INSIGHT
observatory for new technologies and education

NOVEMBER 2011

Spice: Spicing up Science and Maths classes by exchanging practices with teachers from other countries

B. Schwarzenbacher, À. Gras-Velázquez, B. Grečnerová, E. Gérard & A. Paiva

European Schoolnet
dgidc Direcção-Geral de Inovação e de Desenvolvimento Curricular
erte/pte
DZS Centre for International Services
spice

Publisher European Schoolnet (EUN Partnership AISBL)
Rue de Trèves 61
1040 Brussels
Belgium
www.europeanschoolnet.org
info@eun.org

Authors Barbara Schwarzenbacher, Àgueda Gras-Velázquez, Barbora Grečnerová, Eloïse Gérard & Ana Paiva

Collaborators Kim Adler, Daniel Aguirre, Sonja Artac, Bento Baptista, Monika Bartova, Anja Buntrock, Carlos Cachado, Zuzana Christozova, Nadia Circu, Carlos Cunha, Ivan De Winne, Maria Guida, Ausra Gutauskaite, Alena Hrabovska, Beata Jarosievitz, Annunziata Michetti, Hermann Morgenbesser, Vaclav Piskac, Thomas Roche, Pavla Sadecka, Elvira Santos, Eva Seidlova, Irena Skolilova, Emilia Vasconcelos and Malgorzata Zajaczkowska,

Editors Àgueda Gras-Velázquez

Design/ DTP Hofi Studio

Print Run 2,000 copies

Picture credit European Schoolnet (cover photo), Dreamstime.com

ISBN

9 789491 440113

Published in November 2011. The views expressed in this publication are those of the authors and not necessarily those of EUN Partnership AISBL or the European Commission.

The Spice project and the present publication have been funded with support from the European Commission, under the Education & Training, Comenius Lifelong Learning programme. This report reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

For more information on the report, the results or the SPICE project, please contact Dr. Àgueda Gras-Velázquez (agueda.gras@eun.org).

Table of contents

Preface 3

1. Introduction: the SPICE project 5

2. The protocol of experimentation 7

2.1 Criteria for good practice 7
2.2 The 24 GPs developed 8
2.3 Teachers' participation - Reasons for choosing the GP 9
2.4 Spice questionnaires 10

3. Good practice implementation: contents and success stories 12

3.1 Good practices in biology 12
3.2 Good practices in physics 15
3.3 Good practices in chemistry 19
3.4 Good practices in mathematics 22

4. Spice data analysis 25

4.1 Data treatment 25
4.2 Participation in the project 26
4.3 Profiles of teachers 26
4.4 Profiles of students 27
4.5 Results by subject matter 30
4.6 Assessment of students' learning gains – case study 31
4.7 Influence of the subject topic 32
4.8 Opinion questions 33
4.9 Country differences 34
4.10 Teachers' overall reflections 36
4.11 Overall lesons learned by the teachers 37

5. Conclusions 40

References 43

Preface

The main objective of the SPICE project was to collect, analyse, validate and disseminate innovative pedagogical practices, especially those based on inquiry-based learning, while enhancing pupil motivation for science studies at primary and secondary level (12-15 year old students).

The pedagogical approach of inquiry-based learning to teaching and learning in science education requires it to be student-centred rather than teacher-centred. The role of the teacher would therefore be more to guide the students along the process of learning than providing pre-defined knowledge. It is a form of active learning that brings students to work together to solve problems and gather the knowledge they need in order to solve them. It aims to develop experimental and analytical skills and understanding at the same time as knowledge.

As Professor Sir John Holman said in his keynote speech at the Scientix conference in May 2011, the key elements of a good science education system are school curriculum, pedagogy and assessment, but its quality depends ultimately on the quality of its teachers.

And on this issue, the SPICE project which ran from December 2009 to November 2011 and was the result of collaboration between European Schoolnet (*http://europeanschoonet.org*), the Direção Geral de Inovação e Desenvolvimento Curricular (*http://sitio.dgidc.min-edu.pt/Paginas/default.aspx*) from Portugal and Dum Zahranicnich Sluzeb MSMT (*http://www.dzs.cz/*) from the Czech Republic, proved to be an example of what can be achieved with the enthusiasm of teachers.

During the project, 24 teachers from 16 different educational systems (from 15 different countries) helped the SPICE partners and experts' panel in defining good practices that were then tested in classes by 41 teachers during the school year 2010-2011. This translated into around 2,000 students taking part in the SPICE experimentation.

The SPICE teachers, as they became known, helped design the assessment tools, carried out the implementation of the practices in their classes, filled in numerous questionnaires themselves and with their students, provided copious feedback on the effects of the practices in their classes, and after all this, they asked for a SPICE II project.

In this report we describe how the experimentation was designed, how the work was carried out, the success stories and overall analysis, results and tips. While we started the project with a narrow aim, only looking for direct effects on the students, the results reminded us how powerful teachers are in education and how excellent teachers like those we had the pleasure to work with will ensure that the students of today will be well prepared to support and provide for the needs of the future.

For this, and their invaluable friendship, on behalf of the whole SPICE consortium, we wish to dedicate this report to Kim Adler, Daniel Aguirre, Sonja Artac, Bento Baptista, Monika Bartova, Anja Buntrock, Carlos Cachado, Zuzana Christozova, Nadia Circu, Carlos Cunha, Ivan De Winne, Maria Guida, Ausra Gutauskaite, Alena Hrabovska, Beata Jarosievitz, Tina Michetti, Hermann Morgenbesser, Vaclav Piskac, Thomas Roche, Pavla Sadecka, Elvira Santos, Eva Seidlova, Irena Skolilova, Emilia Vasconcelos and Malgorzata Zajaczkowska.

Àgueda Gras-Velázquez
Spice Project Manager
European Schoolnet Science Programme Manager

1 Introduction: The SPICE Project

The primary objective of the two-year Science Pedagogy Innovation Centre for Europe (SPICE) project was to collect, analyse, validate and disseminate innovative pedagogy in terms of good practices (GPs) in mathematics and science, which included inquiry/problem-based learning approaches. A strategy was designed to establish a European methodology observatory and to develop the GPs as the basic ingredients of the project.

Additionally, the SPICE project aimed to create a catalogue of policy actions from the participating countries that supported the implementation of inquiry-based learning experiences in Mathematics and Sciences, while enabling better sharing and peer-learning between Ministries of Education, researchers and teachers in the domain of inquiry-based science education.

While the work carried out with the teachers and practices is presented in this publication, the catalogue of policy actions was published in November 2010 and updated and expanded a year later (see Kearney, 2010 and 2011).

Naturally, the overall aim of SPICE was to contribute to addressing the lack of student interest in maths and science careers present at different levels in all EU countries.

The selection of the practices to be implemented in different countries was accompanied by the criteria which would allow classifying a certain classroom practice as a good one beforehand. On the other hand it was necessary to define criteria and instruments that would bring to light evidence of what really are the results/benefits of the use of a particular practice. The selection of the teachers for this panel was one of the first steps in this project as well as the selection of GPs that guaranteed the equity of the distribution of the practices to be tried out.

The expected result of this project was to support the criteria for designing GPs in Europe that allow teachers to teach their subjects using innovative teaching methods within the concept of inquiry-based learning. Furthermore, students' understanding of science and their ability to relate the school subject to real life should increase, as this is the crucial factor which will in the long run increase students' motivation to study science and ideally also choose it as a career in their future lives. It is obvious, however, that the results of the students and their change in attitude will change slowly and not from one day to another. Therefore, it is important to be aware that the results of the SPICE questionnaire will not show vast improvements, as the project and the implementations of the GPs only took place for a limited time; but over a longer period and with the continuous efforts of the teachers the students' attitude towards science, their motivation and their understanding of the subjects will improve.

The starting hypotheses of the project can be summarized by the following five statements:

H1. The design of the SPICE project is technically sound and will provide valuable data.

H2. Students who are taught with the new methodologies and tools that are used in the GPs will understand, integrate and remember the topic better.

H3. The GPs are effective for the teachers: not too time-consuming in preparation; not too time-consuming in teaching; motivating; adaptable for other topics.

H4. The GPs are effective for the students: they enjoy the topic, they understand it better, they see the relation to real life, they can use it in their everyday life, they can improve a variety of skills (communication skills, working autonomously, research skills, etc.).

H5. The project will provide data to support the criteria for GPs in Europe that enable teachers to teach their subjects using innovative teaching methods within the concept of inquiry-based learning.

The SPICE project addressed these challenges by experimenting with a set of GPs developed for various subject areas in natural sciences and mathematics.

The aim of this report is to give a detailed overview of the project and an analysis of the results and evaluation derived from the implementation of a number of GPs in the participating European countries. We shall stress the successes and the detected failures and problems, as well as the room for improvement. Additionally, we will summarize the highlights of the SPICE projects, giving guidelines on the criteria for GPs, introduce each GP with additional feedback from the teachers who implemented it, show some results of the evaluation and mention the lessons learned by everyone involved in this project.

The Protocol of Experimentation

As a first step in the project, a European methodology observatory made up of science education experts and maths and science teachers from 16 different EU educational systems was set up. The role of the experts was to support the partnership in establishing the criteria for the selection of best practices. Based on these criteria, the teachers brought three good practices (GPs) in science teaching to a meeting in Brussels in May 2010. There the teachers had to present their GPs to each other and together they had to select the best 24 GPs out of the 72[1]. Then each SPICE teacher had to choose three GPs that he or she would implement during the following school year in their own countries. The GPs covered various scientific subjects, such as Mathematics, Biology, Physics, Chemistry, Geometry and Astronomy.

Criteria for GPs were defined, which led to the development of classroom working materials for each GP. Then participating teachers chose which GPs they were willing to implement in their classrooms, and a set of questionnaires was developed in order to collect data on the whole experiment.

2.1 Criteria for Good Practice

One of the results of a GP should be that students **understand, learn and master** the **subject better**. This can be achieved only by **respecting the diverse talents and ways of learning** of students. There are different learner types (haptic, visual, and auditory learners) who need different kinds of activities to be able to understand and internalize a topic well. Therefore, a GP should be made up of various types of exercises that cater to all of these different learner types. This is not only important for the memorizing process, but also for students to be able to show their talents, which might be very different, and thus to grow as a person and gain confidence. Teachers should keep in mind that: “Brilliant students in the seminar room may be all thumbs in the lab or art studio. Students rich in hands-on experience may not do so well with theory” (Chickering & Gamson, 1987). By finding teaching methods and activities that cater to all students needs, not only does the capacity to remember exercises increase, but also the motivation of the students rises, with a positive effect on the study process.

A GP should furthermore encourage active learning and thus inquiry-based learning: “Learning is not a spectator sport. Students do not learn much just by sitting in classes listening to teachers, memorizing pre-packaged assignments, and spitting out answers. They must talk about what they are learning, write about it, relate it to past experiences and apply it to their daily lives. They must make what they learn part of themselves” (Chickering & Gamson, 1987). The concept of active learning is thus important as it allows **students** to be better **engaged in the learning process**, involving **student reflection** and providing a **meaningful and lasting effect**. The following sentence should be remembered by teachers when preparing their GPs: “Students learn what they care about and remember what they understand” (Ericksen, 1984); so it is important to **link** lessons **with real life** situations.

1 *In addition to the 16 teachers from 16 different educational systems, four extra teachers from Portugal and four from the Czech Republic participated in the selection of the GPs following the set up of the project consortium, explaining the 24 GPs.*

Another criterion that distinguishes a GP from a regular teaching practice is the fact that students receive **regular feedback** concerning their work. This will show the students what they already know and what they do not know yet.

Besides teaching the topic of the GP in a memorable and interesting way, a good practice should also train students in **social skills** and raise their **self-awareness**; in other words, a GP should encourage **reciprocity and cooperation among the students.** This is not only good for their learning processes, but also for their social skills, and it is team-building.

Furthermore, it is important that students learn to use their time well when studying or when working on a specific task. This will also help them in their later professional life. The GP should thus ideally provide time limits for tasks and should give clear guidelines on when to do which activity and for how long (effective **time management**).

Time management is also a key factor for teachers to be able to implement GPs effectively and is part of the GP requirements **to travel well**. A travel-well GP should not involve too complicated and sophisticated materials, so that it has potential for replication. As in our case, for example, GPs to be tested in **different** countries should be easily transferable between different cultures and languages. It has to be kept in mind that the age of the students who will be taught might vary; therefore, the GP has to be adaptable to different ages. A further point that has to be considered is that the different schools in all the countries might not have the same access to ICT facilities, laboratory facilities or scientific **equipment**. Being an innovative GP means that it should be clearly structured, have defined aims and objectives, use new teaching methodologies and set realistic time indications.

As we are talking about GPs in scientific subjects in particular, it has to be said that several **stereotypes** concerning the individual subjects exist. Maths, chemistry or physics are often considered difficult, abstract and dry subjects. Especially girls drop out of ICT and Science studies after secondary education. Studies suggest as possible factors in women's lack of interest in ICT or science studies the lack of support from role models, persistent stereotyped views that the sector is better suited to men, and in some cases, how easy or difficult they find the subject (e.g. Gras-Velázquez, Joyce & Debry, 2009). However, the stereotypes that exist concerning science subjects concern not only girls but also boys. It is the role of the teacher to change these student misconceptions. Therefore, if the GPs are constructed in such a way that students discover the relation between "real life" and these topics, this can lead to big changes in students' attitudes towards science.

2.2 The 24 GPs Developed

The GPs chosen for this phase of the SPICE project are shown in Table 1 organized by subject area, as defined by the author of the GP. The names of the authors of the GPs are also provided, but it is important to note that the term "author" is used in a broad sense, as in some cases the teachers were not really the authors of the GP but adapted known practices from their countries for the SPICE project. These GPs are described briefly in Section 3.

Table 1: The 24 SPICE good practices, their authors and countries where they teach, sorted by subject.

GP	Subject	Author	Country
Comparing Leaves	Biology	Annunziata Michetti	BE (FR)
What are the uses of natural resources?	Biology	Bento Baptista	PT
Energy consumption - What can we do?	Biology	Carlos Cachado	PT
Make stringy DNA molecules visible	Biology	Irena Skolilova	CZ
Human body, general properties	Biology	Sonja Artac	SI
Digital mapping study of a school environment	Biology	Thomas Roche	IE
The position of the image	Physics	Vaclav Piskac	CZ
Magnetic properties of materials	Physics	Pavla Sadecka	CZ
Diffusion	Physics	Zuzana Christozova	SK
Study of inclined plane efficiency	Physics	Nadia Circu	RO
Light spectrum – Colour	Physics	Ausra Gutauskaite	LT
Simulations in the physics class	Physics	Daniel Aguirre	ES
Electric motors	Physics	Beata Jarosievitz	HU
Astronomy	Physics	Emilia Vasconcelos	PT
Biocatalyzers	Chemistry	Monika Bartova	CZ
Science in the kitchen lab and in the language lab	Chemistry	Malgorzata Zajaczkowska	PL
Reaction velocity	Chemistry	Carlos Cunha	PT
Golden coins	Chemistry	Anja Buntrock	FI
Maths Show	Maths	Kim Adler	FR
Constructing triangles with GeoGebra	Maths	Hermann Morgenbesser	AT
Didactic game in maths lessons	Maths	Eva Seidlova	CZ
Dudeney's haberdasher puzzle	Maths	Ivan De Winne	BE (NL)
More and more triangles	Maths	Elvira Santos	PT
Earth's radius (Eratosthenes' method) using GeoGebra	Maths	Maria Guida	IT

2.3 Teachers' participation – Reasons for choosing the GP

The teachers had to choose the GPs that they would implement in their classes during the first meeting which took place in Brussels in May 2010. They had different criteria for choosing the GPs but the most common reason was that the subject of the GP **fitted into the national curriculum** of their country. Another reason that influenced the choice of the teacher was the age of the students that the GP targeted. As the instructions given about each GP had to be closely followed by the implementers, it was important that the GP could be easily adapted to the **level of their students**.

Other teachers tried to choose the GPs according to the preferences of their students. As a Portuguese teacher mentioned, "[I chose] those GPs that seemed to be most **interesting from the standpoint of my students** and those that best fit the curriculum of the subjects I teach. Furthermore, as I use a **hands-on** approach with students this age, I tried to choose GPs which were largely based on hands-on activities." It is of course in the interest of the teacher to teach in such a way that students are motivated, that they discover their interest in a subject and want to learn more about it themselves.

Another criterion that influenced some teachers' choices was the interest they had in learning something new. For example, a few teachers who had never worked with "GeoGebra", a dynamic tool for geometry, but had heard of it, wanted to take the opportunity to learn how to use this program and so chose GPs that provided possibilities for **professional development**. The **material and tools** that were required by the GP also influenced the teachers' choices: some teachers were interested in GPs that they did not choose, as they did not have certain equipment in their school.

In some cases, the problem arose that some teachers were very interested in testing certain GPs that were created for subjects other than those they were teaching. In these cases the teachers selected a few additional GPs for some of their colleagues in school, if they knew that their colleagues might be interested in testing these GPs. Furthermore, some of the GPs were meant to be taught in **cross-curricular** teaching with for example English; teachers often worked together on the implementations and built team-teaching classes.

Finally, the authors trained the teacher implementers (those from other countries who were going to implement the author's GP) on how to use their GP and its course materials via a Moodle platform, after an initial discussion face-to-face in Lisbon in September 2010. Both in person and through the online environment the teachers also discussed possible modifications needed and adaptations to be able to use the GP in the new countries.

2.4 SPICE Questionnaires

As indicated by the initial hypotheses presented in the Introduction, it was important to see whether the GPs selected did indeed fit the criteria that make up a good teaching practice plus having positive effects on both teachers and students. For this reason, a set of questionnaires to be filled in by the teachers and the students participating in the project was designed in order to collect and evaluate the implementation of the activities.

General questionnaires were designed to see the overall effectiveness of using the GPs as well as whether the implementation of the GPs did indeed improve the students' attitudes towards maths and science subjects, as well as their knowledge. It was therefore important to find out the students' attitudes towards science and maths and their preferences in learning (e.g. learning through group work, individual work, using ICT tools, etc.). In these general questionnaires, the students were asked about their age, gender, subject preferences, learner types, etc. Whereas the teachers were asked questions about their teaching habits: what methods they usually use in teaching, what learner types they cater for, and their experience with inquiry-based teaching.

In order to be able to receive appropriate feedback from the students and teachers about each GP, specific questionnaires were created for students and for the teachers who carried out the implementation. The specific questionnaires were aimed at testing the students' knowledge about the topic that each GP covered. These questionnaires were created by the teachers who had authored each GP. The specific questionnaires for teachers were designed to concretely ask the teachers about the success of the GP that they implemented, how the students liked it, whether they intended to re-use it in the future or what they would need to adapt in the GPs to make them useful for them.

Each questionnaire existed in a pre- and post- version. The general pre- and post- questionnaires had to be filled in only once by each student and teacher before and after each GP implementation for a given class. However, students and teachers had to fill in the specific pre- and post-questionnaires before and after each GP implementation. In order to be able to see the effect the GPs had on the students' and teachers' motivation in the various subjects, test and control groups were established. The test groups (T) were the groups that would test the GPs, whereas the control groups (C) were, as far as possible, classes of the same level and age where the teacher would teach the same subject as in the GP but in a traditional way. This would allow us to compare the results of the students in the test groups and in the control groups, and assess the success of the GPs in terms of student motivation, scientific thinking and understanding.

All questionnaires are available via *http://spice.eun.org*. The teachers' questionnaires were provided in English while the students' questionnaires were in their local languages.

Good Practice Implementation: Contents and Success Stories

In this section we shall present briefly the 24 GPs generated for the project, organized by subject matter. The full contents of the GPs can be found at the project's website: *http://spice.eun.org* and are available under Creative Commons Attribution-NonCommercial-ShareAlike 3.0 Unported License.

Additionally we shall describe briefly some success stories described by the implementers of each GP. They reflect important but difficult to quantify data in terms of students' and teachers' satisfaction with the project, and learning outcomes in all aspects of the teaching and learning environment, especially regarding motivation, cross-disciplinary interaction, collaboration, general and basic skills development, etc.

3.1 Good Practices in Biology

Comparing leaves

Origin: **BELGIUM** (French community)
Implemented in: Portugal, Slovenia, Czech Republic and Austria

The main aim of this GP is to learn about plants and their leaves and to be able to compare them. This GP is very nature-based and its implementation does not require complicated materials or tools, but rather field trips. It encourages the students to go outside and carefully look at trees, their leaves and fruits, to touch them and collect some samples. Students are made aware of the plants' life cycle and needs; they learn to pay more attention to nature around them and to be more observant.

In general this GP was very well received by all the implementers, as their feedback was overall positive. For instance, one of the Portuguese teachers mentioned that even though, or maybe especially because the GP is quite simple and asks the students to study the leaves of the trees in their surroundings, they were very motivated by it and learned to pay more attention to nature. According to this teacher, this GP is "important to alert students to the problems of the preservation of ecosystems". He says that "Portugal has serious problems with forest fires and these activities may be important for community awareness." The Slovenian teacher had a similar impression to the Portuguese one.

Remarkably, all the teachers mentioned that the students had some very interesting findings at the end of their own observations. Most students had different ways of noting down their observations; some students were taking photos regularly and at the end they had good documentation on the life cycle of the plants that they observed, whereas other students wrote down notes on the evolution of the plants in various forms such as diary format.

According to most of the teachers, the success of this GP lies in its simple hands-on method and its basic but very important topic. Students enjoyed being given the freedom to use their creativity and resources in order to record the life cycle of plants. The success of this GP can be seen by the example of one of the Portuguese teachers who said that the topic "leaves of plants" is not foreseen in the national curricula, but due to its importance in raising awareness with the students, and seeing how the students enjoyed the observations of nature, the school will introduce this topic to their biology curriculum and they will continue using this GP in the future.

What are the uses of natural resources?

Origin: **PORTUGAL**
Implemented in: Finland, Austria and Czech Republic

The aim of this GP is to teach students the characteristics and uses of natural resources, such as gold, trees, cotton, carbon, etc. The students are confronted with various objects, such as clothes, pens, tools and paper, and they have to find out which natural resources have been used to create them. After that, the students have to do some research on the Internet to find out the characteristics and uses of the resources and create an identity card for each natural resource. These identity cards will finally be used for an exhibition that the students will organise themselves by bringing samples of the natural resources and products that have been created.

Teachers who implemented this GP mentioned that what they liked most about it was that the students would have to prepare an exhibition themselves with material and artefacts that they bring and research that they do. A Finnish teacher mentioned that the fact that the students had to organise an exhibition themselves which they would make available for the whole school to visit would be a team-building experience for the students and it would motivate them to do proper research in order to create something interesting and good, which would make them proud in front of their whole school. The teacher herself was proud to see that her "students created a 12m long exhibition gallery, that can be expanded and filled with additional materials every year by new students". She also mentioned that it was great to see that other students could learn from the exhibition and could therefore learn from their fellow students.

Energy consumption - What can we do?

Origin: **PORTUGAL**
Implemented in: Spain

The GP starts with a general discussion between the students and the teacher on what can be done to save energy and reduce consumption. Following that, the students watch a video ("Energy! Let's save it") created by the European Commission to raise awareness. This video serves as inspiration for the students to create energy-saving plans for their school and possibly for their own homes. They have to prepare a poster presentation to introduce their concrete ideas to the fellow students, which is followed by composing a formal letter to the headmaster addressing the issue and suggesting ways to reduce the energy consumption of the school. Once the energy-saving actions have been implemented, the students need to make notes about energy consumption by having access to the electricity bills of the school. These results are compared with the energy bills of the previous months and years in order to see the savings.

This GP has proven to be an effective way of internalizing the change in students' attitude to energy consumption, as most students also started taking measures to reduce energy consumption in their homes. The implementers of this GP mentioned that they liked it due to its efficiency and the combination of motivational exercises that were used, such as designing posters in groups, watching an inspirational video, and becoming aware of the schools' expenses by seeing past as well as new energy bills.

Make stringy DNA molecule visible

Origin: **CZECH REPUBLIC**
Implemented in: Slovenia, Portugal and Belgium (French Community)

The lesson is intended as a first introduction to DNA or as a quick, easy and impressive hands-on accompaniment to or refreshing of the topic. The objective of the GP is that students learn about DNA and basic procedures that are used in molecular biology by sampling their own DNA. They learn basic laboratory skills such as pipetting, measuring fluid volume and respecting rules in laboratories, besides of course knowledge on DNA structure.

A Portuguese teacher stated that in his view this GP is very important for the students, because "laboratory activities are of the utmost importance for understanding the content and this was particularly attractive: the mystery involved in making invisible DNA visible, research, problem solving and understanding of content." The fact that students have to extract their own DNA was mostly very motivating for the students; in a few cases in Belgium some parents were not willing to let their children extract their own DNA, so the teacher decided to extract DNA from a kiwi with the students, which was equally interesting. In general, as mentioned by a Slovenian teacher, the students "were fascinated by the fact that DNA molecules are unique in the living world, and it doesn't matter what kind of cells they use for the isolation, kiwi, banana, tomato or human epithelia cells."

Human Body - General properties of the human body

Origin: **SLOVENIA**
Implemented in: Portugal, Lithuania, Austria and Czech Republic

This GP was created for students aged 15-16 and aims at teaching the key facts of human anatomy and physiology. Students have to work in groups and find out about typical human body characteristics by performing simple measurements, experiments and observations. Topics such as the human organs, the locomotor system, the senses, the nerve system, the digestive tract, the blood and heart, the immune system, respiration, reproductive system and homeostasis are investigated by the different groups. The conclusions have to be presented in form of a poster and presentation to the rest of the class, so that everyone will learn from the research of the other groups.

This GP is based on a topic that is present in all national curricula. As a Portuguese teacher mentioned, "these contents are usually taught with the use of partial exposure or some movies, but the fact that the GP suggested laboratory activities as well as group research work, allowed the students to understand the contents more easily and in a more participatory way". For the other two implementers this GP was a success, but as they had to teach it in classes with younger students, it was not easy for the students to understand all the concepts as quickly as intended in the GP; so the implementation took slightly longer, but the students were motivated in their work.

Digital mapping study of a school environment

Origin: **IRELAND**
Implemented in: Slovenia and Portugal

The overall aim of the GP is to use the local environments as outdoor laboratories for the teaching and learning of Environmental Science by using innovative teaching such as a GPS, which allows an interactive collaborative approach. The students are asked to capture data outdoors using a GPS and bring them to the classroom. This initiates the investigation and further observation, examination, predicting, metering, debating, collaborating, concluding and recording on concepts of latitude and longitude, time, speed and distance. The portfolios of personalized maps are exchanged, compared and contrasted, and the conclusions of these activities are packaged, presented and communicated to the school community.

The teachers who implemented this GP generally gave good feedback and reported increased interest from all students; the biggest challenge in this case is having enough GPS available for the students to be able to make their measurements. However, few students would think that a GPS could be used as a tool at school. For this reason, as the students could relate to the GPS as a tool that is used in their surrounding in everyday life, their motivation in being able to use this tool at school and to make calculations with it themselves was clearly higher.

3.2 Good Practices in Physics

The position of the image

Origin: **CZECH REPUBLIC**
Implemented in: Portugal, Finland and Italy

The aim of this GP is to show students the different positions of images made by mirrors and lenses. The teacher and the students are supposed to bring all different types of mirrors, so that a range of plane, concave, convex mirrors and converging and diverging lenses is available. The students are asked to work individually to try out the different mirrors and see the position of the images changing. The role of the teacher is to guide the students individually through their discovery phases.

A Portuguese teacher mentioned that after his initial difficulties in obtaining all the different kinds of mirrors, once the implementation started, he noticed a great interest within the students. They were curious to handle the lenses and mirrors and they enjoyed the hands-on approach of this GP. An interesting thing that the Portuguese teacher mentioned is that “some students who participate less in classroom activities were very active during the implementation of the GP, sharing very interesting examples of their day to day activities and willing to perform the experiments with great care and attention.” An Italian teacher mentioned that instead of buying all the different types of mirrors, she tried to use objects from every-day life that could act as a mirror or a lens, for example she used a spoon instead of a concave mirror. This little adaptation made the GP even closer to real life for students. Something that shows how much the students enjoyed this GP is that the teachers noticed that some students shared their newly acquired knowledge with their families and friends, particularly with the people who wear glasses.

Magnetic properties of materials

Origin: **CZECH REPUBLIC**
Implemented in: Portugal and Ireland

The objective of this GP is to activate all the knowledge that students already have about magnets and to extend it with further knowledge. The lessons start with an experiment carried out by the teacher, which is then followed by a brainstorming in class to find out what the students already know about magnets and what they would like to know about them. The teacher writes the students' answers down on a flipchart and once the list is complete, the teacher splits the questions into different home groups and topics and distributes them among the students in order to create expert groups. The students have to do research together in their expert groups to find out the answers to the questions, which at the end they will present to the members of their home group, as well as by posters to the whole class. Finally the students have to answer a quiz to see if they can apply their acquired knowledge to various examples and experiments.

This GP requires a set of materials, and organizational skills in the teacher in order to keep control over the home, expert and puzzle groups. However, the teachers who tried this GP did not report any particular problem. A Portuguese teacher only mentioned that for the expert group method she realized how important it is that all the members of the group work well, as otherwise that "could compromise the learning of other members of the home group". In most cases, however, the teachers noticed that the method used in this GP motivated the students to work efficiently, as they had responsibility towards their groups. An Irish teacher said that the "task on magnetizing the iron bar was very impressive" and that the students enjoyed it. As he saw his students working very well during the implementation of this GP, he even filmed the students while they were working on their experiments in order to create a video for them.

Diffusion

Origin: **SLOVAKIA**
Implemented in: Czech Republic, Romania, Spain and Hungary

Its objective is to make a visualization of the real experiment of diffusion and to explain its principle and process, as well as to teach the students to work with digital sound, digital camera and creating movies. The concept of diffusion is first shown to the students with an experiment made by mixing water with liquid $KMnO_4$ which changes the colour of the water. During this process the students have to use a camera to take photos and videos in order to create a short movie that they will use in presentations explaining the process of diffusion.

The Czech Republic teacher said "the GP on Diffusion was what both my pupils and I enjoyed the most. Children loved the work with the camera and the subsequent editing of the video, and also creating the presentations. I got carried away a little bit with the enthusiasm of my pupils and as a result we gave more time to this GP than planned. It was definitely not a waste of time because in the presentation the pupils showed only the process of diffusion but also the variations of its speed under different conditions". According to a Spanish teacher, this GP is good because it is simple but it helps the students to relate Science with Technology. The GP combines features that are present in the daily life of a scientist, as it asks the students to make experiments, do calculations, interpret results, take notes by taking photos and creating a multimedia presentation, and finally communicate the results to their fellow students.

Study of inclined plane efficiency

Origin: **ROMANIA**
Implemented in: Czech Republic, Italy, Slovakia and Spain

The aim of the GP is to teach the students recognition and graphical representation of forces acting on an object moving on an inclined plane and an object moving vertically, by showing them computer simulations and real experiments. Students have to make accurate measurements of the inclined plane experiment, calculating the efficiency of an inclined plane using a spreadsheet and finally they have to make graphical representations of its efficiency as a function of tilt angle.

The Spanish teacher, who said that he teaches this topic to his classes every year, but using a different methodology, praised the method of combining lab and computer simulations, as he noticed the increased interest of the students in this topic. Therefore he will continue implementing this GP in the future and he will adapt the lab work to his equipment. A Czech teacher said that as his students had already learned about the inclined plane the year before, he implemented this GP in English, so that the students would get to practise their English and of course to review and build on what they had already learned before. He gave very good feedback, as he said that the students did not have problems with the English, but even remembered some phrases that they repeat every time they talk about the inclined plane ("Pushing up, pushing up the inclined plane"). Furthermore, he noticed that his students had remembered quite a lot from before and could apply their knowledge very well to the GP. An Italian teacher gave similar feedback to that of the Spanish teacher, saying that "the strength of the GP lies in the combination of inquiry-based learning, traditional lab and use of technology: a rail and a trolley with the integration of a worksheet on the Interactive Whiteboard (IWB), Java applets and videos."

Light spectrum - Colour

Origin: **LITHUANIA**
Implemented in: Czech Republic, Portugal and Slovakia

The aim of this GP is to teach students in English the spectral composition of light and object colours by using ICT to search for information, make hypotheses, process research, experiment, observe and analyse. It is important for the implementation of this GP that the classroom is equipped with about 15 computers so that the students can be divided into 2 groups. One group of students is asked to work on the computers to do practical work such as virtual experiments and simulations, while the second group works with exercise sheets to cover the more theoretical tasks. After a while the two groups change places and work on the field that they have not covered yet. The role of the teacher throughout this GP is that of a facilitator: students have to work by themselves with the guidance of the teacher.

The teachers who implemented this GP gave good feedback on it, saying that the materials and worksheets were well prepared and clear for the students, which allowed them to achieve their objective. This was motivating for the students, as well as the combination of different exercises: computer-based exercises, paper-based exercises and communication among the students.

Simulations in the Physics class

Origin: **SPAIN**
Implemented in: Romania, Hungary and Slovakia

The main objective of this GP is to develop a didactic sequence where students learn about buoyancy, sinking concepts and the Archimedes principle using computer simulations. The lessons start with an experiment and discussion in order to provoke reflection and to try to challenge some of the misconceptions students have concerning these concepts. This GP is designed to combine lab work and simulations in order to learn Physics laws from various angles, without neglecting the concepts defined in the inquiry-based learning methodology. Students are confronted with computer simulations and real hands-on experiments, in order to stimulate their curiosity and provoke questions and predicted solutions before working on finding the answers themselves by doing real and virtual experiments. It is particularly important to connect the virtual experiments and simulations to real-world experiences as students will learn more if they can see that the knowledge is relevant to their everyday life.

The teachers who implemented this GP were happy with the results of their students due to the combination of hands-on experiments and simulations, which allowed the students to compare the results and gain a better knowledge of Physics concepts. A Slovakian teacher mentioned that the students were highly motivated: “They joined in the work actively and also improved their study results in the given tasks”.

Electric motors

Origin: **HUNGARY**
Implemented in: Czech Republic, Slovakia and Romania

Its aim is to teach students the basic principles of electric motors by building a working model of an electric motor for classroom use. The lessons start with a short pre-questionnaire that the students need to fill in order to show the teacher how much knowledge they already have on this topic. Then the students are divided into groups of three. Each group chooses one experiment and collects the required materials from a little box, and each student within the group is assigned a role: a reporter, a camera person and a presenter who has to create a short presentation on the experiment. The work of the students starts by watching a video on an experiment which they have to reproduce. During the reproduction the students have to follow their roles. The mechanical construction experiment is filmed with a digital camera by the camera operator, the video can be embedded in the presentation that the reporter creates, and the third student will finally have to present the whole experiment to the class. The added value of this GP, as stated by the creator, is that “students are able to make their experiments alone; they can discuss in teams and even argue about a scientific topic during their observation. Students are involved in the teaching of the new material, and they start to learn to predict before they conclude their observation.”

According to all the teachers who implemented this GP, their students enjoyed creating mechanical constructions very much, as it was motivating for the students to construct something themselves that is functional at the end. A Czech teacher mentioned that during the hands-on construction exercise some of his students realized that they were not very good at handiwork, as they are not used to it. This made them realize that they should try to do more things by hand instead of by computer whenever this is possible.

Astronomy

Origin: **PORTUGAL**
Implemented in: Czech Republic, Italy and Lithuania

The aim of this GP is that the students learn to recognize the organization of the universe, by being able to characterize the different heavenly bodies of the solar system and knowing some of the instruments that are used to explore the universe. The students have to discover the universe by using the software “Stellarium”, which the teacher introduces to them at the beginning of the lesson. After that, the students are asked to do some Internet research in groups. Each group has to cover a different planet and at the end of the lessons the groups have to prepare an illustrated text about what there is to be found in a trip to the solar system and present their findings to the rest of the class. During this GP it is important that the students learn to work autonomously, to be organized and to use scientific terms correctly.

A Lithuanian teacher stated that this GP was the one that the students preferred, as they enjoyed discovering our universe with the software “Stellarium”. During the implementation of the GP “most of the students downloaded the program onto their home computers.” The teacher also noticed “how some students taught others to use this program”. Further, the Lithuanian teacher says: “I had some unmotivated students in my class. Nothing interested them. But these students downloaded Stellarium and taught others. I watched and could not believe it.” The Italian teacher gave similar feedback; she said that she used “Stellarium” on the IWB and the students were impressed as it “looked as if they could touch the sky with their hands and could travel through the Universe. Going to the Moon and looking at the Earth from there is a useful change of perspective.” The fact that students had to produce a final product after their research, namely a report of their trip in the Universe, gave her students more motivation to discover the unknown. This also gave the teacher the opportunity to evaluate her students in a different way.

3.3 Good Practices in Chemistry

Biocatalyzers

Origin: **CZECH REPUBLIC**
Implemented in: Poland, Ireland and Portugal

The aim of this GP is to raise students’ interest in chemical compounds by discussing vitamin C. Students are split into groups and receive six information cards about six different chemical elements. They match the symbols in the right order to find the name of the compound: vitamin C. After that the whole class discussed what contains vitamin C, why it is necessary for our health and what diseases appear due to lack of vitamin C. Following this introductory lesson the students return to their former groups and start online research on the recommended daily amount of vitamin C, which fruits and vegetables contain vitamin C and how much, and how to cook without losing vitamin C. This exercise will open the eyes of many students and make them more aware of their own consumption of fruit and vegetables. Following the lessons the students are asked to count on a daily basis how much fruit and vegetable they eat during a day/week and calculate how much vitamin C they get from it. In a following lesson the students have to carry out an experiment in which they mix various substances with vitamin C tablets and make the vitamin C change colour so that they can see the amount of vitamin C that is contained in their mix.

A teacher from Poland used this GP as a cross-curricular lesson, as she taught it in English. Her students enjoyed this GP very much and some of them were surprised to learn that "a lack of vitamin C in the body can cause weak immunity, and even scurvy." The students also enjoyed doing the experiment in which they had to find out whether they had enough vitamin C to stay healthy. This motivated them, as vitamins are a very real-life topic that they can relate to. The fact that this GP was taught in English was also useful, as according to the teacher "learning science in English will help students learn both subjects. They will be handling real meaning rather than just words and structures. Something more than language must carry messages. That something else is what we see, hear and feel around us". A teacher from Portugal and a teacher from Ireland were both also satisfied with the learning result of their students after having implemented this GP. The students were motivated and therefore participated in all the activities with enthusiasm, but they were also made more aware of the importance of healthy nourishment and the role of vitamin C.

Science in the kitchen lab and in the language lab

Origin: **POLAND**
Implemented in: Portugal, Lithuania and Czech Republic

This GP is based on the idea that a kitchen is just like a science laboratory. It is the objective of this GP that students understand that not only are the products stored under the sink chemicals, but also all the ingredients that are used to cook are made up of chemical compounds. The lesson is built on experiments called "Invisible Chemistry", which are based on the properties of a few water solutions, such as table salt, baking soda and vinegar mixed with water. Students have to learn that there are substances in water which they can find using their senses and there are others which they can identify using tools. The students have to carry out experiments, observe the colour changes of the water solutions, describe them using scientific explanations of the chemical reactions and record the data by filming and taking photos.

Each of the teachers who implemented this GP said that the fact that it asked the students to work with materials closely related to everyday life increased the students' motivation incredibly. Students were familiar with most of the substances and even use them in their daily lives, but they were surprised to see these substances and material could be used in chemical experiments and not only serve as food or drink. A Czech teacher said that the "students had a lot of fun during the lessons." Concerning the fact that the GP was meant to be taught in English, all the teachers agreed that it was a good exercise for the students to prepare the final presentations in English. This was not easy for the students, but during the whole process they learned many scientific terms. A Portuguese teacher summed up the effect and success of this GP by saying: "The students showed great interest in the activities proposed, executed them with enthusiasm, and repeated them at home with their family and friends. The materials used were easy to find and so I think this is an activity that easily adapts to the curricula of different countries and educational realities. It has an excellent hands-on nature, and is perfectly framed in the spirit of inquiry-based learning."

Reaction velocity

Origin: **PORTUGAL**
Implemented in: Czech Republic, Finland and Poland

The aim is that students learn to draw graphs and to interpret a velocity graph. The lesson starts with a theme presentation in the form of a video and a discussion. After that the students have to carry out an experiment using different vinegar concentrations and the same mass of bicarbonate and record the mass evolution during reaction using their cell phone. The videos are used to up draw a table indicating concentration versus time. The same procedure can be repeated using another reagent concentration. During this GP students learn to be observant, to do hands-on work and solve problems, to interpret graphs and their results, and to use computers and mathematical concepts.

The teachers who implemented this GP all applauded the idea of using mobile phones during the experiments, as they noticed that this was extremely effective and motivating for the students. According to a Polish teacher the students "were taught how to make graphs and avoid mistakes. The GP worked both with younger as well as older students because of the power of visible results, namely the carbon dioxide gas that we see bubbling and foaming as soon as we mix baking soda and vinegar together. Two common non-hazardous materials found in almost every kitchen help us understand the basic postulate of chemical kinetics that 'The velocity of chemical reaction at a given moment of time is proportional to the concentrations of reagents raised to a certain power.'"

Golden coins

Origin: **FINLAND**
Implemented in: Czech Republic, Poland and Belgium (French Community)

This GP's objective is to teach students through a motivating and hands-on approach the concept of density and its measurement by using the volumetric difference method to distinguish between elements and alloys. In the introductory lesson the teacher performs an experiment while the students are asked to "write down the different steps and materials used in the experiment in order to train their ability to observe and write protocols." Only after a session of reflection and discussion are the students asked to perform the experiment.

The teachers said that the students as well as they themselves enjoyed this GP very much. It was interesting for the students to see how coins could be turned into golden ones. A Polish teacher mentioned that one of her students even said "You've performed a miracle", but that through this GP students could see very well how chemical substances work and react. The greatest success of this GP is, as all the implementers said, that "The children could show the result to their friends and their parents" by taking the golden coins home. Students generally enjoy doing experiments where they produce something themselves that is either functional, that they can take home to demonstrate to their families and friends, or that they can even repeat at home.

3.4 Good Practices in Mathematics

Maths show

Origin: **FRANCE**
Implemented in: Czech Republic, Portugal and Belgium (Flemish Community)

Its aim is to show students that maths can be fun and that it can be learnt in combination with other disciplines. In this case, the other discipline which plays an important role is language, as the lessons are based on group work, where students have to solve mathematical problems that are wrapped in stories. Through these exercises the students learn to pay close attention to the vocabulary used in mathematics.

This GP had initially been planned for students aged 12-13, and as such it was a great success in the Czech Republic. A Czech teacher said: “The pupils were working very hard, they found out the results easily. Each group solved a different problem. The group which solved the cats problem made the bus some metres long and they drew themselves, cats, kittens and their calculation into each window of the bus. Then they played drama to show the mathematics problem to other pupils.” A Belgian teacher who intended to implement this GP in a class to students aged 15-16 had to adapt the exercises somewhat by including some more difficult mathematical concepts, such as freeze patterns, gothic windows and Escher tessellations. Nevertheless, the method of the “mathematical show” worked very well and it motivated students to find solutions to their problems and present their group activities to the other students in the class.

Constructing triangles with GeoGebra

Origin: **AUSTRIA**
Implemented in: Portugal, Czech Republic and France

The aim is to teach students how to construct triangles by using the computer program GeoGebra. Students have to work in groups, and each group has to choose one flag that contains a triangle, which they have to reconstruct using GeoGebra. After that, the groups have to prepare a short presentation to show how they chose to solve the task. These presentations are aimed at starting a discussion among the students about the different possibilities of constructing triangles with GeoGebra. It is important that the students can reproduce their construction in front of the class and that they can discuss their solutions.

For some of the teachers who implemented this GP the program GeoGebra was new, which meant that they had to familiarize themselves with it before the implementation. Other teachers already knew GeoGebra and had the opportunity to get to know it better through this GP. The teachers who had never worked with GeoGebra in class needed more preparation time with the students, as they had to take time to show the program to them. Once the students started creating the flags themselves, they were motivated to be able to construct a mathematical figure in the shape of an object that they know from everyday life. The teachers reported that they will continue using this GP and they will use the program GeoGebra for more mathematics lessons, as they noticed that the students enjoyed constructing mathematical figures on the computer.

Didactic game in maths lessons

Origin: **CZECH REPUBLIC**
Implemented in: France and Belgium (French and Flemish Communities)

The objective of this GP is that students revise all the mathematical terms that they have learned in previous lessons in a fun way. The lesson is based on a game called "draw and guess," for which the class is split in two halves. One student from each group comes to the teacher's desk and sees a mathematical term. He or she has to draw it for the group to guess which term it is. Once the group guesses the term, another student can go to the teacher to receive a new term. The group that guesses all the terms most quickly wins. The students are very motivated by this game as first of all they don't have the feeling that they are studying, because they are having fun, and secondly the game gives them the feeling of competition, which encourages them to work extra hard. Another virtue of this game is that its duration can vary depending on how long the teacher wants the students to review terms. Furthermore, it is a good way to let students do some self assessment, as they report whether they had problems with the terms or whether they knew them all.

The Belgian teacher (from the French Community) stated: "I could see that the pupils like this game and that they learn a lot. I really enjoyed it and I'm still enjoying it. I will use this GP in the future. Furthermore, I'm trying to motivate all my colleagues to use this game in all subjects. This GP is exactly the one that I was thinking of testing at the beginning of the project: a GP that teachers can adapt to their class and to the content that they teach." The Belgian (Flemish Community) teacher gave similar feedback, as he also said that he liked the fact that this GP was universally useable: "Training in use of mathematical keywords, concepts and representation by playing this game is possible in different classes and at different levels." Another point highlighted as positive was that the teacher can use the game as a longer activity in class, but it can also be easily integrated as a short 10 minute revision activity that students will enjoy.

Dudeney's haberdasher puzzle

Origin: **BELGIUM** (Flemish community)
Implemented in: Czech Republic, Portugal and Ireland

The objective is to build up the students' mathematical knowledge through problem solving, and to teach students to make geometric constructions by using GeoGebra, the tool for dynamic geometry. The lessons start with a short presentation of the problem, namely Dudeney's dissection of an equilateral triangle into a square. After that the students have to cut a square into four pieces and create equilateral triangles. Furthermore, they have to do some online research on keywords such as Dudeney, Canterbury puzzles, hinged dissections, etc. Once this preparatory work is done, the students have to construct Dudeney's puzzle with GeoGebra. They have to make calculations on the area of the triangle and the exact length of the sides of the square. After that the students are encouraged to compare their solutions with the actual solutions proposed by Dudeney in 1908 and to reconstruct Dudeney's puzzle step by step with GeoGebra.

An Irish teacher gave as feedback before implementing this GP that he had "what is called a gentleman's knowledge of GeoGebra but did not really understand its full potential" and therefore he wanted to learn something more himself, which he would then happily pass on to his students who are "very interested in hand to eye exercises worked on graph paper." He quickly realized that "through this medium the students acquired massive knowledge and accuracy on grids, axes, co-ordinates, quadrants, lines, angles, bisections and various types of triangles and other 2D shapes. This was the obvious progression and the fact that implementation on the IWB magnified and illustrated their activities made the work on the A4 graph sheet very Neanderthal indeed." Another Irish teacher said that thanks to this GP and its success with the students, now there are two GeoGebra groups in his school actively engaged in this subject. Also, according to a Czech teacher, this GP was a success as the students, who did not previously know how to work with GeoGebra, quickly learned how to use it and enjoyed working with it. They seemed to enjoy the combination of group work and using computers.

More and more triangles

Origin: **PORTUGAL**
Implemented in: France

The aim is to work on different triangles with the students and to make them discover the relationship between the longest side of the triangle and the other two sides. They find answers to questions such as: "If the angles of the triangle stay the same, can the length of the sides change?" Students have to construct different triangles using spreadsheets to find out what changes if they modify the angle or the length of a side. Furthermore, they learn about Pythagoras' theorem with the teacher in the role of facilitator.

According to the teachers who implemented this GP, the method of letting the students construct many different triangles to allow them to find out the relationship between the corresponding sides of two triangles was very effective, as they could internalize and understand the concept. A French teacher said about Pythagoras' theorem: "My colleagues really liked this GP and will implement it again next year."

Earth's radius (Eratosthenes' method) using GeoGebra

Origin: **ITALY**
Implemented in: Belgium (Flemish Community), Spain and Hungary

The aim is for the students to learn about Eratosthenes' Earth radius measurement and to make practical estimations of the error in measurement of physical quantities as well as to develop the capacity for abstraction. Students have to work with GeoGebra to draw ellipses using the gardener's method. In order to get the feeling for it, the students can go into the garden to put a stick in the ground and observe the shadow and its length at different hours of the school day. It's not meant to be a precise measurement but a device to promote discussion among students in order to train them in arguing scientifically. Back in the classroom, the teacher introduces Eratosthenes' idea about the measurement of the Earth's radius, which the students have to reproduce using GeoGebra. The students are asked to do online research and to calculate the difference between Eratosthenes' measurement and the current value. This should encourage a discussion on what Eratosthenes' imprecision was.

This GP was praised for its combination of hands-on experiment with the use of ICT and GeoGebra. A Spanish teacher said that a mix of mathematics and a real experiment got him better results and more motivation of his students. Furthermore he said that this GP also helped him to introduce GeoGebra and ICT to his Maths classes. A Belgian teacher even said: "I persuaded other science colleagues and two students to do this real experiment during their trip to Rome. Students also started to work with GeoGebra to represent this problem. Since this experiment, some students have been viewing mathematics in unconventional ways, generating new ways of thinking, and they are engaged in problem solving, communicating, reasoning and representing these problems using geometric models in real life situations."

4 SPICE Data Analysis

The implementation of the SPICE project produced a large amount of interesting data. In this section we present a summary of the main findings. First we shall briefly describe how we managed the SPICE raw data. Then we shall comment on some results concerning the application of the GPs, comparing the results of test groups of students with control groups of students. In particular, results by subject matter and topic will be analysed, as well as students' learning outcomes, students' opinions on GP-related questions, and country effects in test results. Participant teachers' opinions will also be commented upon. We shall conclude by presenting a number of success stories that derived from the application the GPs according to the teachers.

4.1 Data Treatment

As mentioned in the previous sections, each GP was delivered by a number of teachers in various countries. In order to check for learning gains, the same pre-questionnaires were administered to test (T) and control (C) groups of students before the topic was covered and the same post-questionnaires were administered to T and C groups after the GP topic was covered. The GP was used only for the T groups, while the usual material was used for the C groups.

The project raw data contained students' responses to pre- and post-questionnaires as well as teachers' pre- and post-data. In the data treatment process, data corresponding to either T or C groups are first separated and evaluated for individual teachers, and average values are obtained for each student group. Then we group the T and C average scores for a given GP, both for pre- and post-questionnaires. The opinion questions based on a Likert scale were treated separately.

The many variables in the project can be grouped in four main topics: GP data, pre-/post- data, students' data, and teachers' data. The vast amount of data generated by the SPICE project can be analysed in a multitude of ways and from various perspectives. In the next sections we shall discuss some significant results. In conclusion, and also in relation to the numbers of participating teachers and students described in the following section, we may state the first conclusion of the SPICE project as follows:

conclusion 1: A vast amount of useful data is available.
The SPICE project generated a large amount of data that has been analysed in some aspects in this document, and is useful as a reference and baseline for a number of further studies.

4.2 Participation in the Project

Table 2 shows the overall data concerning teachers and students participating in the SPICE project. Thanks to our very committed SPICE teachers and their good dissemination work, it turned out that finally more teachers and more students tested the GPs and gave responses and feedback to them via questionnaires than we had expected at the beginning. Furthermore this meant that some GPs were tested more than three times as planned from the beginning, as seen in Table 2. This provides us with an exhaustive amount of feedback on the GPs.

spice

conclusion 2: Very positive and extensive response to the SPICE project.
The number of students and teacher groups participating in the project almost doubled the initial expectations.

Table 2: *Teachers and students participating in the SPICE project*

FORMS		Expected	Actual
General questionnaires			
Form 1.1 Students' general pre-questionnaire	1 per student	~ 1200	2010
Form 1.2 Students' general post-questionnaire	1 per student	~ 1200	1871
Specific questionnaires			
Form 3.1 Students' specific pre-questionnaire	1 per student	~ 3600	6030
Form 3.2 Students specific post-questionnaire	1 per student	~ 3600	5613
General questionnaires			
Form 2.1 Teachers' general pre-questionnaire	1 per teacher	24	41
Form 2.2 Teachers' general post-questionnaire	1 per teacher	24	41
Specific questionnaires			
Form 4.1 Teachers' specific pre-questionnaire	1 per teacher, per class	72	153
Form 4.2 Teachers' specific post-questionnaire	1 per teacher, per class	72	128

4.3 Profiles of Teachers

The profile of teachers in relation to their previous experience with Inquiry-Based Science and Maths Education (IBSME) is shown in Figure 1. We see that most teachers had some and even ample experience in the implementation of inquiry-based teaching and learning methods in the classroom. Only two teachers lacked experience.

spice

conclusion 3: Optimum participating teachers' background.
The majority of participating teachers shared a common background in IBSME pedagogies.

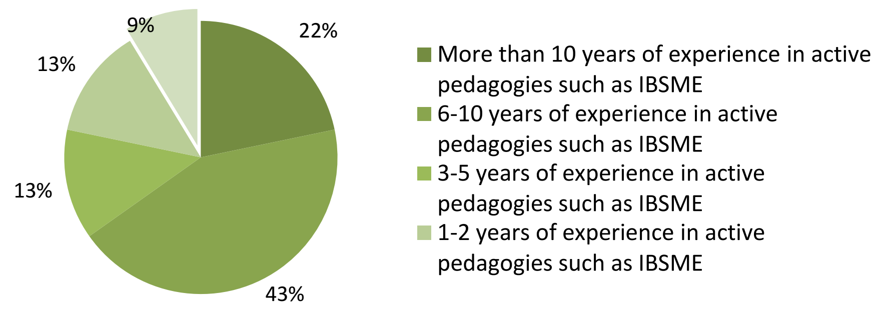

Figure 1: Profile of teachers (from Spice project evaluation questionnaire carried out by Educonsult)

In addition, for all of the teachers the workshops and training mentioned in section 2.3 were quite useful because they served to homogenize the different teachers' backgrounds in the management of the Moodle virtual classroom tool and in the design of GP course materials to be shared among teachers.

Figure 2 shows which learner type the teachers cater for (according to their own opinion). More than 60% of the teachers take into account all kinds of learners, tactile/kinaesthetic, auditory, and visual. We shall discuss these data in connection with students' opinions later on. We shall also see that there is a good match between students learning types and teachers perceptions and methods they use to address those types.

conclusion 4: Teachers aware of students' learning preferences.
The necessity of implementing active learning methodologies is noted by the participating teachers, and the "Auditory learner" type receives the least attention in comparison with tactile/kinaesthetic and visual learners but teachers are also aware they should implement all methodologies to cater for all types of students.

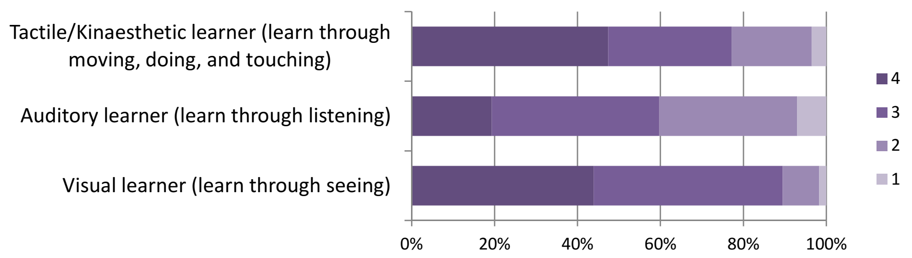

Figure 2: Learner types that teachers cater for, according to the teachers. Likert scale ranges from 4: Strongly considered (darkest) to 1: Not considered (lightest).

4.4 Profiles of students

The number of participating students per country is shown in Figure 3. The majority of countries contributed between 50 and 150 students, with the exception of Portugal and the Czech Republic, the partner countries, which contributed over 300 students each.

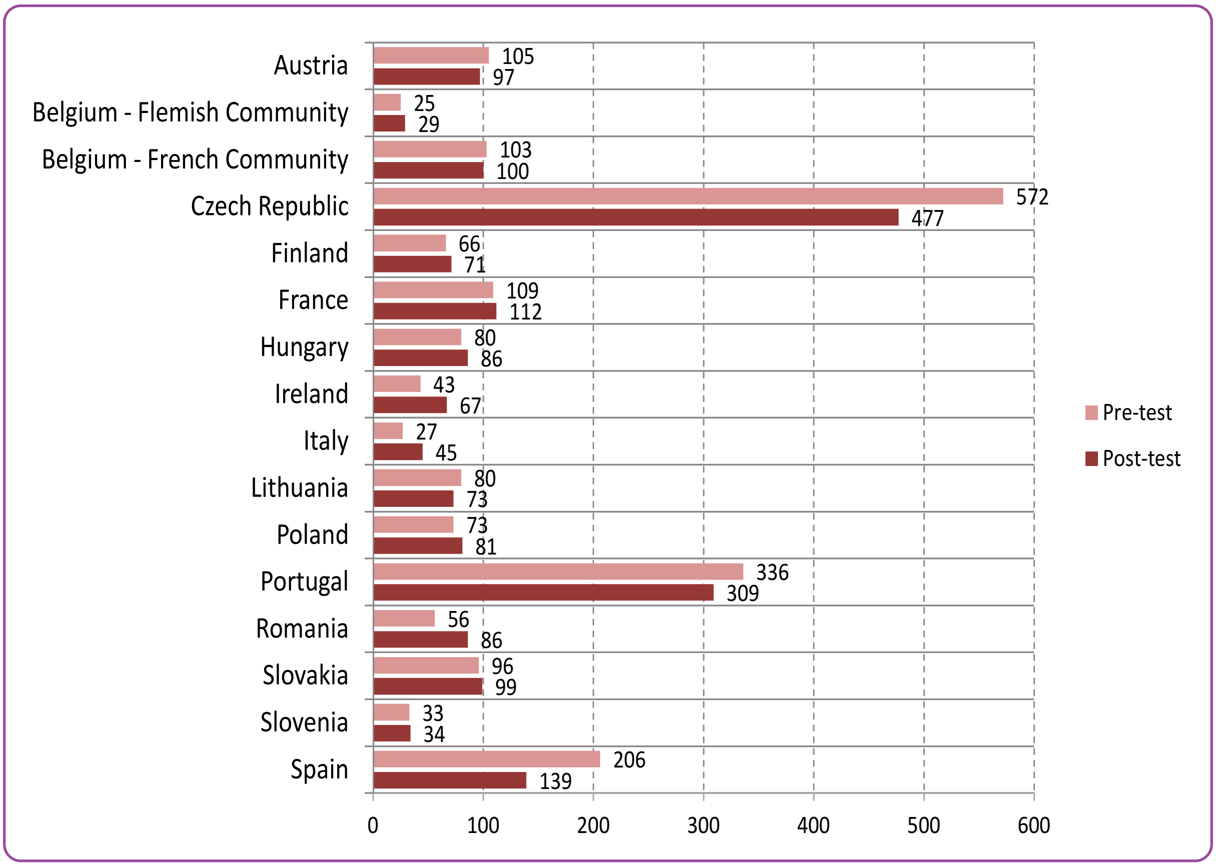

Figure 3: Students per country

conclusion 5: Homogeneous student participation by country.
In the majority of participating countries the order of magnitude of the participating student population is similar (~100).

Figure 4 shows students' responses to a question about their interest in various school subjects. A Likert scale was provided, ranging from 1 (strongly dislike) to 4 (strongly like). As we can see in this graph, the student populations that participated in the SPICE project were not biased.

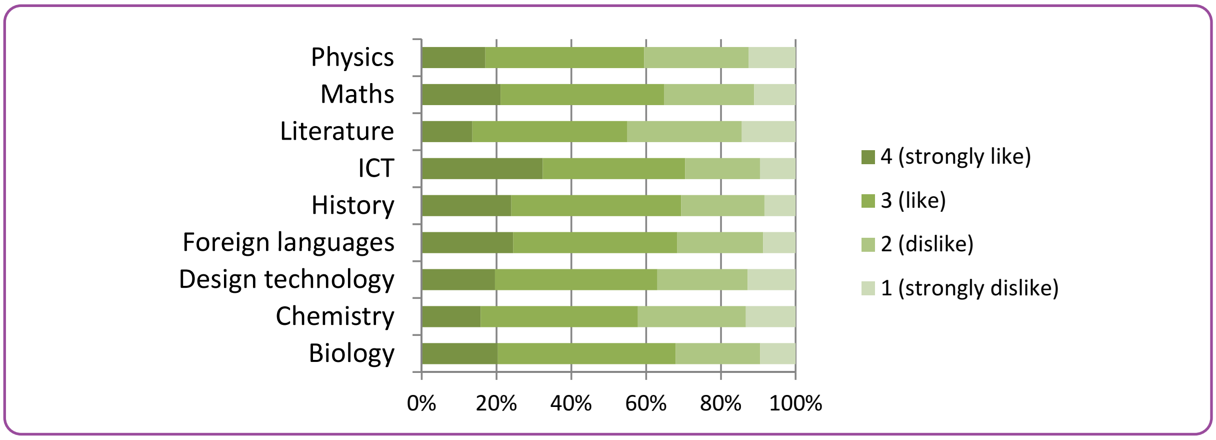

Figure 4: Students' interest in some school subjects.

conclusion 6: Unbiased student population with regard to liking/disliking school subjects.
The largest response is "I like it" in all subject areas considered, including natural science and maths as well as ICT, languages, history, etc.

Information about students' learner types according to the students' own opinion is shown in Figure 5. As we can see, most students consider they have one learning style or two and not all three. Inquiry-based learning caters in part for all of the learner types, and matches perfectly the teachers' responses analysed with regard to Figure 2.

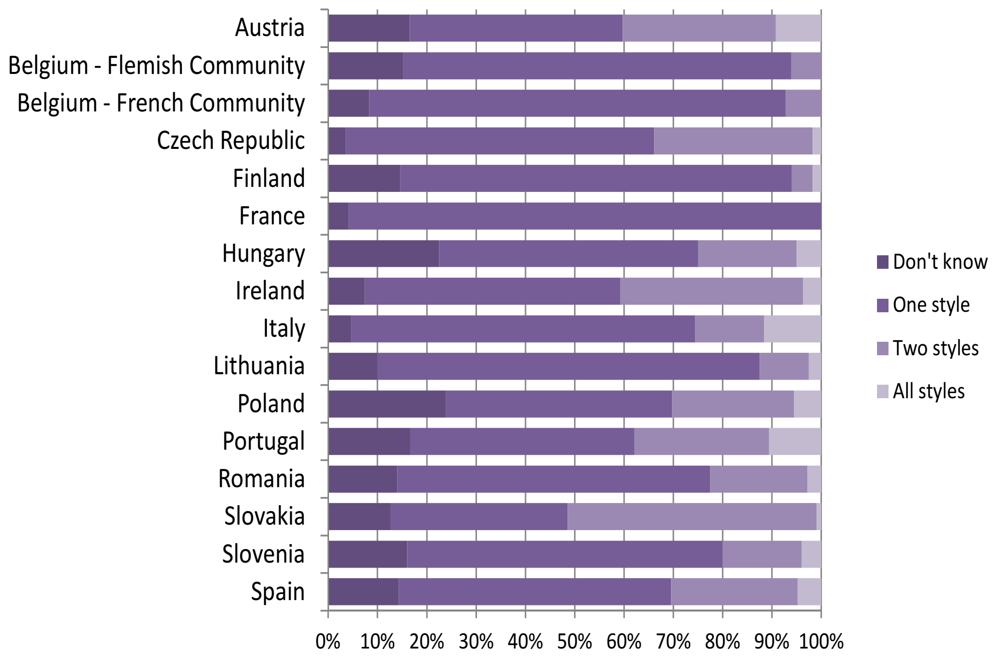

Figure 5: *Students' learner types according to themselves. Styles: either Visual, Auditory or Tactile. Over 90% of the students do not think they fit all three learning types.*

conclusion 7: All kinds of learner types are present in the student population.
Depending on the student sample, the self-defined type of learning is quite diverse, as one expects in a typical classroom. To make sure all students learn, it is important for teachers to cater for all learning styles within a lesson.

4.5 Results by Subject Matter

In Figures 6a and 6b we have the average percentage of correct answers to the pre and post questionnaires for all the GPs, separated by subject, which allow us to see whether the GP materials developed and implemented in T-groups had an influence on students' learning and attitude towards the subject matter.

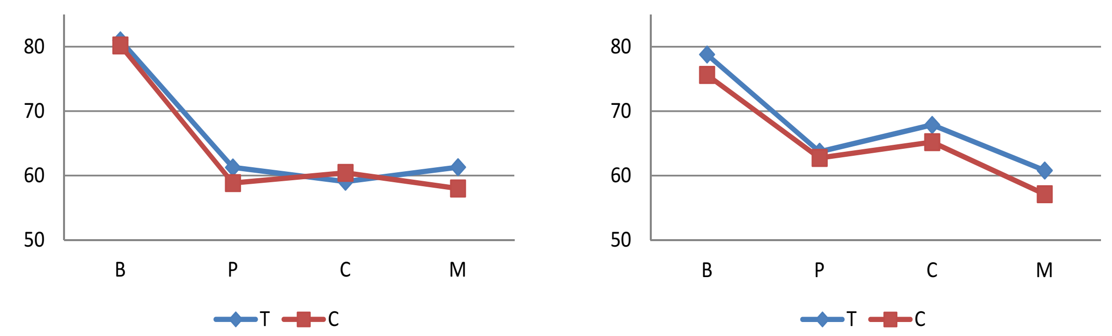

Figure 6: *Percentage of correct answers in **a)** pre- and **b)** post- questionnaires, for "T" (test groups) and "C" (control groups) of students, and grouped by subject. "B": Biology and Natural Science. "P": Physics. "C": Chemistry. "M": Mathematics.*

"Pre-" and "post-" tests were administered to T and C students, before and after implementing the corresponding GP only with T students. As expected for a random choice of T and C groups of similar students (as regards age, conditions, etc) to participate in the SPICE project, we can see in Figure 6a that pre-questionnaires completed by both T and C groups of students show minor differences in the results; the tests' results are slightly higher for T students in Physics and Mathematics, whereas they are slightly higher for C students in Chemistry, and roughly equal for Biology. So we may say that:

conclusion 8: Similar starting point for T & C groups ensures project validity.
T and C groups fulfil the necessary randomness with similarity requirement for initial project conditions.

Once the GP has been implemented the differences in T post-test results are, on average, noticeably in favour of the T groups of students for all subjects, Figure 6b. In fact, when one looks into the data corresponding to individual GP implementations, in 80% of the cases T scores are higher than C scores. So we may state another conclusion of the SPICE project:

conclusion 9: GP implementation gives better test outcomes for T students.
On average, T groups obtain better post-test results than C students in all subjects, thus backing the main assumption in the SPICE project.

The minor differences for Physics in post-tests are due to the averaging of data. The average values shown in Figure 6 tend to obscure the existence of significant differences in many GP projects in favour of T students, as Figure 7 shows. When the post-test results for individual GPs are compared (Figure 7) we see that there is a larger homogeneity in the results for Biology/Natural Sciences than for the other subjects, in that there are always gains for T-students in the corresponding GP. Also, absolute scores in Biology tend to be higher than the scores in other subjects, a well known result reported in the education research literature (Strenta and Elliott, 1987). Relatively lower scores occur in Maths. The Physics results show more fluctuations, with even one case in which C students fared much better than T students.

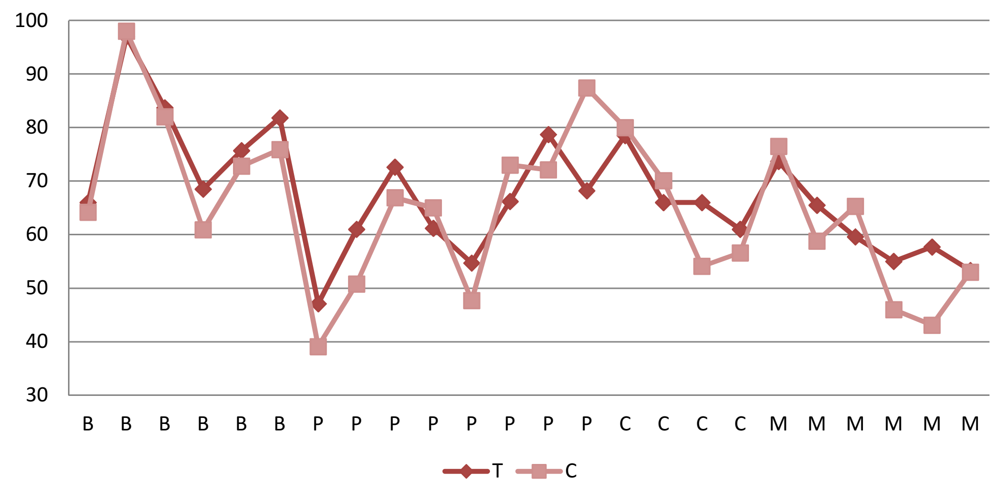

Figure 7: *Percentage average scores for post-tests for individual GP projects, grouped by subject. "T": test groups of students, "C": control groups of students. "B": Biology and Natural Science. "P": Physics. "C": Chemistry. "M": Mathematics.*

As stated in conclusion 1, several interesting aspects of the data in Figure 7 could also be analysed further, but with the present analysis we may already state another obvious conclusion from the data:

spice

conclusion 10: Positive effects of individual GPs on T student groups.
In most GPs, T groups obtain better post-test results than C students.

Of course this conclusion should not be taken in absolute terms as there are a large number of variables that could influence the results, such as the fact that for some GPs a different teacher taught the C and T groups.

4.6 Assessment of Students' Learning Gains – Case Study

The normalized gain "g" (Hake, 1998) is a measure of students' learning in the implementation of a teaching proposal. It is defined as the ratio of the actual average gain between pre and post tests to the maximum possible average gain:

$$g = \frac{< post\ test(\%) > - < pre\ test(\%) >}{100 - < pre\ test(\%) >}$$

We take as an example the GP Digital Mapping Study of a School Environment where the post questionnaire contains all the pre-questionnaire questions (plus a few extra questions). The results for the gain factor for the common part of the tests are shown in Figure 8 for both T & C groups. The results for T groups are also shown as a reference.

We see a gain factor 1.0 for the T group in question 2 (Q2), a result that one obtains when the post test is 100% correct. Negative gains in C & T groups are present in several questions (that is, students fared worse in the post-test). The average T gain with all 11 questions considered is 16% and 9% for C. So, although the data show that there is room for improvement, we reach the following conclusion:

spice

conclusion 11: Individual test questions show larger learning gains for T students.
When detailed results of GP post-test implementation are analysed, T students show overall larger learning gains than C students.

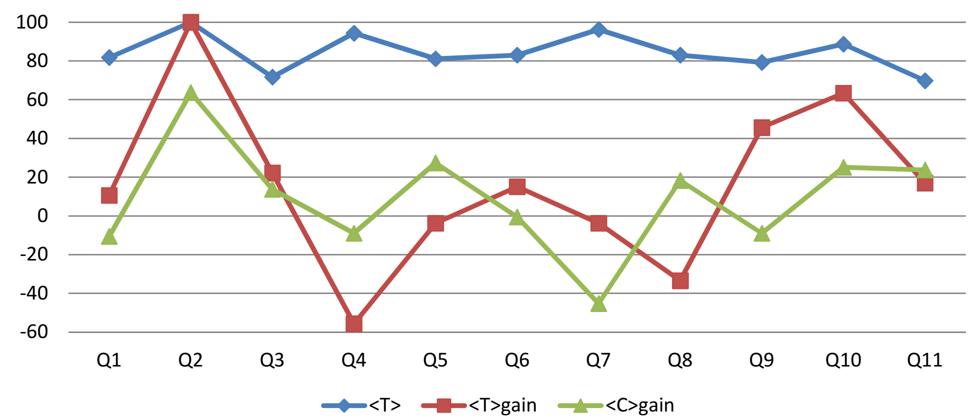

Figure 8: *Hake's gain factor analysis of post- and pre-test application for the GP Digital Mapping Study of a School Environment. The gain for each question in the test and for T & C groups is calculated. The scores of the post test for T students are also shown as a reference.*

4.7 Influence of the Subject Topic

Now we shall discuss the topic of the specific GPs in some detail, specifically for those cases where major relative effects of GP implementation have been observed, namely, in some Physics GPs. We see in Table 3 the average results of the pre- and post-questionnaires for both T and C groups and a few remarks on each project. Since the contents of the post- and pre-tests are different, it is difficult to compare absolute figures of correct responses in the pre- and post-tests for the same groups of students. However, T students' results can be compared with C students' results when only looking at pre- or post-questionnaires separately. The comments in Table 3 demonstrate that detailed analyses are possible for particular sets of data. For instance, it is well documented in the physics research literature that mechanics concepts are difficult (Savinainen & Scott, 2002) and that the study of light and optics presents many difficulties to students (Colin, Chauvet & Viennot, 2002). This may be the reason for the decrease in both T and C scores in the first GP in Table 3, dealing with the position of the image. So, we may state that:

spice

conclusion 12: Interesting topic data effects are observed, with T students faring better.
With T students faring better than C students in post-tests even in difficult subjects like Physics, SPICE data show intriguing additional results which deserve further analysis.

__Table 3:__ Trends and interesting results observed in the average scores for pre- and post-tests in T and C classes. GP project numbers are I: Position of image. II: Magnetic properties. III: Diffusion. IV: Astronomy.

GP	<T> %	<C> %	Comments
I-pre	52.5	46.6	T groups fare better than C groups in the pre-test (by 13%) and in the post-test (by 21%). The grades in both groups decrease slightly in the post test. The reason may lie in the difficulty of the topic (Optics), as commented upon in the text above.
I-post	47.1	39.1	
II-pre	49.1	44.0	The percentage improvement in T versus C groups is similar to that in GP-I, especially in post-tests (20% better results for T). This proves again the value of the GP materials.
II-post	61.0	50.8	
III-pre	66.5	81.8	This GP provides an interesting example: the C group fared initially better than the T group of students (a 23% difference in the pre-test), but the situation is reversed (T students perform better by 9%) after GP implementation.
III-post	72.6	66.9	
IV-pre	37.8	39.4	Here, the pre-test differences are small (4% in favour of C) but become larger in the post test (28% larger in C). Although T students fare much better in the post-test than in the pre-test, it would be interesting to analyse the underlying reasons (like test contents, for instance).
IV-post	68.2	87.4	

4.8 Opinion Questions

Some GP questionnaires included questions demanding a response on a Likert scale ranging from 1 (totally disagree) to 4 (totally agree). As Table 4 shows, the average numbers in the responses are generally larger for the T classes. This shows an effect of GPs for T classes.

In GP-II the C result is higher (3.4) than the T result (3.1); but when one takes into account the large difference in the pre-test (not shown in Table 4), with a T-student average of 3.2 and much smaller C-student average of 2.6 in response to the statement "I usually print my school materials" one sees that T students did much better than C students initially, so the larger post-test result just shows a larger relative improvement in C students' attitudes.

In the post-test of GP-III the averages coincide, as expected, since the question concerns eating habits. In the Maths GP-IV and V, though, the T students have relatively larger increases over C students. We may then conclude that:

conclusion 13: Measurable larger attitude-related changes due to GP can be traced and are larger for T students.
Likert-type questions are a good measure of students' attitude changes, and GP implementation shows larger effects in T students.

Table 4: Average responses to opinion questions in post-tests for T and C students, with a four-point Likert scale: 1 (totally disagree) to 4 (totally agree). The GP projects are: I-Comparing leaves. II-Energy consumption - What can we do? III-Biocatalyzers. IV-Maths show. V- Triangle construction with GeoGebra.

GP	$\langle Q \rangle_T$	$\langle Q \rangle_C$	Question
I	4.0	3.9	Do you think that the presence of trees is important for humankind?
II	3.1	3.4	If we take some simple actions we will reduce the amount of energy consumption.
III	3.4	3.4	How often do you eat fresh fruit and vegetables per week?
IV	3.3	3.7	Is it important to use a precise vocabulary in geometry?
V	3.1	2.6	I like to construct geometric figures.
	2.8	2.2	It was helpful for me to construct triangles with GeoGebra.

4.9 Country Differences

In the application of a given GP, various countries with different school cultures are involved. For example, in GP Human Body a larger than usual number of C and T groups participated. The countries (and the 7 teachers) involved were Portugal (1), Czech Republic (2), Lithuania (2) and Austria (2). The overall results (without separating the contributions by country) for this GP are shown in Figure 9a for each question. In Figure 9b we also show the results for the GP Comparing Leaves, tested by a teacher in each of the following countries: Portugal, Slovenia, Austria and Czech Republic.

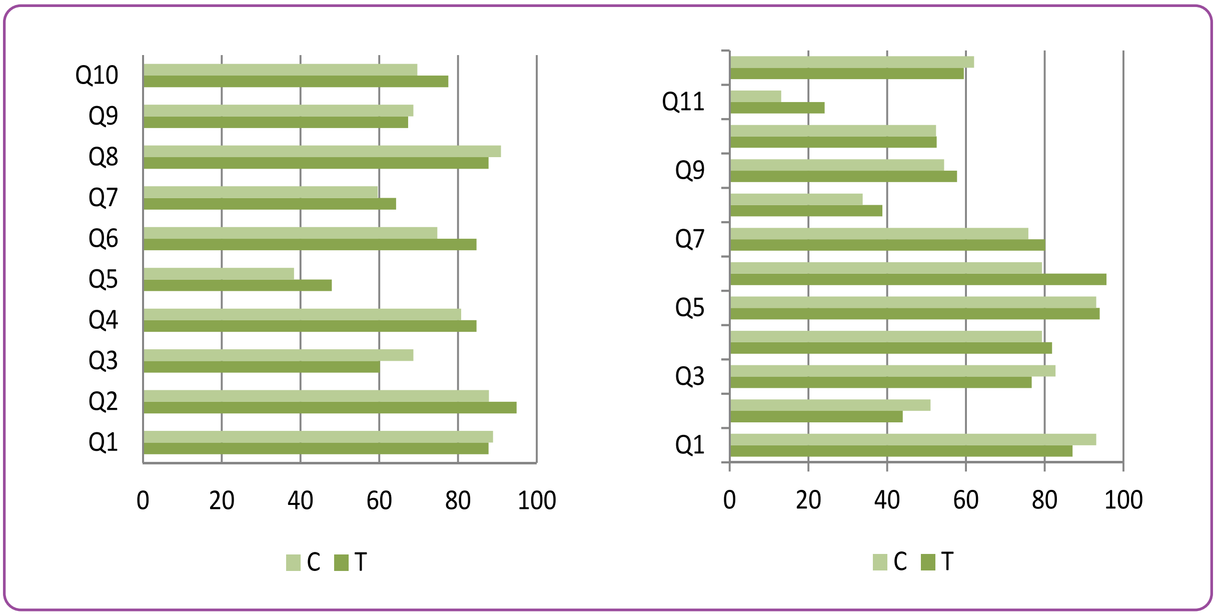

*Figure 9: Average percentage of correct answers to each question for the post-test results for **a)** 10 questions in GP Human Body, **b)** 12 questions in GP Comparing Leaves, for T and C students*

We show in Figures 10a and 10b the detailed results for each country, only for T-students. Large fluctuations occur for some countries for a given question, which are evened out in the global averages of Figures 9a and 9b. Also, the pre-test data (not shown) indicated that some countries performed completely differently in the pre- and post- tests. The reasons for the countries' differences (e.g. between the very positive results in Austria and Lithuania, compared with Portugal and the Czech Republic) would require the compilation of further data. Therefore SPICE data provide a starting point for country analysis that should be completed with further studies. So, we may state that:

conclusion 14: Deep analysis (by country, by class) initiated by SPICE data.
Initial country and class by class studies are possible with the SPICE data, which show scope for improving the teaching and learning proposals.

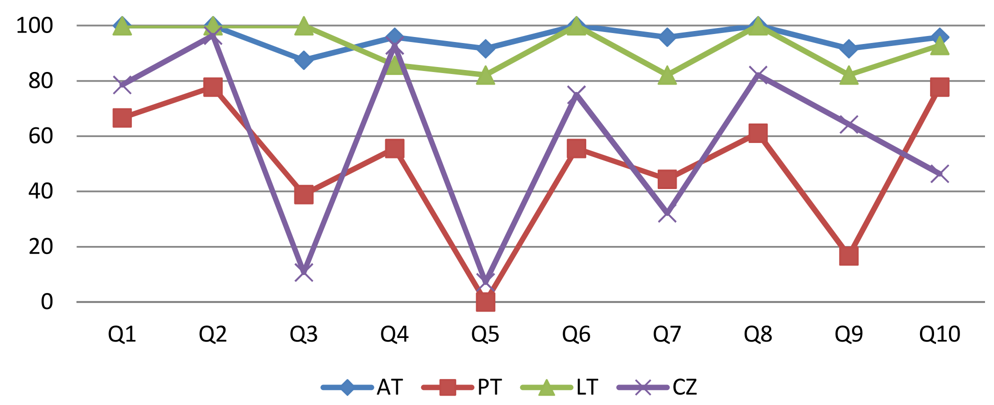

Figure 10a: *Average post-test percentage correct answers results for each question in GP Human Body separated by country. Only the results for T students are shown. When the data are weighted by the number of students, the average values for all countries' data are T: 75.7 and C: 72.8.*

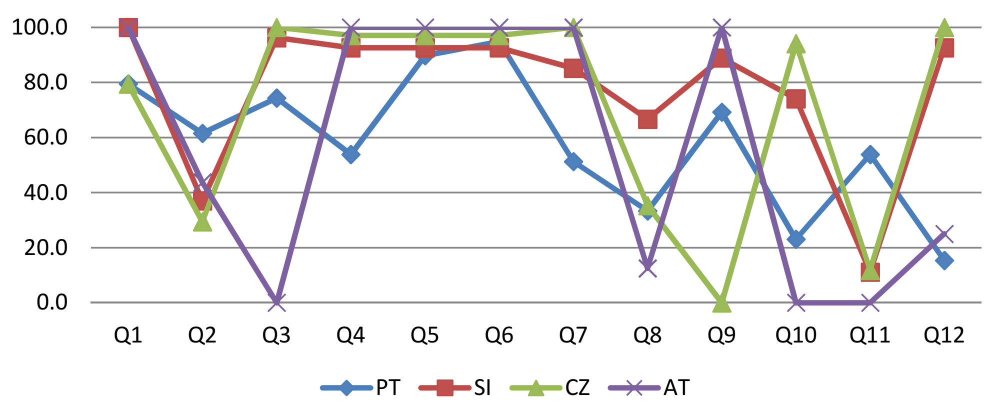

Figure 10b: *Average post-test percentage correct answers results for each question in GP Comparing Leaves separated by country. Only the results for T students are shown. When the data are weighted by the number of students, the average values for all countries' data are T: 66.0 and C: 64.2.*

4.10 Teachers' Overall Reflections

Teachers' pre- and post- GP implementation data reflect various interesting facts: students work in groups in at least half of the cases, as well as with computers during the lessons. The interactive whiteboard is used by few teachers and, in general, teachers always seek connections of the corresponding topic with real-life problems. The number of lessons usually devoted to the GP is quite diverse, from 1 to 5 or more, depending on the teacher, and the number of lessons suggested in the GP was not always sufficient. Some minor adjustments are required for GP implementation in specific schools.

On the other hand, the percentage of teachers or groups that use the methodology of presenting the topic (i.e., a traditional transmission discourse) is similar for T and C teachers. Furthermore, teachers mentioned that while investigation is the key, e.g. discovering something special in simple things from ordinary life, motivation is also important and SPICE to that effect contributes by providing hands-on experiments, by students making presentations, by use of computers in Physics class, talking about the observation, and working in teams. All these are valuable social and intellectual skills.

We show in Table 5 some specific figures related to the facts mentioned above.

Table 5: *Percentage of teachers' positive responses to post- questionnaires.*

Question	Yes (%)
Did you describe the topic and its issues to the students?	52
Did the students have to find out about the topic by autonomous research?	55
Did the students have to work in groups?	85
Did the students have to give presentations at the end of the topic?	57
Did you ask the students to work with computers during the lessons? (e.g., using simulations)	56
Do you use the interactive whiteboard to implement this GP?	18
Were the students motivated?	95
Did you try to teach the students the connections between real life and this topic?	96

Very interesting data contributed by the teachers refer to students' motivation and interest in GP implementation, as well as skills development. Table 6 contains a few sample teachers' remarks.

__Table 6:__ Teachers' observations about students' interest in GP and the development of students' skills.

Why are students motivated or like some specific GP

- All my students were motivated because the issues presented are interesting, well presented and useful for learning science in school
- Astronomy – interesting topic for the students, and work with interesting software (Stellarium)
- Triangle construction with GeoGebra, because it was targeted work but with room for creativity and decision by the students.
- Diffusion, because they were happy to create little films, record their hands-on experiments with their own camera, and finally they made a PowerPoint presentation which was shown to all classmates.
- Earth's radius. Combines real experimentation with ICT.
- Electric motor – real experiment. They created their own equipment.
- Energy consumption – they feel that is something that they can do and that produce results.
- Extracting DNA. The students were excited to see the substance that makes them unique.
- Golden coins because they were astonished to see the coin transformed into silver and then into gold.
- Hands-on experiment and the use of ICT made the Physics classes more attractive
- My students were motivated because they had to build up real experiments, and had to create little films and presentations about their observation. They worked in teams, and also learned how to communicate amongst each other about a common topic.
- Non-traditional approach in teaching and learning.
- Students like outdoor activities'. Many different tasks and concrete results out of the school and home surroundings.

The teachers' pre- and post-questionnaires provide a large amount of additional data that we do not have the space to discuss here. If interested, all the information can be found in the project deliverables available via http://spice.eun.org, which may serve as a reference for further analysis and comparisons. The overall conclusion from the previous data on teachers' contributions is, then, the following:

conclusion 15: Teachers and students feel the value of the GPs.
Teachers' opinions reflect the fact that teachers participating in an EU project like SPICE share similar starting-point characteristics in terms of motivation, ability to communicate with peers, desire to innovate, etc. And students receive the teaching proposals with enthusiasm for various reasons (innovation, hands-on, motivational, real-world problems, ICT tools, active work).

4.11 Overall Lessons Learned by the Teachers

The experience of working together in this project was very motivating, interesting and fruitful for all the involved parties, but especially for the teachers, who could implement lessons of their European colleagues and thus exchange teaching experience and knowledge.

A point that many teachers mentioned that increased the students' motivation was the fact that students generally enjoy doing experiments where they produce something themselves that is functional, that they can take home to demonstrate to their families and friends, or that they can repeat at home. They also noticed that students will learn more if they can see that the knowledge is relevant to their everyday life. The Italian teacher said in this respect: "I think its success depends on making students reflect on very ordinary objects and find out laws of nature: it's good to see surprise or even astonishment on their faces when they look at common objects as if they were seeing them for the very first time" (Maria Guida, Italy).

conclusion 16: Very positive outcomes in subject learning and skills development in T students.
Teachers' contributions show that both formal and informal contributions and opinions extracted from participating students are very positive in terms of attitudes, perceived learning and general and basic skills development (team work, arguing in scientific terms, collecting data and preparing presentations for the class, etc.).

Furthermore, the fact that the students practise scientific ways of working combined with fun exercises increases the potential learning capacity of the students and is the best way for them to remember the topics. A Portuguese teacher said that "after some experiments, when the students felt that they were doing the activities by themselves they started feeling confident and engaged. That means that questions and curiosity come to the class. That was the great moment for me, [when] they started to ask questions, which means that they were thinking about the work we had been doing."

Some teachers mentioned that thanks to their experience with the GPs they changed some important aspects in their way of teaching: they have introduced more Inquiry-based learning processes in their daily work. The Spanish teacher Daniel Aguirre said "the GPs were not only useful to improve my science teaching methods, but also to introduce communication and reflection tasks with my students". Other teachers mentioned that they discovered cross-curricular working together with some of their colleagues, and as this was a great success, they will continue teaching some topics together.

The whole process from learning the method used in the GPs to teaching it and then reflecting on it, has brought the following conclusions from the teachers, as the Spanish teacher sums up nicely:

"I have learnt from colleagues from many other different countries and from very different styles of teaching. Last year I followed the instructions very carefully, but now I have the knowledge to adapt the GPs according to my needs and my students. And now, I can apply my new point of view on teaching to other activities and units. In fact, in this school year, I'm practising new methods in other topics. And I'm trying to involve more colleagues in my immediate environment to improve science education. This year, if I use the GPs, I will be careful to apply the main qualities of an inquiry process: Pose questions more than give answers, try to enhance the reflection of my students, provide them with a good scaffolding, prepare better worksheets for the students, look for a balance between lab and computer simulations" (Daniel Aguirre, Spain).

Every teacher drew somewhat similar conclusions for themselves. One of the Czech teachers said as a conclusion to this project: "I'm glad that I could try three kinds of lessons – the computer lesson, the presentation lesson and the building lesson.

Each way has its own beauty. The reactions of my pupils showed me that the best way is to mix all the different kinds of lessons and methods" (Vaclav Piskac, Czech Republic). The same teacher noticed that when he asked the students to work too much on the computer, their motivation sank. He asked them why and was surprised to hear that they do not like to work with computers all the time. The students said that they are "tired of computers", as they already use them at home a lot for doing their homework and for some entertainment. Therefore, they prefer to have some variation at school.

An important point that was noted by the teachers was that the students seemed to learn more when they communicate their ideas and produce arguments and reasoning to each other. Therefore, discussions and group work are enriching and crucial to foster the students' learning process.

Finally, the teachers show a high interest in continuing the use of the GPs, as Figure 11 shows: almost 60% of the teachers are certain they will continue using the GPs in the future.

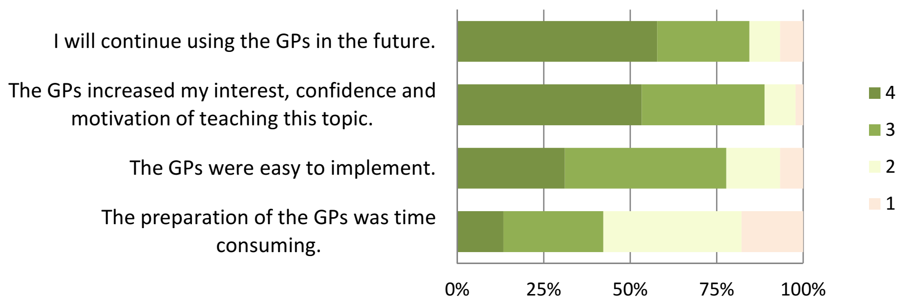

Figure 11: Characteristics and interest of GP according to the teachers. The Likert scale ranges from 1: Not at all, to 4: Certainly.

conclusion 17: High teacher satisfaction with the GPs and desire to keep using them.
The majority of teachers expressed satisfaction with the overall development of the project and showed a big interest in continuing using and improving the GPs materials in the future.

5 Conclusions

In spite of the limitations of the project in terms of size, with only around 40 teachers and 2000 students taking part, the efforts of these teachers and the appropriate settings put in place have shown the outstanding results that can be achieved when the teachers are involved in all steps of a project (creating questionnaires, selecting the practices, contributing to the good practice criteria, being free to adapt the practices to their styles and cultural situations, etc).

Concretely, if one looks at the hypotheses of this project which were given in section 1 and are reproduced here for convenience and from the main conclusions which have been derived from the SPICE project and which have been commented upon in the course of the text (collected in Table 7), highlighting the relevance of each conclusion in connection with the corresponding project hypotheses, we can see that all the hypotheses have been confirmed in varying degrees.

H1. The design of the SPICE project is technically sound and will provide valuable data.

H2. The students who are taught with the new methodologies and tools that are used in the GP will understand, integrate and remember the topic better.

H3. The GPs are effective for the teachers: not too time consuming in the preparation; not too time consuming in teaching; motivating; adaptable for other topics.

H4. The GPs are effective for the students: they enjoy the topic, they understand it better, they see the relation to real life, they can use it in their everyday life, they can improve a variety of skills (communication skills, working autonomously, research skills, etc.).

H5. The project will provide data to support the criteria for GP in Europe that enable teachers to teach their subjects using innovative teaching methods within the concept of inquiry-based learning.

Table 7: SPICE project conclusions in relation to the project hypotheses.

Conclusion, related mainly with hypotheses...	H1	H2	H3	H4	H5
1: A vast amount of useful data is available.	X				
2: Very positive and extensive response to the SPICE project.	X	X	X		X
3: Optimum participating teachers' background.	X		X		
4: Teachers aware of students' learning preferences.	X				
5: Homogeneous student participation by country.	X				
6: Unbiased student population with regard to liking/disliking school subjects.	X				
7: All kinds of learner types are present in the student population.	X				
8: Similar starting point for T & C groups ensures project validity.	X				
9: GP implementation gives better test outcomes for T students.		X		X	
10: Positive effects of individual GPs on T student groups.		X		X	
11: Individual test questions show larger learning gains in T students.		X		X	
12: Interesting topic data effects are observed, with T students faring better.				X	X
13: Measurable attitude-related positive changes due to GP can be traced and are larger for T students.		X		X	X
14: Deep analysis (by country, by class) initiated by SPICE data.	X				X
15: Teachers and students feel the value of the GPs.			X	X	
16: Very positive outcomes in subject learning and skills development in T students.				X	
17: High teacher satisfaction with the GPs and desire to keep using them.			X		X

These facts will lead to improvements in the teaching and learning GP proposals. We may also mention that although IBSME short term effects are not always significant, the data which are now available are an excellent database and starting point for further projects. In particular, collaboration and exchange between teachers lead to positive effects in terms of innovation in methodologies and in the development of curricular materials.

The importance of assessment methods in IBSME should be stressed. In particular, the assessment and evaluation stages of project development are closely related to the design of teaching materials and questionnaires. For instance, one should take into account the so-called Hawthorne effect, whereby subjects improve or modify an aspect of their behaviour being experimentally measured simply in response to the fact that they know they are being studied, not in response to any particular experimental manipulation (Hawthorne, 2011), especially in those cases in the SPICE project where the same teacher was involved with the classes belonging to the test and control groups. However, quantification of this effect is a difficult task and should be investigated in detail.

As mentioned in the introduction, the SPICE project has generated an enormous amount of diverse data, which may be used for a number of partial and comparative analyses. Also, the data can serve as a reference for future studies with similar objectives, where the establishment of timelines is a necessary condition (PISA, 2011).

The SPICE project has been a successful example of how teachers from across Europe can work together and learn from one another. Students' attitudes towards science are often still rather negative as they see science subjects as boring or dry; however, these GPs based on Inquiry-based learning are meant to excite the students' interest in various scientific subjects, to allow them to see the relation between science and real life and to investigate and research the topics themselves. These GPs, which were created by the SPICE teachers, represent a big step in the right direction, but of course students' attitudes will not change from one day to another, but rather in a long-term process. Therefore, it is important that teachers keep encouraging students by offering them interesting, innovative and motivating lessons. However, it is not necessary or productive for teachers to have to re-invent the wheel over and over again. The value of projects like SPICE is clear in this regard, as they allow teachers to collaborate and grow together.

Malgorzata Zajaczkowska, the Polish teacher, said that for her the importance of this project could be seen in the fact that "all students need creative materials that engage their interest and improve their abilities, but nowadays, teaching science is still done in most cases like a process of pouring information into the heads of the students and waiting for them to integrate this information on their own. Unattractive and overloaded school curricula provide only a superficial approach to science and scientific methods." Therefore, when she participated in this project and chose her GPs, she "knew that she had found useful authentic material that would challenge not only the students' understanding but also their ability to reason and make associations".

The Spanish teacher, Daniel Aguirre, mentioned that since his participation in SPICE he feels "more confident to apply innovative practices with [his] students". Teachers should not be afraid to try out new methods, as this will allow them to grow in their teaching abilities, but it will also keep the students more interested, as they are offered some variation. According to a Portuguese teacher, since the SPICE project "some innovation has been introduced into our 'traditional' way of teaching at school" (Carlos Cunha, Portugal). Other teachers from the school were interested in adopting certain GPs. Maria Guida, the Italian teacher, noticed "a certain interest and curiosity in several colleagues looking with smiles on their faces at our experiments and I hope to involve them in further projects for the renewal of science education." She also said that "many parents expressed their appreciation during teacher-parent meetings." These results show that the teachers involved in projects will act as multipliers of the lessons learnt and will continue working beyond the duration of the project, proving the sustainability of the exercise.

All of this positive feedback confirms the need for collaborative projects, as they not only allow teachers to learn from each other's experience, but are also an important opportunity for professional development because they make teachers reflect on their own way of teaching and evaluating.

References

Bybee, R. W. et al. (1989). Science and technology education for the elementary years: Frameworks for curriculum and instruction. Washington, D.C.: The National Center for Improving Instruction. Adaptation available at *http://faculty.mwsu.edu/west/maryann.coe/coe/inquire/inquiry.htm* [Accessed: 10 November 2011].

Chickering, A. W. & Gamson, Z. F. (1987). Seven Principles for Good Practice in Undergraduate Education. AAHE Bulletin, Vol. 39 (7) 3-7. Available at *http://crunchie.tedi.uq.edu.au:200/blendedlearning/pdfs/fall1987.pdf* [Accessed: 15 November 2011].

Colin, P., Chauvet, F. and Viennot, L. (2002). Reading Images in Optics: Students' Difficulties and Teachers' Views. International Journal of Science Education, Vol. 24, Number 3, pp. 313-32.

Duit, R. (2009). Students' and Teachers' Conceptions and Science Education, Bibliography – STCSE. *http://www.ipn.uni-kiel.de/aktuell/stcse/fv09.rtf* [Accessed: 18 November 2011].

Engelhardt, Paula (2009). An Introduction to Classical Test Theory as Applied to Conceptual Multiple-choice Tests. Reviews in PER: Volume 2, Issue 1.Getting Started in PER. Online: *http://www.compadre.org/PER/items/detail.cfm?ID=8807* [Accessed: 1 August 2011].

Ericksen, S. (1984). The Essence of Good Teaching. San Francisco: Jossey-Bass. Available at *http://adminblogs.shc.edu/facdev/Files/IssuesTeach%20Links/ActiveLearningintheClassroom.pdf* [Accessed: 19 October 2010].

Gras-Velázquez À., Joyce, A. & Debry, M. (2009). Women in ICT, Why are girls still not attracted to ICT studies and careers? Cisco White paper (online). Available at *http://eun.org/whitepaper* [Accessed: 17 November 2011].

Hake, R.R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. American Journal of Physics, Vol. 66, No. 1, pp.65-74.

Hawthorne (2011). Hawthorne effect, see for example *http://en.wikipedia.org/wiki/Hawthorne_effect* [Accessed: 3 November 2011].

Kearney, C., (2010, 2011). "Efforts to Increase Students' Interest in Pursuing Mathematics, Science and Technology Studies and Careers.pdf", ed. Wastiau, P., Gras-Velázquez, A., Paiva, A., and Grečnerová B., November 2010 and November 2011 Available from *http://spice.eun.org/web/spice/publications*

PISA (2011). Programme for International Student Assessment, *http://en.wikipedia.org/wiki/Programme_for_International_Student_Assessment* [Accessed: 25 November 2011].

Savinainen, A. and Scott, P. (2002). The Force Concept Inventory: a tool for monitoring student learning. Physics Education, Vol. 37 Number 1, pp.45-63.

Strenta, A. C. and Elliott, R. (1987). Differential Grading Standards Revisited. Journal of Educational Measurement, Vol. 24, Issue 4, pp. 281–291.

INSIGHT
observatory for new technologies and education

http://insight.eun.org
http://spice.eun.org

Education and Training

This report has been funded with support from the European Commission. This document 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.

Education and Culture DG
Lifelong Learning Programme