. It is a sort of *agorà* in which teachers, students and researchers debate, analyse their opinions, generate knowledge and share future prospects. Every edition is dedicated to different themes (at least two per edition), selected because of their centrality to the contemporary scientific debate.

The project is articulated in 4 phases, which correspond to those pointed by the deliberative democracy process: **1. Prior Knowledge**, **2. Information**, **3. Dialogue** and **4. Future Scenarios**. Everything happens on the web-platform especially developed for the project itself. The project ends up with a **final live event** where the participants’ shared proposals are then delivered to researchers and representatives of the public Institutions as a contribution to the discussion on the topic.

**History and Impact**

**ACTIVE SCIENCE™** was started in 2009 thanks to a contribution by the Torino Province and is now held at the national level thanks to the support of the Italian Ministry of Education and Research (MIUR). The 4 editions held involved so far **100 researchers**, **220 teachers** and **5200 students**. **About 3.000 students are foreseen for the next, national edition** that will be implemented for the school year 2013/2014.
A deep analysis has been conducted over the years to evaluate the impact of ACTIVE SCIENCE™ on teachers and students in terms of effectiveness of the deliberative democracy tools and participants’ satisfaction.

Deliberative democracy produces various effects, most notably: learning, awareness, informed opinion, recommendations. An interesting parameter as a proxy variable for cognitive learning, to measure its effectiveness, is the students’ change of opinion following the debate developed during the whole process. We focused our attention on this parameter with the support of social scientists.

A questionnaire was administered at the beginning at the end of the project. Students selected their preferences among a certain number of possible solutions to the various questions. This allowed us to check for each question how many students did change their opinion and the intensity of their preference at the end of the process.

In addition, after the final event, the students were asked to self-evaluate the deliberative process on the basis of a series of statements, through another questionnaire. We noticed – as in other empirical studies conducted in Italy on the deliberation issue – that the deliberative process acts on the organization of individual preferences, even when they are not significantly modified.

In the 4 final events so far examined (one per edition), the overall change (opinion and intensity) has been considerable: on the average between 30% and 48%.

With regards to the self-assessment, we have observed a significant satisfaction among the participants concerning several features of the process: involvement of the participants, active participation, quality of the dialogue, impact on the participants’ knowledge, etc.
The project has proved itself capable of achieving the objectives set out to involve young people on current issues in science and technology thanks to innovative communication and training tools, different from the traditional ones. Students appreciate the method and the various phases, in particular the opportunity to dialogue among themselves, with other classes and with researchers and to tackle a “school” project as protagonists and not just recipients. This aspect has been made possible by the adoption of the tools offered by the web. Teachers appreciate the work method and believe that the extra time dedicated to the project is definitely productive.

Transferring ACTIVE SCIENCE™

Successfully extended in Italy from the Regional to the National level in 2012, the big challenge for the future is now to export the format of ACTIVE SCIENCE™ in other Countries and other contexts. In fact, thanks to its structure, ACTIVE SCIENCE™ is easily replicable and can be addressed to other target groups.

ACTIVE SCIENCE™ has several features that make it easy to be transferred. Here some recommendations for those who are thinking at building their own Active Science™:

- the web platform where the project takes place already exists (both Italian and English version): this means that, on the technological side, nothing has to be done;
- the project has already a precise structure, articulated in phases, with detailed timeline and milestones: this means that the project can be easily handled by other organizations;
- in spite of the already existing structure, the project is flexible enough to allow changes possibly needed because of different contexts/applications. On this side, an important recommendation is to organize at least the final live event: not only an occasion for a lively debate, but also an opportunity to meet the representatives of the Institutions, which is the proper conclusion of the entire deliberative process;
- the format can be used to deepen every kind of topic: each organization is free to choose those that fit better with its own mission. Please remember
that is definitely necessary to involve experts and, also, representatives of the institutions interested in/by the chosen topic;

- the web allows to work with a large number of participants, nonetheless each organization can choose the scale of the project and how many working groups involve: from some hundreds up to few thousands;

At the same time is important to highlight some critical issues that have occurred during the implementation of the project in the last 4 years. Some of them are probably due to the context (Italian Educational system), and can be avoided in other Countries.

- **Communication:** Agorà Scienza can count on a great network of schools and teachers, thanks to a strong tradition of projects developed to link schools and universities. Nonetheless, spreading the information on the project and reaching all the Italian schools has not always been so easy, even though the support of the Italian Ministry of Education. Moreover, Active Science™ is a complex project and summarizing it in a brief, promotional material doesn’t allow explaining all the aspects that make it a powerful project that is worth being part.

- **Lack of time:** has stated above, Active Science™ has a precise structure, articulated in phases, with detailed timeline and milestones. The project has been designed to let teachers and students deepen scientific topics. This implies that the participants have to dedicate a certain time to their work in the framework of the project, which can’t be restricted at a couple of lessons. Luckily, a great part of the project takes place on the web-platform and the students can work on it at home, alone or with their working group.

- **Follow up:** A great regret, that is also a future perspective, is that we have never had the chance to follow the students after the end of the project, to help them in making real their recommendations. In fact, over the years, many of the classes have been so involved in Active Science™ to end it with an action of scientific communication (events, conferences, communication material, etc.) aimed at spreading their knowledge through their mates and their families. For the future, we hope that such great initiatives will go on (also to confirm the value of the project) and, on our hand, to be able to follow and help them to implement these actions.

To know more about the project visit: **www.activescience.eu**
**A short introduction**

The Physics Club/Student Research Center of the University of Kassel SFN is located in Kassel, Parkstr. 16. It is open for students of all schools in Kassel and Northern Hess.

We have our own building: 4 floors and about 650 m² of research area.

Our special equipment: workshop, electron microscope, devices for single photon measurements, laboratories for physics, chemistry and biology, observatory with 7 telescopes, library and a lot of other rooms for the research groups.

The students (age 14 – 19) work in small teams. They work on interesting and up-to-date subjects from science (physics, astronomy, biology, chemistry, IT, geophysics). They acquire the necessary knowledge on their own.

After choosing their research topics during the first months of their studies, they begin to solve their problems and questions by themselves with the help of open-ended experiments in which they use real scientific methods.

Younger students (age 10–13) work on interesting projects and learn the expert knowledge without instruction by teachers; in particular they practice their soft-skills.

Teachers and student-teachers act only as advisors, not as instructors, they train the students in soft-skills and self-organization concerning their work.

We arrange contacts between experts at universities and enterprises which very often sponsor the equipment for the experiments.

The student research teams work on an issue for one or two years. After that some of them take part in the competition “Jugend forscht“; usually with great success. Every year they win state awards, 2006, 2009 and 2011 even the national award in physics. 2009 we take part in the European science contest.

The concept of the PhysicsClub is unique in Germany and has won a lot of important national awards.

Our staff: 8 teachers (High school), 18 university students

Participants: 250 students age 10 to 19 coming from 25 schools and working in 85 teams
The impact of the project PhysicClub/SFN on teachers / schools / students:

Teachers: Teachers could make practical experience in inquiry based learning and working as an adviser and coach. They work with high gifted students and learned about their way of thinking and learning.

Schools: They offer the SFN as their own supplemental offer for high gifted students

Students: see below

Is there any pitfall during the implementation (critical issues of the initiative) especially with respect to the relation with teachers / schools / students etc.?

It is difficult to convince teachers who are not involved that our perspective on students is not a wrong one but could be helpful for improving teaching in common school lessons.

Suggestions for the successful transfer of the project (“to do” and “to don’t”)

Do not try to influence the students work too much. Let them do their own research in their own way. Change your position from an instructor to an adviser/coach.

Evaluation about the influence on participants’ university careers (author Prof. Dr. R. Messner, H. Engelke)

Results:

- most of the students decided to study physics or other natural sciences / engineering during or after their work in the SFN
- for 72% of all participants the SFN has a significant impact on the choice of their field of study

Significant aspects:

• *Vivid* presentation of scientific thinking. Productive role-modelling in an attractive scientific environment (personality-driven, teaching by example, both student advisors and teachers)
• Role-taking in research projects: *Be a scientist* (esp. by those who did science fairs etc)
• Group experience, social aspects: mostly important for later non-scientists

Effects on later studies:

• Many received an important basic skill set, view PhysicsClub/SFN experience as useful for university work and learning
• Some experienced university-level work intensity (Jugend forscht, the national contest for young scientists)
• Most feel prepared for university-level autonomy
Some quotes from the interviews:

- “After my project I just had to study physics, even if just because of all the open questions I already had”
- “It is an amazing level of assessment, when somebody in grade 12 can simply ask students about their area of expertise. Be it high frequency electronics or high-level math, you will always find an expert”
- “PhysicsClub/SFN work was very relaxed, in a strange way. A huge effort esp. towards the end, a tight schedule and many things to do, but it was no obligation. It was ... fun”
- Identification with the project and self-structuring character enables students to commit *willingly* to high efforts.
  (especially without grades ...)

IMPACT OF FIBONACCI PROJECT ON TEACHERS / SCHOOLS / STUDENTS

CONTRIBUTION: ANNE LEJEUNE (FOUNDATION LA MAIN À LA PÂTE)
Website: http://www.fondation-lamap.org/

Please explain the impact of your project on teachers / schools / students (what the project “gave” to teachers / schools / students?)

Initially, the Fibonacci Project (http://www.fibonacci-project.eu/) was scheduled to involve 2,500 teachers, 45,000 pupils, and 550 classes. By the end of the project 6171 teachers, 302,000 pupils, and about 10,000 classes had been involved. The impact as to numbers is thus much larger than initially planned. This was possible because several centres managed to secure additional funding from their national, regional or local authorities. Finally, many future teachers studying in pre-service teacher education were also beneficiaries of the Fibonacci Project. It is difficult to put a number to the extent of involvement of pre-service teachers, but it is likely to be several hundreds.

500-600 teacher educators were involved in the various activities implemented during the lifetime of the Fibonacci Project. Researchers also took part, particularly on the occasion of the two European conferences (the Bayreuth Conference in September 2010 and the Leicester conference in April 2012).

As far as the impact of the professional development of the teachers is concerned the evaluators have noticed that the activities have mostly had the impact envisaged in the definition of Guskey. The activities have enhanced the professional knowledge, skills, and attitudes of most of the educators. 80% or more of the teachers indicated that the continuous professional development (CPD) has stimulated their motivation for teaching and that it has increased their knowledge on how to make students work in a scientific manner by focusing on learning though enquiry. Three quarters of the teachers also indicated that they are now more confident to teach mathematics or science or technology (MST) and that it has strengthened their knowledge and skills on how to implement Inquiry-Based Science Educa-tion (IBSE) or Inquiry-Based Mathematics Education (IBME). The professional development has also improved the learning of students.

Moreover it has had an impact on educational structures and cultures. Sometimes this impact has been limited to the teachers and schools involved in the project but in some cases (Austria, Germany, Estonia, Finland, Ireland, Sweden...) the project has had an impact on the educational culture of and the approaches of teaching MST in the whole country or the regions involved in the project. All teachers, irrespective of the type of school they teach in, noticed that the new teaching approach they started to implement as a result of their participation in the Fibonacci Project stimulated students’ interest and motivation for learning science and mathematics. This is very important in view of the Eurydice report Developing
Key Competences at School in Europe: Challenges and Opportunities for policy, where reference was made to academic literature and research proving that the level of motivation to learn mathematics and science is an important determinant of student achievement in school. This was confirmed by some Fibonacci teachers involved in the project who recorded the performances of their pupils during the lifespan of the project. According to these teachers the different teaching approach has had a positive impact especially on low achievers and pupils who were struggling with MST subjects.

Did you measure the impact on the final beneficiaries and, if yes, how? - If not, yet

Indeed, one of the cornerstones of the Fibonacci project’s large scale dissemination of inquiry-based science and inquiry-based mathematics education process was the twinning. From the beginning of the project, 12 Reference Centres were twinned with 12 Twin Centres 1 and 13 Twin Centres 2, which received tutoring and support for 2 years, thus gaining expertise and, in the case of TC1s, becoming able to start tutoring another centre themselves. The twinning proved to be a very effective way to build the capacity of teacher training organisations in delivering quality continuing professional development in IBSE and IBME, and a powerful dissemination tool of good practice and peer-learning at European level. The level of satisfaction of the Fibonacci partners regarding the twinning is such that 80% of the Fibonacci centres have declared their willingness to continue collaborating with their twinned partners beyond the lifetime of the project.

It is in the final phase of the project, between June 2012 and February 2013, that the Fibonacci model genuinely came into its full dimension, with the Twin Centres 3 expanding the network to over 60 teacher support centres, thus demonstrating the multiplying power of the twinning process, and the structuring and catalytic effect of the systemic and holistic approach fostered by the project.

Did you experience any pitfall during the implementation (critical issues of the initiative) especially with respect to the relation with teachers / schools / etc?

NO

Do you have any suggestion for the successful transfer of the project (“to do” and “to don’t”)?

The strategy for disseminating inquiry pedagogy throughout Europe designed and tested within the Fibonacci Project was a transformational approach to change in education. Transformational approaches recognize that:

- Sustainable development in learning takes place when change is seen as inquiry by those concerned with the transformation. Change in teaching practice, for example, is a matter of learning, and effective learning by
teachers has the same qualities as for students. Just as students develop understanding through their own mental and physical activity, as described in the previous chapter, so teachers learn best when they take an active part in deciding how to transform their practice.

- Sustainable change in education takes place when policy makers, researchers and practitioners participate and learn together with integrity, recognizing their shared goals of improving learning for all. This implies changing practices at all the different levels of the educational system: classrooms, schools, teacher education institutions, local and national authorities. It also implies developing the necessary resources to support each of these actors in bringing about the desired changes.

Reference Centres (RCs) were chosen on the basis that they already coordinated a structured and ongoing initiative for supporting teachers in taking inquiry based science and/or mathematics education into the classroom at a local, district, county, or regional level. The RCs’ main objective during the three year life span of the project was to disseminate their expertise on teacher support strategies to two different rings of less experienced centres: 12 Twin Centres 1 (TC1) and 12 Twin Centres 2 (TC2).
"Investissements d’avenir" and project of the Academy of Sciences

Contribution: Dr Philippe Leclere (University of Lorraine, France)

Website: http://www.univ-lorraine.fr/

The French parliament voted in 2010 the “grand emprunt” (also called “Investissements d’avenir” - national programme set up after the financial and economic crisis of 2008-2009). 50M€ are dedicated to the development of scientific culture, in particular the evolution of the teaching in science and technology. The project submitted by the Academy of Sciences was selected. With the strong experience acquired with “La main à la pâte” (hands-on approach), the Academy proposes to focus its efforts on primary and lower secondary schools, key period where interest in science can be developed or not, as observed in research analysis in the world. It requires acting uppermost on in-service training of teachers in science and mathematics.

A national centre and four houses in different French region

This project enabled the creation of a national centre in Paris region and four regional houses for science established in Alsace, Auvergne, Lorraine and Midi-Pyrénées (French regions). These structures provide an interface between teachers and the scientific world.

A house for science aims to change the practices of primary and lower secondary school teachers to allow students to benefit from a teaching based on living and contemporary science in relation to a close and sensitive world.
In this perspective, a house for science:

- provides training in science and technology for teachers and trainers for primary and lower secondary school levels;
- strengthens the partnership between schools and scientific and industrial communities at regional level;
- provides resources and materials for training in science and technology;
- participates, by initiating or by developing them, in science education activities in difficult environments.

A house for science offers various training formats devoted to science, technology and mathematics: 1-to-3 days trainings, degree programmes, on-demand trainings and eLearning.

Trainings focus on:

- the relationship with the scientific community and an opening to the world of research;
- a pedagogy based on inquiry and interdisciplinary;
- the practical implementation in class;
- the training of resource persons.

All these trainings are based on accurate assessment and identification of the teachers needs. Training is provided both in the regional centre and in satellite ones. They can take place outside school hours or during them (with possible inclusion in academic and departmental training programmes).

**House for science in Lorraine**

Located in the heart of the Université de Lorraine composed of 80 research laboratories, the house of science in Lorraine actively contributes to the professional development of teachers.

Resolutely focused on living and contemporary science, the 2012-2013 offer proposed by the house for science in Lorraine was a real success with a participation of more than 600 teachers in primary and lower secondary schools, 15 research laboratories, more than 30 scientists (researchers, teachers, researchers, engineers, PhD students) and more than 20 trainers. The active collaboration of actors from the worlds of research, industry and education allowed meeting the objectives set by the Academy of Sciences: creating relationships with a living science and contributing to lasting changes in the practices in science education, in primary and lower secondary schools.

For the second edition, new actions are developed thanks to an expanded scientific partnership. Some renewed actions will evolve to reflect suggestions made by teachers and stakeholders last year. While keeping the principle of immersion in research laboratories (approach praised by all participants), scientists and trainers will particularly ensure that the research topics can be transposed into class.
Some examples of training

Primary school level
- Earth, its perceptions: from Babylonians up to now
- Ecology of a stream in a warming climate
- Science: a source for challenges in mathematics
- Innovative ideas for energy production
- The stream and the forest: research topics in ecology

Secondary school level
- Nanotechnology: small scale and large development
- Interdisciplinarity to build common scientific culture and skills
- Biology: from the laboratory to the classroom
- The use of statistics by scientists

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PART C:
A STEP TOWARDS BRIDGING THE GAP BETWEEN RESEARCH AND PRACTICE

This book was developed under the ambitious aim of making a contribution towards the bridging of the gap between the current academic underpinnings and school practice. The objective was to provide an impetus for productive dialogue between researchers and practitioners, as a prerequisite for enhancing teachers’ reflective practice. A comparable view of the professionals’ positions and the practitioners’ feedback on thematic areas that are both in the interest of teachers and that spring from state-of-the-art research makes evident that there is consensus on the necessity to mainstream the implementation of innovation and creativity in science teaching within classroom practices. This indicates that a common, basic ground for bridging the gap between research and practice does exist. To this effect of interest is the teachers’ response to the proposed methodological orientation, in relation to the prevailing regulatory conditions.

In relation to Inquiry Based Learning (IBL) methodology, as highlighted in the contributions from the professionals in Part A and as exemplified from the initiatives described in Part B, it seems that at the current stage we are at the state of applying inquiry methods in science teaching from diverse perspectives, under the scope of enhancing learning. In addition, there seems to be consensus between researchers and practitioners perspectives on the potential of the inquiry based natured approaches to facilitate science learning and to make science more attractive to pupils. Yet—as manifested both from teachers’ reflections in this book and as highlighted in the STENCIL ‘Guidelines for teaching and learning science in a creative way’—the wide use of IBL in schools remains problematic. This might be due to multiple reasons, embedded on the relation between the premise in which IBL methodology is founded on, and the enacted content intensive oriented curricula.

There is an undeniable agreement between research and practice perspectives on the contribution of ICT to support the effective and efficient application of Inquiry Based Learning in the school praxis. This agreement is further supported by the positions expressed regarding the instrumental role ICT plays in facilitating inclusiveness: the use of social media and networking—to which girls are actively engaged—comes to balance the ICT gender gap. Of interest would be the results from investigation into the combined effects of the IBL and ICT onto gender.
As far as teacher training is concerned, action research seems to be a promising professional development approach, not only as a stimulus for teachers to reflect on their teaching practices, but also as a vehicle towards teachers’ actual engagement and participation in the complex process of introducing innovation in the classrooms settings. Such an approach could come to respond to teachers’ needs for continuous professional development based on collaboration, reflective practice and experimentation. It will be welcome to see in the near future teacher training programme initiatives that take into consideration the dimension of the changing role of the teachers, in the view of the technological advances and possible evolutions in the next 20 years.

This book could by no means cover the broad range of themes pertaining to creativity and innovation in science teaching today; yet, the hope is that it has provided a sufficient amount of information on professionals’ views and on teachers’ reflections in thematic areas that are at the heart of everyday school practice. From the perspective of the authors, the added value of the knowledge negotiation process between researches and practitioners is on the emergence of the identification of new perspectives on IBL, ICT, equity issues and teachers’ professional development. The dialoguing process applied for the development of this volume has proven effective to highlight the perspective orientation of, and embedded to it challenges for, science learning. It constitutes a tool that can deepen understandings on the interrelations between intensions, practices and outcomes and can unfold the driving forces to ensure INNOVATION and CREATIVITY in science teaching and learning.
**Expert Contributors’ Short CVs**

**Georges-Louis Baron** is currently professor of education at Université Paris 5- Rene Descartes, Faculté des sciences humaines et sociales - Sorbonne, Department of Education and head of the EDA (Education et Apprentissages - Education and Learning) research lab. He has, for a long time, been investigating questions tied to the educational use of various forms of ICT and digital resource and has a long experience of collaborative research led with practitioners. His main current research interests are linked with the study of how ICT innovations in educational settings eventually transform themselves into everyday realities, which leads him to work on the history of pedagogical ideas and values. He is also working on research themes linked with students’ representations and knowledge of ICT, the mutation of resources for learning and for teacher education.

**Stanko Blatnik** (PhD in physics) has expertise in teaching different courses at Univ. of Tuzla (1966–1985), Uni. of Sarajevo (1995-2003) and face to face and distance learning courses (2000-2004) at West Valley College, Silicon Valley. He is an author of several articles in the field of eLearning and books in the field of web applications. He has industrial experience leading R&D units in industry from 1985 till 2000. He was project leader of research and applied projects in physics, mathematical modelling, web application, eLearning and creativity. He is an active veteran swimmer, participating in competitions and a volunteer in the use of swimming as a therapy for persons with special needs. He prepared several patents for educational tools and gamed and lead workshops on creativity in early childhood and in schools. He was a project leader of eSwimming project ( LLP), several Eureka projects and Phare projects.

**Foteini Chaimala** is currently a post-doc researcher of IACM group, FORTH, Greece. She studied Physics at University of Crete in Greece and obtained her MA degree in Education. Received her PhD from the University of Southampton, UK, in the area of peer learning and argumentation by the aid of ICT. She has ten years of experience as a secondary and high school physics teacher. Research interests in teaching and learning in the context of interactive pedagogies, by the use of ICT, prospective teachers education and teachers’ professional development in the context of scientific argumentation.

**Alexandra Okada** is a research fellow at the Knowledge Media Institute of the Open University, UK. She is also a guest Lecturer at Getúlio Vargas Foundation FGV Online Rio de Janeiro, Brazil and the University of the Arts London, UK. Her research interest focuses on open educational resources, social media and collaborative learning. Her recent EU projects (from 2008-2011) were iCOPER and OPENSOUT,
whose aims were to provide mechanisms to ensure European-wide user cooperation to access a critical mass of integrated educational content. Her postdoctoral research in Knowledge Mapping focused on the uses of knowledge media technologies to foster open sense making communities in the OpenLearn project from 2006 to 2008. She holds a BSc in Computer Science, a MBA in Knowledge Management and Marketing and a MA and PhD in Education.

Dimitris Stavrou is assistant professor in the Department of Primary Education at the University of Crete. He has a degree in Pedagogy and in Chemistry and a Master in Science Education from the University of Athens. He received his PhD in Science Education in 2004 from the IPN-Leibniz-Institute for Science and Mathematics Education of the University in Kiel in Germany. His research interests are the Educational Reconstruction of modern science contents (quantum mechanics, nonlinear systems, relativity and nano-science) and the pre- and in-service teacher training in science education.

Cathrine Tømte is currently a research professor. She has for years worked with issues related to digital literacy, ICT and learning as well as online learning, both nationally and internationally. She specializes in formal and informal learning, learning environments, innovative schools and their pedagogies, teacher professional development along with interdisciplinary research on ICT and education. At NIFU, The Nordic Institute for Studies in Innovation, Research and Education, she is responsible for research activities related to ICT and education and online learning. Tømte has previously been involved in several strands within the OECD project "The New Millennium Learners", such as ICT in teacher education, gender and ICT-issues and self-efficacy and ICT. She holds a PhD in digital communication from The Norwegian University of Technology and Science, NTNU.

Stefan Zehetmeier is assistant professor at the Institute of Instructional and School Development at the School of Education at the University of Klagenfurt (Austria). His research interests include mathematics teacher education, continuing teacher education, school development, action research, quality management and evaluation of educational initiatives and impact analysis of teacher professional development programmes. In a former position, he worked at the University of Vienna (Austria) as senior scientist and teacher educator. Before that, he earned a master degree as grammar school teacher for mathematics and science.
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