Photonics Explorer: Revolutionizing Photonics in the Classroom

Amrita Prasad[a], Nathalie Debaes[a], Nina Cords[b], Robert Fischer[a,c], Johan Vlekken[a], Manfred Euler[b], Hugo Thienpont[a]

[a] Vrije Universiteit Brussel, Pleinlaan 2, 1050 Brussels, Belgium; [b] Leibniz Institute for Science and Mathematics Education (IPN), University of Kiel, Olshausenstraße 62, 24118 Kiel, Germany; [c] Universidade Federal de Alagoas, Maceió, AL Brazil

ABSTRACT

The 'Photonics Explorer' is a unique intra-curricular optics kit designed to engage, excite and educate secondary school students about the fascination of working with light – hands-on, in their own classrooms. Developed with a pan European collaboration of experts, the kit equips teachers with class sets of experimental material provided within a supporting didactic framework, distributed in conjunction with teacher training courses. The material has been specifically designed to integrate into European science curricula. Each kit contains robust and versatile components sufficient for a class of 25-30 students to work in groups of 2-3. The didactic content is based on guided inquiry-based learning (IBL) techniques with a strong emphasis on hands-on experiments, team work and relating abstract concepts to real world applications. The content has been developed in conjunction with over 30 teachers and experts in pedagogy to ensure high quality and ease of integration. It is currently available in 7 European languages. The Photonics Explorer allows students not only to hone their essential scientific skills but also to really work as scientists and engineers in the classroom. Thus, it aims to encourage more young people to pursue scientific careers and avert the imminent lack of scientific workforce in Europe. 50 Photonics Explorer kits have been successfully tested in 7 European countries with over 1500 secondary school students. The positive impact of the kit in the classroom has been qualitatively and quantitatively evaluated. A non-profit organisation, EYESTvzw [Excite Youth for Engineering Science and Technology], is responsible for the large scale distribution of the Photonics Explorer.

Keywords: K12, education, intra-curricular, kit, hands-on, photonics

1. INTRODUCTION

Innovation, scientific excellence and future sustainability rely on motivated and skilled scientists and engineers. However, there is an alarming decline of interest towards science prevalent amongst young people. It is said that based on the complexity of social, political and technological environment many people have increasing troubles in understanding their surrounding world[1]. This trend could soon result in a lack of skilled workforce for high-tech industries worldwide and become the primary limiting factor in the rapidly growing field of photonics, like all other scientific sectors. To avert this trend and encourage more young people to experience the fascination of science, the European Commission funded the 'EXPEKT' project in 2010, which resulted in the development of the 'Photonics Explorer' – a novel, intra-curricular, educational kit designed to *engage, excite and educate* students about the fascination of working with light and optics hands-on, within the classroom.

2. CONTENT DEVELOPMENT

Conventional outreach kits often rely on demonstration activities and use interesting visual effects to entertain students. They are driven by motivated and enthusiastic scientists and, as such, have local and rather limited impact. While such activities succeed in momentarily raising the interest and curiosity of students, they seldom influence their future career choices or image of science as a whole. Therefore it is important that, complementary to such activities, students experience the fun and fascination of scientific discovery on a daily basis – with their own hands, in their own classrooms.

The Photonics Explorer is an intra-curricular kit which has been specifically designed to integrate seamlessly into European secondary school science curricula and enhance and complement the teaching and learning of photonics within

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the classroom. The kit has been specifically designed to complement existing European secondary school science curricula and therefore support teachers while engaging students. Each kit contains a class set of experimental components provided within a supporting didactic framework based on guided Inquiry-Based Learning (IBL) techniques. The modules are designed for lower and upper secondary students. The kit is a result of a pan-European collaboration of teachers, experts in pedagogy, scientists at universities as well as European industry and extended photonics community.

2.1 Experimental Components and Didactic Framework

Each kit consists of a class set of experimental components, sufficient for a class of 25-30 students to work in groups of 2-3. The components have been specifically designed to be safely used by students within the classroom. The components are robust, versatile and durable and can be used in a range of experiments.

Figure 1: The Photonics Explorer kit

The experimental components in the Photonics Explorer kit are provided within a didactic framework that is the result of a pan-European collaboration of teachers and experts in pedagogy. It has been designed with the input of an 'Educational Advisory Panel' consisting of 35 teachers and science education professors from 11 countries across Europe. This includes secondary school science teachers, 10 professors in pedagogy and 17 members experienced in teacher training. The didactic content is based on guided Inquiry-Based Learning techniques. The Rocard report[2], states that the EU needs a stronger emphasis on the use of inquiry-based learning in its classrooms to achieve the goals of a knowledge based society and increase the scientific literacy of its citizens. The didactic content has also been developed to satisfy the diverse educational systems and teaching environments across Europe and to give students the opportunity to really work as scientists and engineers in the classroom. The kit is designed in a modular structure with 8 stand-alone modules; 4 for lower secondary and 4 for upper secondary levels. The topics of the modules are as follows:

The modules for Lower secondary level (12-14 years)

- Light signals – the properties of light and its use in telecommunication
- Colours – colour perception, additive and subtractive colour mixing
- Lenses and telescopes – refraction and imaging
- Eye and vision – comparison between human eyes and digital cameras, accommodation in the eye

The modules for Upper secondary level (16-18 years)

- Making light – comparing different light sources, laser
- Diffraction and interference – diffraction on a slit, spectrometry
- Polarisation – applications in displays and life sciences
- A scientist's job – encouraging esp. young women to pursue careers in science and engineering

Each module consists of worksheets and factsheets for the students, a comprehensive teacher guide and, where relevant, supporting multimedia material, like pictures and videos that further help to illustrate the physical concepts. The modular structure allows teachers the flexibility to include and adapt the modules into their individual classroom situations. Each topic is always linked to current technologies thus making the science relevant in the context of students' daily lives.

Worksheets are designed so that students can work in groups to design their own experimental setups, come up with a hypothesis and test it to arrive at a reasonable conclusion. They then discuss the observed phenomenon, its origin/cause and how such an effect could be useful. They then directly relate this optical effect to current technologies encountered in their daily life. For instance, the module 'Light Signals' designed for lower secondary students, allows students to discuss a hypothetical situation of '3 villages in a valley' that need an efficient communication system. They are given a set of criteria that need to be satisfied and thus they learn to come up with solutions, much like in a real engineering situation. Students then encode the alphabet using red, green and blue LEDs and communicate a word across the classroom using an optical fibre.

Figure 2 Students communicate a word using LEDs through an optical fibre

The module on 'Diffraction and Interference' designed for upper secondary students, allows them to build their own 'Spectrometer' to resolve and measure the wavelength of the different colours in the spectrum of light from an energy saving light bulb. This leads to the understanding of differences between an energy-saving bulb and a 'normal' incandescent light bulb. Students are also encouraged to discuss the far-reaching applications of spectrometry.

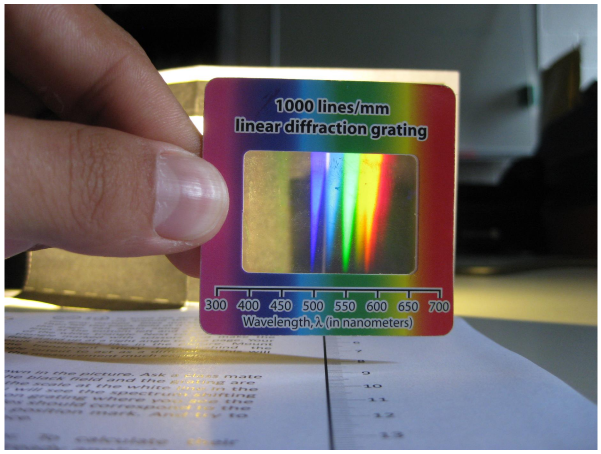

Figure 3 Colours of the spectrum of an energy saving light bulb seen through a diffraction grating provided in the kit

In the module ‘Making Light’ designed for upper secondary level, students are asked to perform a project wherein they assess the way their school is lit (kinds of light sources used for each area, efficiency etc.) and determine if it is being done in the most efficient and cost-effective way. They are asked to design the project, collect and assess their findings. Finally, if they can provide convincing arguments, they are asked to write a letter to their head of school with their findings and a proposal for a better lighting system.

Other modules allow students to measure the width of their hair, replicate the diffraction pattern of DNA and even build a ‘polarimeter’ to measure the concentration of a sugar solution using a laser and polarisers.

Figure 4 Students building a 'sugar polarimeter' as part of the 'Polarisation' module

The didactic content was developed using a ‘Review and Revise’ process where the content of each module was checked by at least 2 secondary school teachers and 1 science education professor, each from a different country. This was done to ensure that the material satisfies the educational requirements of different countries and teaching environments. All the didactic material is copyrighted but editable so that teachers can modify the content to suit their needs. The didactic content has been translated into 7 EU languages based on the first 7 countries where the Photonics Explorer was field tested.

3. FIELD TESTS AND SCIENTIFIC EVALUATION OF IMPACT

The Photonics Explorer underwent extensive field testing in 7 EU countries from September – December 2011; Belgium, Bulgaria, France, Germany, Poland, Spain and UK. 50 Photonics Explorer kits were tested, with the content in the local language, with over 1500 students participating in these field tests. Each module was tested in at least 2 classrooms (~ 60 students).

The field tests provided the basis for the short and long term scientific evaluation of the impact of the Photonics Explorer in the classroom. IPN in Kiel, Germany is responsible for the scientific evaluation and extensive feedback was collected from all testing students and teachers. The feedback consisted of questionnaires specifically formulated based on the kit. These questionnaires evaluated the students before (pre-test), immediately after (post-test) and 4-6 months after (follow-up test) working with modules of the Photonics Explorer. This feedback is currently being used to qualitatively and quantitatively evaluate the impact of the Photonics Explorer. The kit will be evaluated in terms of interest of students, self-awareness, image of science and learning progress. Individual modules will also be assessed in terms of their use, feasibility, difficulty level and acceptance by students and teachers.

Figure 5 Students in Sofia, Bulgaria looking at diffraction patterns with the Photonics Explorer components

The first results of the impact study indicate that the Photonics Explorer indeed increases the self-efficiacy of students in those classrooms where IBL techniques are minimal to moderate. It also raises students' interest in Physics especially in the case of weaker and average students (level determined based on pre-test) and, in particular, also for female students. A full report will be completed by October 2012.

The team responsible for the development of the content (at the Vrije Universiteit Brussel) also visited several testing classrooms to watch and interact with students using the kit in the classroom and collect feedback. This feedback primarily focused on the content, structure, layout and usability from a both a student and teacher perspective. Teachers and students alike have been extremely positive and teachers are eager to continue using and implementing the kit in their classrooms. The experimental components and content has been greatly appreciated, in particular the detailed teacher-guide and examples of current technologies.

The feedback obtained from the evaluation study as well as the classroom visits are currently being used to update the content of the kit.

4. DISTRIBUTION AND SUSTAINABILITY

The Photonics Explorer kit is provided to secondary school teachers completely free-of-charge but only in conjunction with teacher training courses always conducted by local, professional teacher trainers who are familiar with the content of the kit. This ensures that the kit is correctly implemented to maximum advantage of students in the classroom. Further, the teacher training courses ensure that the principles of Inquiry Based Learning are well explained along with the role of the teacher within this context. Teachers are also given the opportunity to work with the experimental material and gain an overview of the didactic content during the teacher training course.

In order to ensure the long term sustainability of the Photonics Explorer kit, a non-profit organization EYESTvzw has been established. EYESTvzw is responsible for the assembly and wide distribution of the Photonics Explorer kit [www.eyest.eu]. The kit is assembled in sheltered workplaces in Belgium.

At present EYESTvzw is working with European industry, photonics communities and ministries of education to raise funds to support the distribution of the kits throughout Europe. The successful field tests have already resulted in a demand of at least a 100 additional Photonics Explorer kits in every testing country. Additional countries such as Austria, Netherlands, Ireland, Italy, Sweden and the Czech Republic are mobilizing industry and governments to implement the kit in their classrooms. EYESTvzw aims to distribute 10 000 Photonics Explorer kits in the coming three years to reach over 2.5 million students across Europe in the years to come.

5. CONCLUSION

The Photonics Explorer is a novel, intra-curricular kit designed to support teachers with class sets of experimental materials provided within a didactic framework, completely free of charge. The didactic framework uses guided Inquiry Based Learning techniques and has been specifically designed to engage, excite and educate students. The experiments encourage them to work hands-on in the classroom to get a flavour for working like scientists and engineers in the real world. The intra-curricular nature of the kit allows it to integrate into the existing European secondary school curricula thus enhancing the teaching and learning process within the classroom and not requiring additional time or effort on the part of teachers or students. The field tests show extremely positive results with teachers and students alike favouring the content and the material. First results of the scientific evaluation of impact also shows that working with the kit indeed increases the self-efficiacy of students and in particular, it has positive impact in those classrooms with minimal to moderate Inquiry Based Learning techniques.
Thus, the Photonics Explorer aims to improve the image of science among young people, encourage them to pursue scientific and technological careers to raise the next generation of skilled workforce.

6. ACKNOWLEDGEMENTS

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