Romanian Reports in Physics, Vol. 66, No. 2, P. 539–561, 2014

PHYSICS EDUCATION

EUROPE OF INNOVATIVE SCIENCE AND MATHEMATICS EDUCATION

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Received March 25, 2013

Abstract. In the last ten years, pressed by the ageing of work force, the young people lack of interest towards technically related careers, the significant brain drain, European Union set up several goals for year 2010, and now for 2020, in relation to the development of a knowledge-based society. Starting from the guidelines established by official documents, we reviewed nineteen multinational projects funded by EU to promote inquiry-based science education (IBSE) at pre-university level. The study makes available comparative information on projects objectives, outcomes, target groups; countries involved and major players. According to our knowledge, this paper represents the first attempt to assemble, in a comparative manner, the information on major EU funded projects aiming to innovate Science and Mathematics teaching. It can be a valuable tool for scholars interested into the study of IBSE implementations; researchers involved in the build-up of new methods to engage students in the Science learning process and to assess their results; teachers looking for guidance, models and inspiration; persons interested to use the developed resources; teachers' trainers and mentors; central and local administrative employees in charge with Science and Mathematics education; policy makers.

Key words: education policy, inquiry-based science education/learning, science education, teacher training.

1. INTRODUCTION

1.1. EUROPEAN CONTEXT OF SCIENCE, MATHEMATICS AND TECHNOLOGY EDUCATION

In the last ten years a new approach was promoted at European level concerning the way Science, Mathematics and Technology have to be taught in school. Two major phenomena affect the technically skilled manpower market both in Europe and the United States: the globalization, and the decrease of young generation interest in Science and Technology. Official European Union's documents recognize that an adequate supply of scientists is crucial for a knowledge-based economy [1]. The scientific workforce deficit in Europe is significant: Europe counts 5.7 researchers per 1000 citizens as compared to Japan (9.14) and USA (8.08) [2]. In addition, in Europe, scientific literacy is viewed as a dimension of the democratic citizenship [3].

Within this context, the "Working Group on Increasing Participation in Math, Science and Technology" made several recommendations as it concerns the path to be followed on teaching science and technologies in schools: a) "the teaching of mathematics, science and technology should be an entitlement for all children from the early stages of education and should be mandatory at all levels; b) more effective and attractive teaching methods should be introduced in mathematics, scientific and technical disciplines at both primary and secondary level, in particular by linking learning to real-life experiences" [4].

Another study published by the European Commission [5] tried to identify and disseminate "patterns and mechanisms, the adopted learning design strategies and didactical approaches to involve students in significant and exhaustive hands-on activities, within meaningful learning contexts".

The European Union Research Advisory Board – EURAB recommended the sustained support for Science education in schools: a) "the introduction of innovative, hands-on Science education into all Europe's primary schools; b) the introduction of Creative Science Teaching modules into the formal training period of all primary school teachers" [6].

These EU's policy changes were supported by several programmatic reports [7, 8] and position papers [9–12].

It is important to mention few of the conclusions of the [7]: a) "there is obviously a need to prepare young people for a future that will require good scientific knowledge and an understanding of technology; b) improvements in science education should be brought about through new forms of pedagogy: the introduction of inquiry-based approaches in schools, actions for teachers training to inquiry-based science education - IBSE, and the development of teachers' networks should be actively promoted and supported". The other document indicates that improving the public ability to engage into socio-scientific issues requires not only knowledge of the content of science but also "knowledge of how science works" [8].

An OECD study highlights the science impact on every day life, and the need to design cross-disciplinary studies [13].

Within the same line, an emphasis is placed on the promotion of an educational system supportive for the sustainable development as a life-long learning perspective, part of the "Europe 2020 strategy" [14]. Europe's concern on the efficiency of the educational system is present also in a European Council's document on the implementation of the "Europe 2020' strategy" where was included the recommendation for "learning outcome-based qualification systems and greater validation of skills and competences acquired in non-formal and informal contexts” [15]. Among the eight key competences of the Lifelong Learning initiative supporting the newly adopted strategy in education are “mathematical competence and basic competences in science and technology; digital competence; learning to learn; sense of initiative and entrepreneurship” [16]. The next change will come as new educational models will be introduced such as “personal learning plans and inquiry-based learning” [16].

For the expected “revolution” in education, the Council and the Representatives of the Governments of the Member States call for “more joined-up policy-making and cooperation between the fields of education, research and innovation” in order to fully integrate the “knowledge triangle” [17].

The contemporary scene of the European educational system as set-up by the official policies mentioned above is completed by two reports which reveal the situation in Science and Mathematics education at ISCED 1 and 2 levels (primary and lower secondary education), for 31 European countries, corresponding to the school year 2010/2011 [20, 21].

1.2. THE STUDY OBJECTIVES

In order to implement at European level the educational policies on Science and Mathematics education in school, several calls were launched under the FP6 and FP7 research programs and Lifelong Learning (LLL) program, aiming to support the development of new teaching/ learning methods, based on inquiry.

The scope of this study is to review various approaches, methodologies and outcomes promoted by nineteen projects run in Europe in the last nine years, projects focused on innovative, and in some cases Inquiry-Based Science Education (IBSE) and/or Mathematics education. The paper provides an overall image of the IBSE projects landscape, as appropriate: objectives, methods novelty, stakeholders’ involvement, European dimension, results, dissemination schemes, impact, follow-ups. It tries to offer some answers to questions such as: “How these projects respond to the requirements of the European educational policy in relation to the innovation of Science and Mathematics teaching and learning?”, “What is missing and what have be done to correct this situation?”.

The effectiveness in implementing European education policy as stated by official documents can be evaluated by focusing on: the outcome of the funded projects, the entities and countries involved. The number of participants to these projects per country could be another tool for the assessment of the way individual countries apply locally the EU’s guiding lines in relation to the introduction of inquiry-based, pupils centered methods in Science and Mathematic education. An analysis of the pupils’ age addressed by each project offers an inside view on the children population base of this educational change.

2. METHOD

The research was carried out as an Internet-based activity, data being gathered from the open sources available on the web in relation to the investigated projects. The starting point for picking up primary information on most of the discussed projects are: EU's synopsis on FP7 funded projects in the frame of the "Science in Society" Program, the "Scientix" data base, the EU's CORDIS data base, and the 2006 – 2012 versions of the "Lifelong Learning Programme**,** Comenius School education" compendiums. Details on each project objectives, outcomes, impact, development, target group, etc. were picked up from the respective projects web sites. Table 1 summarizes projects duration, filed of education addressed, education level, funding received, number of participants and countries involved. In addition to information on projects deliverables, participants' publications or conference contributions, EC official documents were used to assemble the vision on the innovative pedagogies proposed.

Whenever possible, quantitative data are provided for a better assessment of these projects impact and costs. In most of the cases, the analysis refers to novel pedagogical aspects; activities run; outcomes and resources generated by each project; competences of the personnel involved; number of schools/ teachers accessed by the project; set-up networks; events organized. This comparative evaluation considered the most significant nineteen multinational project having a European wide participation and impact. Of course there are also other national or more subject focused projects run in Europe over the considered period as for example, "La main a la pate", "SINUS-Transfer". The analyzed projects span over the 2006 – 2014 period, operating for 2 to 4 years (Table 1). Most of the projects address general Science teaching and learning, with some exceptions which focus both on Science and Mathematics education (Table 1). Few exceptions have as subject the innovation in natural sciences, environmental sciences, ICT or applied Mathematics only. Countries are identified in the study by their ISO 3166 Codes.

Table 1

Characteristics defining the projects

Acronym/ contract	Project duration	Filed addressed*	School level**	EU funding (Euro)	Number of participants	Countries involved
Pollen FP6 grant agreement no. 518399	2006 - 2009	GS	PS, PrS, LS, US	1,750,000	12	BE, DE, EE, ES, FR, HU, IT, NL, PT, SE, SI, UK
LEMA grant 128740-CP-1-2006-1-DE-COMENIUS-C21	2006 - 2009	M	PrS, LS, US	417,985	7	CY, DE, ES, FR, HU, UK

Table 1 (continued)

Inspire LLL grant 133867-LLP-1-2007-1-BE-COMENIUS-CMP	2007 - 2008	M, GS, ES, ICT	PS, PrS, LS, US	291,021	5	AT, BE, DE, LT
InnoMathEd LLL grant 141831-LLP-1-2008-1-DE-COMENIUS-CMP	2008 - 2010	M	LS, US	291,096	10	BG, CY, CZ, DE, IT, NO, UK
Mind the Gap FP7 grant agreement no. 217725	2008 - 2010	GS	LS, US	780,276	8	ES, FR, DE, DK, HU, NO, UK
SPICE LLL grant 502244-LLP-1-2009-1-BE-COMENIUS-CMP	2009 - 2011	M, GS, ES	PrS, LS, US	299,397	4	BE, CZ, PT
ITEMS LLL grant 143485-LLP-2008-ES-KA4-KA4MP (2008-3603)	2009 - 2010	M, GS	LS, US	-	5	BE, DE, ES, IE, SI
COMPASS LLL grant 503635-LLP-1-2009-1-DE-COMENIUS-CMP	2009 - 2011	M, GS	PrS, LS, US	299,916	6	CY, DE, ES, NL, SK, UK
S-TEAM FP7 grant agreement no. 234870	2009 - 2012	GS	PrS, LS, US	4,699,928	25	CY, CZ, DE, DK, EE, ES, FI, FR, IL, LT, NO, SE, TR, UK
KidsINscience FP7 grant agreement no. 244265	2009 - 2013	GS, T	PS, PrS, LS, US	999,224	10	AT, BR, CH, DE, ES, IT, MX, NL, SI, UK
Fibonacci FP7 grant agreement no. 244684	2010 - 2013	M, GS	PrS, LS, US	4,784,597	37	AT, BE, BG, CH, CZ, DE, DK, EE, ES, FI, FR, GR, IE, IT, LU, NL, PT, RO, RS, SE, SI, SK, UK

Table 1 (continued)

PRIMAS FP7 grant agreement no. 244380	2010 - 2013	M, GS	PrS, LS, US	2,996,236	14	CH, CY, DE, DK, ES, HU, MT, NL, NO, RO, SK, UK
ESTABLISH grant agreement no. 244749	2010 - 2013	M, GS	LS, US	3,389,648	14	CY, CZ, DE, EE, IE, IT, MT, NL, PL, SE, SK
INQUIRE FP7 grant agreement no. 266616	2011 - 2013	ES	LS, US	2,234,024	17	AT, BE, BG, DE, ES, FR, IT, NO, PT, RU, UK
PROFILES FP7 grant agreement no. 266589	2010 - 2013	GS	LS, US	3,447,945	22	AT, CH, CY, CZ, DE, EE, ES, FI, IE, IL, IT, LV, NL, PL, PT, RO, SE, SI, TR, UK
STENCIL LLL grant 510177-LLP-1-2010-1-IT-COMENIUS-CNW	2011 - 2013	M, GS, T	LS, US	433,738	21	BG, DE, GR, FR, IT, MT, PT, SI, TR
PATHWAY FP7 grant agreement no. 266624	2011 - 2013	GS	PrS, LS, US	3,378,770	26	AT, BE, BG, ES, DE, FI, FR, GR, IE, IT, RO, RU, SZ, UK, USA
Creative Little Scientists FP7 grant agreement no. 289081	2011 - 2014	M, GS	PS, PrS,	1,491,900	11	BE, FR, FI, DE, GR, MT, PT, RO, UK,
Pri-Sci-Net FP7 grant agreement no. 266647	2011 - 2014	GS	PS, PrS,	2,837,695	17	AT, BE, CY, CZ, DE, FI, FR, GR, IT, MT, PT, SK, TR, UK

*Field addressed: M – mathematics; GS – general sciences; ES – environmental science, biology, geography; T – technology; ICT – information communication technology.

**School level: PS – preschool; PrS – primary school; LS – lower secondary school; US – upper secondary school.

3. RESULTS

Projects are presented in the chronological order of the financing period. The activities, results, outcomes are presented generically. They are not described in specific terms in order to make possible the comparisons between projects. The final part of the study includes a comparative assessment as it concerns the countries involved in EU funded projects, the number of projects and participants per country, and the subjects treated in each project frame.

3.1. POLLEN – SEED CITIES FOR SCIENCE (http://www.pollen-europa.net/?page=cldgdjvwsky%3D)

Objectives. To demonstrate the way teaching science can be reformed through the collaboration of local actors (schools, universities, educational authorities, research institutions, local authorities, business community, associations, students families); to assist the implementation of IBSE principles with courses, resources, and educational tools developed in the project frame, compatible with each country curriculum; to create 12 reference centers as it concerns the local communities contribution to Science teaching and learning change;

Resources developed. A resource database is available to the educational community; 25 learning units for Science teaching of children from 3 years old to 13 years old are available for downloading; guides on the specific topics mentioned under "Examples of activities" can be accessed; "Guide for teachers"; "Guide for trainers"; "Strategic plan guide";

Outcomes/ impact. The project final report; a European network for twinning and collaboration between teachers and education experts; over the project lifetime was developed; 2377 teachers were involved, engaging 35999 form 506 partner countries schools and about 3184 hours of training were run; an interactive web portal (E-centre) was prepared for exchange of best practices and the dissemination; the project was mentioned as a good example of practice in two reference reports (Rocard, 2007; Osborne & Dillon, 2008); publication and distribution of booklets and videos on best practices in Belgium, France, Germany, Slovenia and Sweden; "Pollen Booklet"; "Pollen Inquiry guide"; "Pollen Handbook"; three European seminars;

3.2. LEMA – LEARNING AND EDUCATION IN AND THROUGH MODELING AND APPLICATIONS (http://www.lema-project.org/web.lemaproject/web/eu/tout.php?v2= /web.lemaproject /web/eu/som01.htm&v3=/web.lemaproject /web/eu/page01.htm)

Objectives. To develop skills to Mathematics teachers related to the application of modeling in the classroom; to design, pilot, test, evaluate a course for pre-service and in-service teachers;

Resources developed. Trainers' guides, PowerPoint presentations, resources and teachers diaries referring to: modeling, tasks in the classroom, lessons, assessment strategies to be used during courses for teachers, educational videos;

Outcomes/ impact. Preparation of a DVD with the course materials and demo videos; the project booklet containing description of real life strategies, reflecting opportunities situation and possible associated tasks in the classroom, support to Mathematics teaching.

3.3. INSPIRE – INNOVATIVE SCIENCE PEDAGOGY IN RESEARCH AND EDUCATION

(http://inspire.eun.org/index.php/Inspire:About)

Objectives. To prepare, analyze, test, and validate new didactic tools (Learning Resource Exchange service applied to Science, Mathematics and Technology) as 60 learning objects/ resources to be used in the classroom are available to schools, on the project portal; to develop a protocol and to organize training sessions for schools on the use of the new instruments; set-up of a virtual community of practice for the new tools;

Resources developed. "Inspire Handbook – Smile of eLearning", which includes a set of 60 digital learning resources (LR) available for school practitioners, in the field of Physics, Chemistry, Biology, Mathematics and ICT;

Outcomes/ impact. The project was implemented in 62 schools in Germany, Austria, Italy, Spain and Lithuania (74% secondary schools, 11% primary schools, 11% vocational schools, and 3% pre- schools); "220 teachers filled in the questionnaires before the use of the LR, while 190 teachers completed the project piloting; 4049 students filled in the initial questionnaire on their interest in MST, while 3411 students responded to the questionnaire on the impact of the LR"; Inspire project brochure; permanent online community of practice; Inspire results report; 26 questionnaires for national coordinators, school principals, teachers, students, addressing school context, teachers opinions on available resources and training, students response to the use of newly developed resources; a Summer School for dissemination of project results.

3.4. INNOMATHED: INNOVATIONS IN MATHEMATICS EDUCATION ON EUROPEAN LEVEL

(http://www.math.uni-augsburg.de/de/prof/dida/ innomath/index.html)

Objectives. The development, testing, evaluation, implementation and dissemination of didactic concepts, pedagogical methodologies and innovative learning environments for Mathematics teaching at European level, with a focus on active, self-responsible and exploratory learning; the use of ICT in relation to "dynamic mathematics", GEONExT and GeoGebra;

Resources developed. Development of “Learning Environments”; the InnoMathEd Book; 22 geometry lessons based on the use of the dynamic geometry software included in the book “Teaching Geometry in Elementary School with the Use of Dynamic Geometry Software” (ISBN 978-9963-689-99-6);

Outcomes/ impact. Over 90 publications and conference papers; a CD; a pilot project using Interactive Whiteboards (IWB); a platform for mathematics; workshops and training sessions for teachers.

3.5. MIND THE GAP – LEARNING, TEACHING, RESEARCH AND POLICY IN INQUIRY-BASED SCIENCE EDUCATION
(http://www.uv.uio.no/english/research/projects/mindthegap/about/index.html)

Objectives. To fill the “gap” existing between theory and practice, teaching and learning practices, research, policies and practice, educational policies and teachers CPD practice, as it concerns the use of Inquiry-Base Science Teaching (IBST) in Europe, with a focus on scientific literacy, ICT, communication and argumentation;

Outcomes/ impact. “Report on Policies and Framework for Inquiry Based Science Teaching (IBST) Across Seven European Countries”; Report “Science Curriculum and Evaluation Minding the Gap between Policy and Practice of Inquiry Based Science Teaching in Seven European Countries”.

3.6. SPICE: CREATING A SCIENCE PEDAGOGY INNOVATION CENTRE FOR EUROPE
(http://spice.eun.org/web/ spice/home)

Objectives. To collect, analyze, validate and disseminate best practice in Science and Mathematics education, especially in relation to inquiry-based methods; to establish a task force formed by 16 experts on education (from national Ministries of Education) and 16 Science and Mathematics teachers able to perform the mentioned tasks; to support collaborative actions between formal and non-formal Science teaching;

Resources developed. Learning units to be used in the classroom on Biology – 6; Physics – 8; Chemistry – 4; Mathematics – 7; SPICE Moodle courses; presentations from the SPICE Summer Academy;

Outcomes/ impact. 16 policy actions and 24 best practice projects in Mathematics, Science and Technology teaching; a catalogue of European wide MST education good practices; a booklet with project results published; the report “Efforts to Increase Students’ Interest in Pursuing Mathematics, Science and Technology Studies and Careers”; ~ 40 testing teachers and ~ 2000 students are involved in the evaluation; set-up of a Community of Practice on IBSE and PBL;

five publications: “Spice project summary brochure”, “Efforts to Increase Students’ Interest in Pursuing Science, Technology, Engineering and Mathematics Studies and Careers: National Measures taken by 21 of European Schoolnet’s Member Countries – 2011 Report”, “Spice: Spicing up Science and Maths classes by exchanging practices with teachers from other countries”, “SPICE-summer-academy-Programme_final”, “Efforts to Increase Students’ Interest in Pursuing Mathematics, Science and Technology Studies and Careers”; a Summer School as an opportunity for results dissemination.

3.7. ITEMS – IMPROVING TEACHER EDUCATION IN MATHEMATICS AND SCIENCE
(http://itemspro.net/?page_id=17)

Objectives. The development, testing, and implementation of integrated e-learning modules for Science and Mathematics teaching; organization of courses for teachers to use the modules; set-up of a common infrastructure to access the modules; development of interactive animations to explain science concepts;

Resources developed. On-line courses on Sciences (Astronomy, Electricity, Environment, Climate change) and Mathematics (Geometry, Graphs, Linear functions); six e-learning modules to be downloaded;

Outcomes/ impact. A Moodle platform to distribute the developed modules/ courses; “89 teachers have used the modules in the classroom, guiding 1,945 students, students at primary (305) or secondary (835) level; 2 university teachers have used modules with 67 science education students”; workshops and conferences for teachers.

3.8. COMPASS – COMMON PROBLEM SOLVING STRATEGIES AS LINKS BETWEEN MATHEMATICS AND SCIENCE
(http://www.compass-project.eu/)

Objectives. Development of transversal competences and problem solving competences to students; to assist teachers in connecting Science and Mathematics to everyday life of individuals and communities; the use of an interdisciplinary approach in order to include ICT

Resources developed. Interdisciplinary learning materials on biodiversity, alternative energy sources and energy saving, water related problems, pollution, weather, food, translated into participants languages; lesson plans, students’ worksheets and specially designed applets to explain Science and Mathematics concepts;

Outcomes/ impact. Journal papers presenting the project materials – 12,000 copies; DVD and USB flash driver with classroom materials; evaluation instruments; project outcomes presentations to conferences and workshops; papers publications; directly outreached to 9316 people with face-to-face activities; two professional development workshops; organization of a teleconference session with students from partners' countries; round table meetings with stakeholders; conference for in-service teachers.

3.9. S-TEAM – SCIENCE-TEACHER EDUCATION ADVANCED METHODS (http://www.s-teamproject.eu/)

Objectives. To increase motivation and to help change pupil attitudes on science for the improvement of the scientific literacy and rise of their interest towards science-based careers; to assist teachers in adopting Inquiry-Based Science Teaching (IBST) methods through workshops, training packages, video case-studies, teaching materials and publications; to provide training session and access to innovative teaching methods;

Resources developed. Training materials, Part 1 & 2; "Inquiry in initial teachers training"; "Developing scientific thinking through inquiry"; "Teachers professional development programms"; "Augmentative competence: How to develop it?"; "Drama, scientific literacy and student interest";

Outcomes/ impact. A set of Newsletters describing the project life milestones and developments; a training package and training units to assist teacher in developing their own learning set-ups; a site on Scientific Literacy (Mind the gap) with concept maps and videos highlighting means to improve the scientific literacy by IBST methods; Report on science education policies and teachers' training in participating countries; Report "Dissemination strategy for inquiry-based methods in France"; "Baseline Report and Indicators Review for Science Teaching Methods and Attitudes in the Context of S-TEAM"; "Scientific literacy and teachers professional development"; "Augmentation in Europe and P4CM teacher manual"; "Digital learning resources"; "Baseline report and indicators review"; an international workshop to evaluate project's results.

3.10. KIDSINSCIENCE: INNOVATION IN SCIENCE EDUCATION – TURNING KIDS ON TO SCIENCE (http://www.kidsinnscience.eu/ home.htm)

Objectives. To assist experts involved in science education to develop creative teaching and active learning systems; to increase the performances and interest of young generation in Science and Technology; to develop and implement learner centred approaches such as inquiry based learning in the educational system, by using an adaptive strategy;

Outcomes/ impact. Studies on innovative methods in Science education: "Innovative methods in learning of science and technology – National findings and international comparison", "Report on Adaptations of Innovative Practices in

Science Education"; "Teaching materials"; "National contexts and innovative practices in Science Education. A Comparative Report"; "Evaluation Report of Field Trials"; "A total of 186 teachers were involved, teaching 181 classes and teaching groups at 98 schools. 4104 learners from pre-primary to upper secondary level and from pre-service teacher education were reached. 20 schools, 19 teachers and 198 learners participated in more than one implementation".

3.11. FIBONACCI – LARGE SCALE DISSEMINATION OF INQUIRY-BASED SCIENCE AND MATHEMATICS EDUCATION (IBSME) IN EUROPE (http://www.fibonacci-project.eu/)

Objectives. The development of the methodology (design, implementation, testing and formalizing) for transfer, through a twining strategy, of expertise on inquiry-based education (teaching and learning methods) in Science (IBSE) and Mathematics (IBME) at European level, from 12 Reference Centers towards 12 type 1 Twin Centers and 24 type 2 Twin Centers, along with local initiative for innovation and sustainability;

Resources developed. Three booklets on inquiry basics: "Learning through Inquiry", "Inquiry in Science Education", "Inquiry in Mathematics Education"; learning units developed by partners: 12 on Mathematics and 15 on Science;

Outcomes/ impact. Minimum of 3,000 teachers and 45,000 students will be involved in project's activities; preparation of five guiding booklets on: deepening the specificities of scientific inquiry in mathematics; deepening the specificities of scientific inquiry in natural sciences; implementing and expanding a Reference Centre; cross disciplinary approaches; using the external environment of the school; a European wide collaborative science project (Greenwave); four project newsletters; project booklet; two European conferences; 12 field visits to reference centers; 48 field visits for twin centres 1 and 2; 24 field visits for twin centres 3; two seminars; four starting workshops on the common topics; five European training sessions on the common topics.

3.12. PRIMAS – PROMOTING INQUIRY IN MATHEMATICS AND SCIENCE EDUCATION ACROSS EUROPE (http://www.primas-project.eu/en/index.do)

Objectives. To assist teachers in participating countries to develop themselves Inquiry-Based Learning (IBL) pedagogical means to teach Science and Mathematics; to prepare teaching aids/ materials to be used in the classroom; to deliver courses for teachers; to offer advice and support to teachers trainers involved in teachers' professional development; to work with existing or to develop networks; to establish at national level a National Consultancy Panel formed by experts in education, representatives of teachers/ parents associations, educational authorities; curriculum designers, teachers trainers, panels operating in coordination with an International Expert Panel; to identify IBSL materials, practices, CPD methods, educational related events of interest for the project development;

Resources developed. A database of teaching materials; seven professional development modules exemplifying various aspects of IBSL: “Student-led inquiry”, “Tackling unstructured problems”, “Learning concepts through IBL”, “Asking questions that promote reasoning”, “Students working collaboratively”, “Building on what students already know”, “Self and peer assessment”;

Outcomes/ impact. “Training of about 20 in-service trainers per country, in 12 countries and supervise the training of about 100-150 teachers in each country”; “about 70,000 teachers were acquainted with Inquiry-Based Learning (IBL) through multipliers training, professional development courses, and other forms of support (materials, events and activities for teachers and student teachers)”; “PRIMAS guide for professional development providers”**;** “PRIMAS guide for supporting actions in promoting inquiry-based learning in out-of school target groups”; “PRIMAS guide of supporting actions for teachers in promoting inquiry-based learning”; “PRIMAS survey report on inquiry-based learning and teaching in Europe”; over 90 dissemination events were organized in partner countries over a 18 months period; distribution of a newsletter; a project conference.

3.13. ESTABLISH – EUROPEAN SCIENCE AND TECHNOLOGY IN ACTION BUILDING LINKS WITH INDUSTRY, SCHOOLS AND HOME (http://establish-fp7.eu/)

Objectives. To promote IBSE teaching and learning in secondary schools through teachers education (in-service and pre-service), support with appropriate teaching materials, involvement of different stakeholders, local business community and industry; to create learning environments; identification of best practice on IBSE approach;

Resources developed. Teaching and learning units (finished or to be produced in the future) entitled – sound, disability, exploring holes, designing a low energy home, chitosan – fatmagnet, direct current electricity, cosmetics, blood donation, photochemistry, renewable energy, chemical care, light, photosynthesis, polymers around us, forensic science, medical imaging, ecology, water in the life of man;

Outcomes/ impact. Journal publications; articles for teachers; “Framework for IBSE Teaching and Learning Units”; “Report on how IBSE is implemented and assessed in participating countries”; “Piloted, culturally adapted, teaching and learning IBSE units - Part I”; “Interim Report on the key forces for driving change in classroom practice across participating countries”; “Piloted, culturally adapted, teaching and learning IBSE units – Part II”.

3.14. INQUIRE – INQUIRY-BASED TEACHER TRAINING FOR A SUSTAINABLE FUTURE (http://www.inquirebotany.org/en/)

Objectives. Implementation of IBSE practice in 11 countries by developing, testing and organizing courses

Resources developed. PlayDecide Kit: Climate Change; lessons plans and teachers notes; an INQUIRE Course Manual (for teachers and educators) and an INQUIRE Train the Trainers Course Manual;

Outcomes/ impact. Special issue of Roots, BGCI's Education Review on IBSE; 60 hours course on IBSE on biodiversity loss and climate change; set-up of a community of practice through the ProConet – Network; reports to national and international conferences/ meetings; 181 teachers and 57 educators are participating in INQUIRE courses; INQUIRE conference.

3.15. PROFILES – PROFESSIONAL REFLECTION-ORIENTED FOCUS ON INQUIRY-BASED LEARNING AND EDUCATION THROUGH SCIENCE (http://www.profiles-project.eu/)

Objectives. To promote IBSE by developing teachers' partnership, using exemplary existing means and materials, by improving teaches' skills in a creative learning environment; to provide support (courses and access to IBSE teaching methodology) to teachers by CPD activities and interaction/ cooperation with stakeholders; to establish teachers' networks at local, national and international level; to evaluate students progress; to narrow the gap existing between the science education community and other actors (researchers, local stakeholders);

Resources developed. Interim report;

Outcomes/ impact. Project newsletters; country reports based on the "Instrument for Analysing the 'Motivational Learning Environment' (MoLE)" used for data collection; PROFILES Booklet; CPD modules based on the three level model (teacher as learner; teacher as teacher; teacher as reflective practitioner); an international conference of stakeholders.

3.16. STENCIL – SCIENCE TEACHING EUROPEAN NETWORK FOR CREATIVITY AND INNOVATION IN LEARNING (http://www.stencil-science.eu)

Objectives. To identify, evaluate and promote innovative practices in science teaching; to offer to science education practitioners the opportunity to share expertise and best practice by organizing study visits and workshops; to disseminate materials and results generated by EU funded projects; to assist educational authorities and policymakers to promote innovating science education practice and to develop links between research institutes, schools and industries; to help interested parties past projects outcomes and partners for future cooperation;

Resources developed. STENCIL project on YouTube / TeacherTube; two "Annual Report on the State of Innovation in Science Education"; search engine for science education resources "European Online Catalogue of Science Education Initiatives";

Outcomes/ impact. 22,500 teachers beneficiary of the web portal, 1,200 participants to dissemination events, the Guidelines and Manifesto distributed to 1,500 authorities and schools; survey to identifying innovative science teaching methodologies and good practices in Europe; update of the eBook "Science Education in European Schools – Selected Practices from the STELLA Catalogue"; European community of practice; study visits and workshops; international conferences.

3.17. PATHWAY – THE PATHWAY TO INQUIRY BASED SCIENCE TEACHING PROJECT (http://www.pathway-project.eu)

Objectives. To gather expertise of various groups (researchers, teachers, curriculum developers) in promoting the adaptation of IBSE at primary and secondary school level by a) suggesting a *standard-based approach* for using inquiry in science teaching; b) offering some *methods to motivate teachers* in employing IBSE in the classroom; c) providing *open access educational resources* and teaching *models* in supporting the school curriculum.

Resources developed. Debating resource focused on ethics in genomics research; virtual lessons; PATHWAY ASK Learning Design Toolkit (PATHWAY ASK-LDT) facilitating the development of IBSE scenarios by users; individual descriptive PDF files, each of them referring to: the focus of the activity and its constituents, characteristics of the activity (i.e. location, duration, actors involved, evaluation means, links with the curriculum, etc.), teachers competences to be developed (i.e. content knowledge, nature of science, instructional strategies, use of ICT, planning and use of curriculum materials, teaching/learning processes, etc.), files centered on two subjects: Inquiry Activities for Schools; Connecting Schools and Science Centers;

Outcomes/ impact. Book chapter entitled "Sharing of Open Science Education Resources and Learning Designs in Europe: The European Initiatives OpenScienceResources, COSMOS and PATHWAY" in "OER Knowledge Cloud"; "Science Education Future Challenges" Report discussing main issues, tensions, and trends in IBSE at European level, report based on 38 Visionary Workshops (1024 participants), held in 12 countries with interested parties (teachers and teacher trainers, students, school administrators, curriculum developers, policy makers, etc.); national conferences; set-up of national school contests.

3.18. CREATIVE LITTLE SCIENTISTS – ENABLING CREATIVITY THROUGH SCIENCE AND MATHEMATICS IN PRESCHOOL AND FIRST YEARS OF PRIMARY EDUCATION
(http://www.creative-little-scientists.eu/home)

Objectives. To explore the connection existing between Science and Mathematics teaching and learning during early education and the development of creativity to children; to map and comparatively assess existing approaches to science and mathematics education in pre-school and first years of primary school (up to the age of eight), highlighting practices linking Science and Mathematics learning, teaching and assessment with creativity; to promote curriculum design principles and guidelines for pre-service and in-service teachers training courses;

Outcomes/ impact. "Guidelines for the Background Literature Reviews"; "Conceptual Framework"; "Review of science and mathematics education in preschool and early years of primary school"; "Review of creativity in education"; "Review of teacher training for early years educators and primary teachers"; "Review of comparative education"; "List of Mapping and Comparison Factors"; "Report on Mapping and Comparing Recorded Practices"; workshops; project leaflets; a Summer School for teachers.

3.19. PRI-SCI-NET – NETWORKING PRIMARY SCIENCE EDUCATORS AS A MEANS TO PROVIDE TRAINING AND PROFESSIONAL DEVELOPMENT IN INQUIRY BASED TEACHING
(http://www.prisci.net/)

Objectives. To set up a network of educational professionals (academics, teachers' trainers, and teachers) in the field of primary school Science education, in order to promote Inquiry-Based Learning (IBSL); to support primary teachers and student teachers through training courses and materials sharing to encourage them to include in their classes IBSL; to endorse small projects and promote them as examples of good practice; to offer professional development courses to primary science teachers trainers; to develop educational resources to be distributed in different languages on-line;

Resources developed. 45 different science teaching activities on IBSE, to be distributed in 15 languages;

Outcomes/ impact. An on-line research journal on IBSE; a platform for networking at European level for researchers and teachers working in primary science; two international primary science conferences; three international courses.

4. COMPARATIVE DATA. DISCUSSION

Nineteen multinational projects addressing the development, testing, evaluation and dissemination of innovative methods in teaching and learning Science and Mathematics at pre-university level (from pre-school to high school) were presented. These projects involved, over a period of nine years, 266 participants (some of them participating to multiple projects) from 36 countries (three from outside Europe – Brazil, Mexico and United States). All EU member states took part in one or more of the examined projects; besides that, there were also partners from Israel, Norway, Switzerland, Russian Federation, Republic of Serbia and Turkey (Table 2). In some cases, more than one entity from the same country was among the participants. For this reason, some countries counts a greater number of institutions involved in these projects. The leaders according to this criterion are Germany (34 participants, including those participating to several projects) and United Kingdom (25 participants), followed by Italy (15 participants), France (15 participants), Portugal (12 participants), Spain (13 participants), Greece and Austria (9 participants each) (Table 2). The countries from EU member states with only one participation are Latvia and Luxemburg. A notable presence from European non-EU countries is Turkey. Considering the countries representation, the conclusion is that the discussed projects have a real European wide impact, involving teachers and schools from all over the Europe.

Table 2

The distribution of funded projects and number of participants per country

Country	AT	BE	BG	BR	CH	CY	CZ	DE	DK	EE	ES	FI
Projects	8	9	5	1	4	8	7	19	4	5	13	6
Participants	9	12	7	1	5	8	7	34	6	5	13	9

Table 2 (continued)

Country	FR	GR	HU	IE	IL	IT	LT	LU	LV	MT	MX	NL
Projects	11	5	4	5	2	10	2	1	1	5	1	7
Participants	15	9	4	7	2	15	3	1	1	6	1	7

Table 2 (continued)

Country	NO	PL	PT	RO	RS	RU	SE	SI	SK	TR	UK	USA
Projects	5	3	9	5	1	2	5	6	5	4	16	1
Participants	5	3	12	5	1	2	7	6	5	6	25	1

The projects leaders and coordinators are highlighted in Fig. 1. German institutions are the most numerous as project promoters (six projects), followed by organizations from Austria, Belgium, France and Norway with two projects each.

In spite of an extensive participation to projects, UK has no leading role in projects with a European visibility. It is worth to mention the role played by smaller countries as Austria, Belgium, Greece and Malta in coordinating European projects.

The great majority of participants were universities, followed by national organizations/ networks and research institutes (Fig. 2). National organizations involved into the evaluated projects are mainly Academies of Sciences, Ministries of Education, national entities in charge with educational policies, national institutions involved in curriculum design. Non-formal science teaching environments such as science museums or science centres are quite poorly represented. Few schools are directly involved as participants to the analyzed projects. Under "pedagogical institutions" were included pedagogical high school and not the initial teachers' education entities which are part of universities. The category "others' includes chamber of commerce, SMEs, etc. This situation proves quite a little involvement of the various stakeholders expected to be interested into the change of the educational system, some of them being either in a decision position (Ministries of Education, curriculum developers) or beneficiaries (professional societies, local authorities, teachers and parents associations, the business community). National and European networks still play a minor role in the dissemination and implementation of the projects outcomes and recommendations. Nevertheless, exchanges of practice at European level started to be visible.

There were some attempts to produce resources to be used in the classroom and courses for teachers combining Science and Mathematics teaching (i.e. Inspire, SPICE, ITEMS, COMPASS, S-TEAM, Fibonacci, PRIMAS, ESABLISH, STENCIL, Creative Little Scientists, LEMA). In some notable situations a cross-disciplinary approach was promoted (Pollen, Fibonacci).

Most of the projects are trying to fill "the gap" existing between the theoretical teaching of Science, as it is practiced in the majority of European schools, and the real life experience students need to acquire, according to the educational policies supported by the official documents cited in the "Introduction" section of this paper.

A lot of resources were developed and are available on line, some of them providing a structured approach in Science teaching according to the IBSE/ IBSL/ IBSME principles; notable examples being: COMPASS, ESTABLISH, INQUIRE, ITEMS, PATHWAY, Pollen, PRIMAS, SPICE. At present only few of the resources validated in the projects frame are available in other European languages than English. This constitutes a real drawback for the dissemination and implementation of the projects outcomes. From the studied materials it is not evident that the courses run during the projects life are in any way certified/ recognized by a national authority. Teachers' results/ follow-ups of the projects implementation are poorly promoted as examples of good practice.

Valuable information on the present status of IBSE/ IBSL/ IBSME in European countries can be found in the deliverables of several projects referred in this paper: Pollen, Mind the Gap, S-TEAM, KidsINscience, PRIMAS, STENCIL, Creative Little Scientists. The reader might be interested to examine programmatic documents about the proposed active methods (IBSE/ IBSL/ IBSME), mentioned in this study and issued by projects such as: COMPASS, Pollen, Fibonacci, S-TEAM, KidsINscience, PRIMAS, ESTABLISH, PATHWAY.

Generally speaking there are not too much exchanges between projects teams and the cross fertilization effort is minimal. In few cases, a project documents refers to other project results, outcomes, activities, practices, etc. Even in the frame of the same project exchanges were organized, in most cases, between experts and researchers and less at grass-root level, through teachers' exchanges. It might be the objective of other forms of projects to promote such exchanges encouraging the innovative methods of Science teaching and learning implementation such as IBSE/ IBSL.

Most of the evaluated projects cover the primary and secondary school students' age (Table 1). Only the last launched projects address the hot topics of early education in Science and Mathematics (Creative Little Scientists, Pri-Sci-Net). It is noticeable the focus of one project on the connection existing or which can be established between Science/ Mathematics education and creativity.

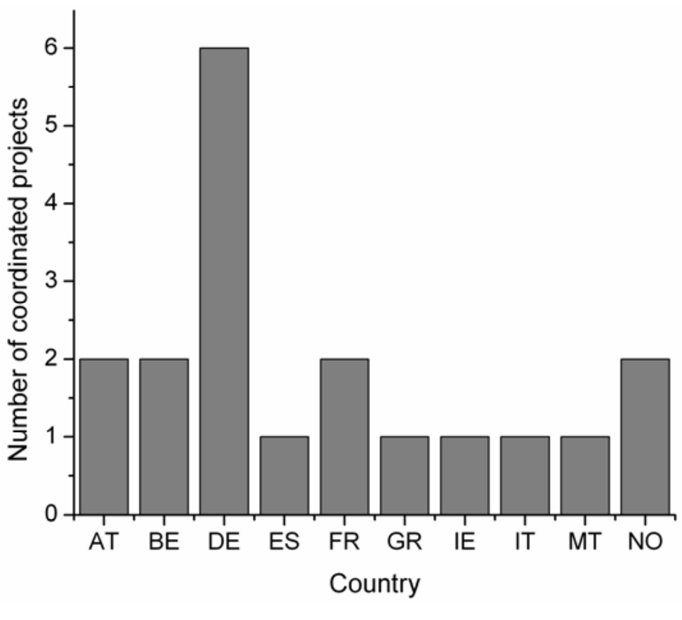

Fig. 1 – The project leaders as distributed per countries.

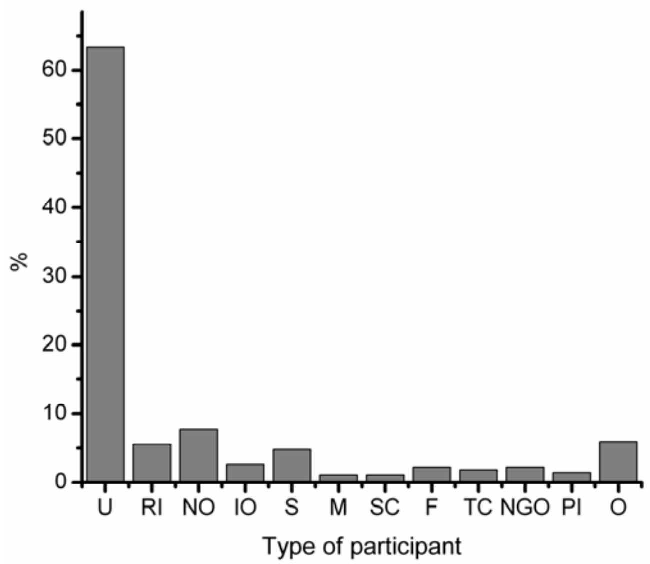

Fig. 2 – The type of entities participating to the analyzed projects: U – universities; RI – research institutes; NO – national organizations; IO – international organizations; S – schools; M – museums; SC – science centers; F – foundations; TC – training centers; NGO – nongovernmental organizations; PI – pedagogical institutions; O – others.

Comparing now the statements of educational policies with the objectives of the studied projects, the following conclusions emerge:

a) An interest towards early age education in Science and Mathematics is present in five projects (Pollen, Inspire, KidsINscience, Creative Little Scientists, Pri-Sci-Net).
b) The concern on Science and Mathematics education in the primary and secondary school is well represented.
c) New tools and pedagogical means are proposed by most of the projects.
d) The development of new assessment methods in relation to Science teaching and learning is under represented in the evaluated projects, exceptions are ESTABLISH, Fibonacci, ITEMS, PATHWAY, LEMA, PRIMAS (which has a special learning module addressing this problem).
e) More than half of the projects promote educational means coupled to real life situation and in some cases with the education of active citizenship.
f) Quite a lot of Science and applied Mathematics activities are supported by the projects team, embedded into new, more attractive teaching format (i.e. COMPASS, ESTABLISH, PATHWAY, Pollen, ITEMS, LEMA).
g) Several projects proposed courses, workshops, exchange seminars for teachers and teachers' trainers.
h) A lot of resources are produced in the frame of these projects; unfortunately they are either in English or only into a national language, limiting the dissemination process efficiency.

i) It was a constant concern of the projects teams to promote transnational cooperation and the build up of teachers and experts networks, but there is little information on the effectiveness of these networks.
j) The connection existing between the Science and Mathematics teaching and learning and the development of creativity at early age is present in the project Creative Little Scientists.
k) Not too much was done in involving a wide palette of stakeholders (curriculum designers, central and/or local authorities, professional associations, the business community, etc.) in the promotion of new pedagogies (IBSE/ IBSL), exceptions are Pollen, PRIMAS and Fibonacci which encouraged the formation of local community boards to support Science education.
l) There is still room for the development of teachers' content knowledge and their education for the understanding of Science role in society and the way it operates; no explicit and sustained efforts were done in the discussed projects on this issues.
m) Informal and non-formal Science and Mathematics education are almost missing among the objectives of these projects, excepting INQUIRE, operating in conjunction with some botanical gardens and Fibonacci which dedicated some efforts in developing outdoor IBSE activities.
n) The studied projects did not offer satisfactory answers up to now to some objectives of the European educational policy such as "learning-to-learn", the ability of lifelong learning, and the use of "personal learning plans".
o) It is hardly to say what is the impact of these projects on the re-design of national curricula, on new strategies for initial teachers' education and CPD programs or on the way Science and Mathematics students knowledge is assessed.

Considering the projects results more has to be done:

a) Decision makers on Science and Mathematics education, as well as curriculum designers from EU member states have to be involved both in the evaluation of projects results and in large scale the implementation of these results.
b) Support has to be offered for the translation of innovative learning units in different languages.
c) A system for the recognition/ accreditation of courses on IBSE/ IBSL for teachers and trainers/multipliers has to be set-up at European level with some form of credit transfer.
d) Teachers own contribution in developing learning units/ teaching materials/ demonstration kits have to be encouraged based on the model of the French program "La main à la pâte".
e) A unitary vision on the assessment (summative, formative, self-assessment, peer assessment, diagnostics assessment) methods used in IBSE teaching and learning has to be developed and applied.

f) Courses to train teachers on preparing lesson plans and running personalised IBSE sessions in the classroom have to be devised.
g) Teachers' ability to conduct Science and applied Mathematics teaching under non-formal conditions has to be cultivated in cooperation with museums, science centres and research institutions.
h) More time has to be devoted to Science lessons for students to be able to analyze, evaluate, experiment, conclude when investigate situations close to real life. Works are in progress to solve part of these problems in the frame of new European initiatives [21].

Acknowledgements. This work was supported by the grant 223/2012 of CNDI-UEFISCDI, in the frame of the project "Inquiry-Based Education in Science and Technology (i-BEST)."

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