"Si(n)Ce you are a driver": a PCTO experience about semiconductor physics in Italy

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Abstract

Electronic devices are found as enabling technology in many objects of daily use. Some show a clear usage of electronic components, such as mobile phones and PCs, whereas in many objects, electronic control reliance is less evident. This is the case with the most recent domestic appliances. The use of the so-called" inverter technology" allows for smarter use of electricity and electric cars, where the inverter is defined as the motor's brain. The inverter is an electronic device that commutes current from continuous to alternate. Though silicon is the most common material employed in electronic device fabrication, the high power absorbed by electric cars requires inverters able to withstand high currents and voltages. The most suitable material for high power devices is silicon carbide, a semiconductor whose improvement is the aim of several research projects. "Challenge" is a project funded under Horizon 2020, coordinated by the National Research Council of Italy (CNR). Its dissemination strategy includes actions to make youngsters aware of the progress in the application of semiconductor technology. This work describes a pathway for transversal skills and orientation carried out by two high schools in Italy. We followed an ideal route from innovation to market for power electronic devices applied in e-mobility. Two whole classes attended thematic seminars on silicon carbide, and one on the European Framework Programs for research and innovation. The practical activity dealt with science dissemination activities towards different types of public. We observed that linking scientific issues with actual objects such as electric cars attracts youngsters' attention towards an extracurricular scientific theme. Simultaneously, communication activities can deepen the level of insight while promoting pupils' critical thinking about the transfer of research findings to the market.

Keywords: *Semiconductor physics, silicon carbide, electric motor, PCTO, science communication*

1. Introduction

Electronic devices are found as enabling technology in many objects of daily use. Some show a clear usage of electronic components, such as mobile phones and PCs, whereas electronic control reliance is less evident in many objects. This is the case with the most recent domestic appliances. The use of the so-called" inverter technology" allows a smarter use of electricity and, in electric cars, the inverter is defined as the motor's brain. The inverter is an electronic device that commutes current from continuous to alternate. Though silicon is the most common material employed in electronic device fabrication, the high power absorbed by electric cars requires inverters able to withstand high currents and voltages. The most suitable material for high power devices is silicon carbide (SiC) [1], a semiconductor whose improvement is the aim of several research projects worldwide. "Challenge" [2] is a project funded under Horizon 2020, coordinated by the National Research Council of Italy (CNR) with the cooperation of 13 European and 1 Japanese partner. The work carried out in "Challenge" can contribute to SDG9 (industry, innovation and infrastructures) and SDG11 (sustainable cities and communities) and, through science and innovation, it aims at promoting high-quality education (SDG4) decent work and economic growth (SDG8). Its dissemination strategy includes actions to make youngsters aware of the progress in the application of semiconductor technology. This work describes a pathway for transversal skills, and orientation (PCTO) carried out by two high schools in Italy.

2. Methodology

The learning pathways have a modular scheme following the methodology developed in the project RM@Schools [3]. This methodology allows tailoring contents and activities to different schools. Fig. 1 summarizes the activities carried out by the two classes.

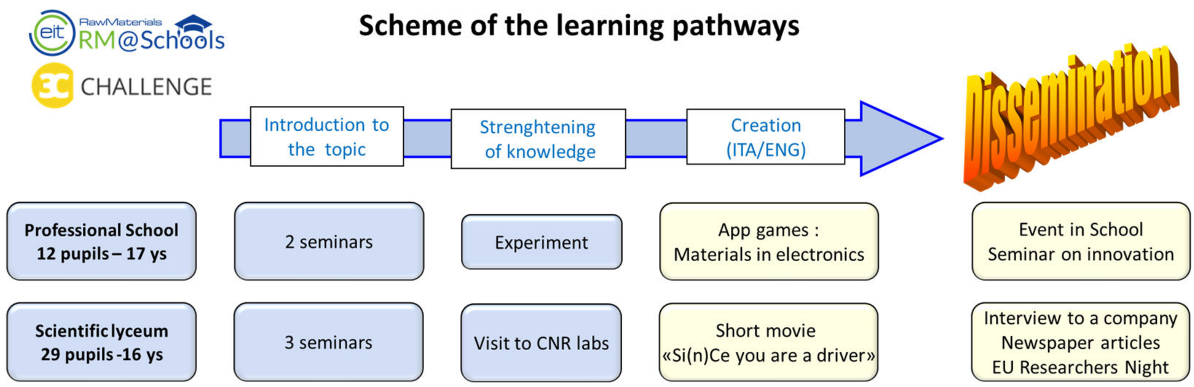


Fig. 1. Scheme (arrow) and details (boxes) of the learning pathways proposed to the Professional School and to the Scientific Lyceum. The blue boxes represent the guided activities, the yellow boxes the communication activities.

The pathways followed an ideal route from innovation to market for power electronic devices applied in e-mobility. The pathways involved: i) 12 pupils, 17-year-old, attending a Technical Professional School, named Class A; ii) 29 pupils, 16-year-old, attending a Scientific Lyceum, named Class B. The proposed topic was extracurricular for both schools.

The classes attended three thematic seminars. A scientist with expertise in processing technologies for electronic devices, held the first two. An introductory seminar explained the use of new materials in emerging electronic technologies and the need to further research in this field; a second seminar focused on the scientific topic faced in "Challenge" and dealt with physics and processing techniques of semiconductor devices made up of SiC and their application in automotive. The third was presented by an SME leading the Challenge communication activities. The seminar focused on Horizon 2020, the European Framework Program financing collaborative research and innovation. The accent was on the strategic role of public funds to sustain new ideas, researchers and economy in the fields of the enabling technologies and innovative solutions for the benefit of the society. In Class A, this seminar was given in the frame of a public event organized in the School, whereas in Class B, it was presented as the learning pathway introduction.

As a practical activity, Class A fabricated a printed circuit board as a practical activity by employing soldering, drilling, and bromographic lithography techniques. The circuit, developed in the frame of the project RM@Schools, incorporated battery, LEDs, and resistors and can be used to provide a visual comparison between the electrical resistivities of quartz slides either uncoated or covered by different transparent conductive materials (indium tin oxide and graphene). We focused on the materials constituting the devices incorporated in the circuit: silicon, the primary semiconductor material in electronic devices; gallium arsenide and gallium nitride as direct band gap semiconductors in LEDs; silicon dioxide as electrical insulator; copper and indium tin oxide as electrical conductors. The bromographic lithography served as a cue to introduce photolithography as a mean to fabricate planar electronic devices with 1-2 µm resolution. Though not directly related to SiC, this experience is suitable for a PCTO because it links the relatively new content about semiconductor physics and processing and the students' background in device integration.

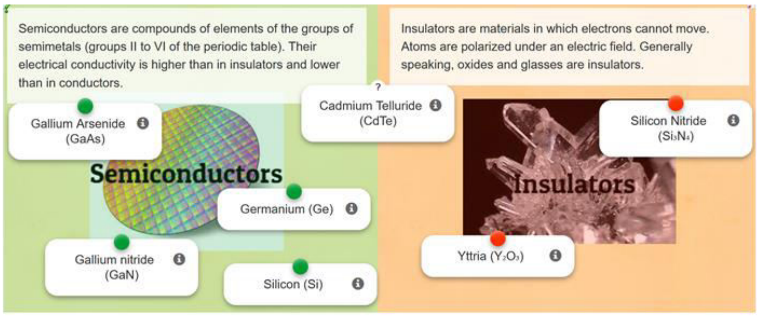
The practical activity proposed to Class B was a visit to the laboratories of the Institute of Microelectronics and Microsystem of CNR in Bologna. They visited a class 100 cleanroom equipped with the technologies for electronic device fabrication: photolithography, silicon dioxide growth, metal deposition, and doping. The specific SiC temperature resistance requires dedicated equipment for the doping step. In this visit, the students could appreciate the need to develop SiC processing technologies.

The next steps of the pathway, i.e. the creation of dissemination products and the participation in a dissemination event, reinforces the link between the new contents about research in the field of electronics and the transversal skills of the students: communication, synthesis, fluency in English, use of technological devices to create multimedia contents.

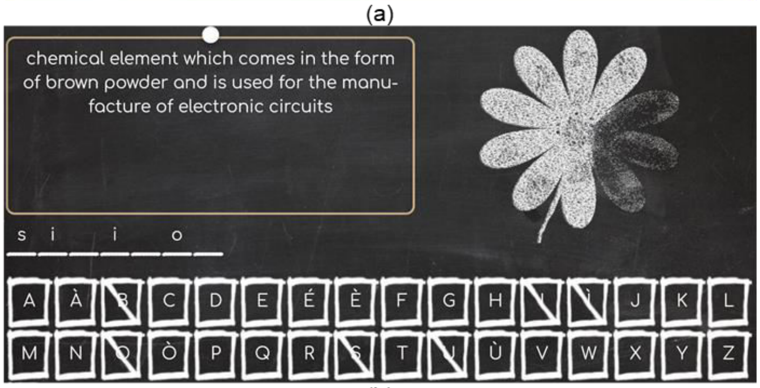
3. Results and discussion

As a result of this "training" the students created dissemination products by re-elaborating in groups the scientific contents treated in the seminars.

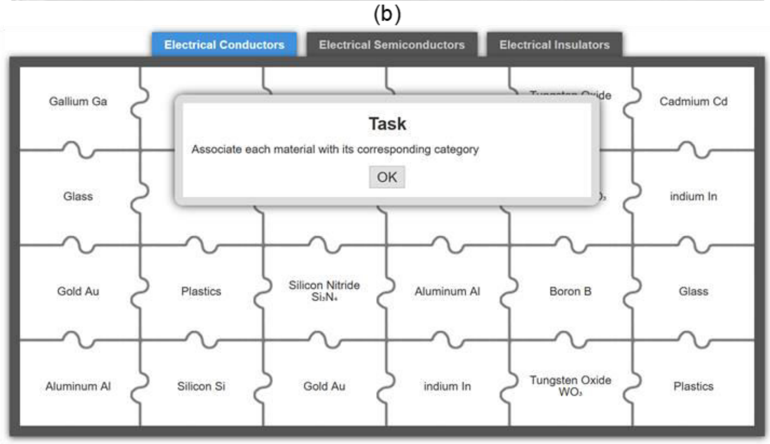
Class A created three digital games: a quiz named "semiconductor or insulator?" where the player has to assign materials to the right category [4]; a "hangman game" where the player has to guess the name of a material, processing technique or device by suggesting letters within a certain number of guesses [5]; a puzzle whose pieces are uncovered by assigning materials to the right category [6]. Fig. 2 shows some screenshots of the games. This set of games focuses on materials and techniques used in electronic device fabrication. These games help students summarize names and electrical properties of materials.
These games served as a playful final during the open event organized in the Professional School, where 80 pupils and teachers of different schools attended seminars on innovation in electronics.



(a)



(b)



(c)

Fig. 2. Screenshots of the games realized by Class A: semiconductor or insulator? (a); hangman game of electronics (b); puzzle of materials (c).

Class B realized a short movie named "SiCcome guidi", in English "Si(n)Ce you are a driver", explaining the advantages of using SiC inverters in automotive and the barriers to their widespread use. They could show the need for research through nice images (some drawn by themselves) and witty use of the language, culminating in the title's pun. Instead of loading the speech, the use of specialist terminology resulted in a clear and precise description. This movie is published on the "Challenge" website and YouTube channel [7] and is part of the Gallery of RM@Schools.
This class made science dissemination experiences addressing different types of public. A selected group of 5 students visited a local company that produces electric vehicles, and they discussed the

advantages and limitations of introducing SiC inverters in their production. The cost and reliability of components turned out to be the key elements guiding companies' choice, highlighting the need for further research to improve the SiC material quality and processing technology.
The whole experience was published in a local newspaper [8], where the class did an intership for a different PCTO. Under the guidance of the editorial officers, the articles about SiC in automotive, the pictures of the company visited, and the interviews with researchers offered a fresh image of a topic that usually requires scientific background knowledge.
Finally, they were the protagonist in the European Researchers Night held in Bologna on Sept 27th, 2019 [9]. "Challenge" set up a stand where people could gather information, ask questions or play games. The pupils, divided into four shifts to cover the whole event, assisted the public in playing and answering questions about scientific issues with the help of a poster and their movie. As the students commented [10], the experience was exciting and engaging.
We observed that linking scientific issues with actual objects such as electric cars attracts attention towards a scientific topic that requires extracurricular knowledge for a deep understanding. The students of the different schools appreciated different aspects of the pathway. The students of Professional Schools found the circuit's realization and the hints to semiconductor processing most appealing. The Scientific Lyceum students were interested in the environmental benefits of using SiC inverters in electric cars. All the students showed a deep engagement in the live dissemination activity, testified by the intense communication with the tutors the week before the events. The realization of a dissemination product turned out to be a slender way to recollect the seminars' content and deepen the insight acquired by the independent search. It also allowed to identify the most complex contents and find convenient strategies to tackle the issue. For example, though the band gap concept was considered awkward, its implications in high-temperature operation of SiC devices were clear. Together with the seminar on innovation, the company visit promoted pupils' critical thinking about the transfer of research findings to the market.

4. Conclusions
This experience shows a successful practice for science dissemination in European research projects and PCTOs based on extracurricular scientific topics. By adopting the methodology developed in RM@Schools, pathways centred on the research carried out in "Challenge" could be adapted to different requirements. We find that the key to interest pupils lies in showing the social relevance of a research issue while involving them in live communication events is both engaging and rewarding.
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