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Promoting Interactive Knowledge to Students in Non-formal Education Activities Dedicated to Solar Energy Processes

Gabriela MĂNTESCU[1]*, Gabriel GORGHIU[2], Gabriel STATE[3]

Abstract

In the context of the world evolution and global changing, the education and research have the responsibility to give new contributions for the society, so that future generations can inhabit in a better world. Experts in educational and research areas are committed in this work, having also as target to deliver innovative methods suitable for non-formal education, answering so to the societal challenges. As the large use of renewable energy is seen like a main key for the sustainable development, teaching the secondary school students concerning the basics of renewable energy and its potential, is working in the interest of sustainability, which has already become a special issue and a necessary frame for dissemination and discussion of the relationship between Responsible Research and Innovation and industry. The paper illustrates the way in which interactive knowledge is transferred in non-formal activities dedicated to students, having solar energy as main thematic area. The innovative feature of activities is represented by learning and acceptance of the functionality and advantages of solar energy systems, by direct experimenting in a special research space and power energy production, at the Scientific and Technological Institute of Multidisciplinary Research (ICSTM) of Valahia University Targoviste. The students were introduced in the "solar world", in order to understand the physical and energetically processes, demonstrated initially at the micro-system level, with the students working individually with educational solar kits, and then validated at the macro-system level, through the interactive graphical demonstrative operating mode of the solar generators integrated into the building.

Keywords: future green solution, solar energy, non-formal education, interactive knowledge, demonstration, IRRESISTIBLE Project.

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1. Introduction

The actual context of our society is characterized by the global evolution of the energy sector, a transition to restructure the global energy sectors, leaving conventional, centralized and CO_2 emitting energy production towards an economical and sustainable energy supply based completely on renewable energy sources and a market growth which reached more installed energy systems. Also, the architecture shapes the world around us with functional, inspiring solutions to create sustainable buildings; in this respect, the strategically concept "Smart Cities" is striving for integral technical solutions for the coordination of renewable energies production, power grid operation, storage facilities and demand of end users. The multifunctional role of the Building Integration of Photovoltaic (BIPV) applications makes this an important aspect to develop especially taking into consideration future targets on zero energy buildings and smart cities, but provides a challenge in the predominance of relatively small capacity energy systems.

New solutions and innovations in all parts of the renewable energy domain, especially in solar energy value chain are important for future success. In present, the European market of renewable energy area still has good opportunities and future perspectives for engineers, managers and policy-makers to performed important solutions for sustainable energy and good life of society [1-3]. In that context, the authors of this paper consider that the learning orientation in order to solve the problems of everyday life towards the acquisition of new information directly from the good practice applications represents a shift in the ways of learning.

Even the evolution of the solar technology in laboratories is well understood, informing citizens and decision-makers in the respect of responsible research and innovation, remains a challenge. By investing in responsible research, innovation and education, the society drives its way to implement the concept of sustainable development [4-5].

2. Problem Statement

Even the new technology has found better solutions for energy sector to be adopted in the society; the specifically educational curricula cannot be changed at the same time. In that sense, students familiarized with the field of scientific research in the energy area, starting with the early stages of education, can add value to understanding and assimilation of their knowledge. Hasta mentioned in [6] that "*in the process of offering to students a stronger voice in order to identify issues and needs, the sense of community in achieving*

success can become a more realistic and much needed goal". Concerning that goal, the novelty of the non-formal activities proposed in this paper consists on the development of a traditional educational structure for the presentation of a topic related to the use of renewable energy in the scientific research.

For a better understanding of the solar energy conversion and solar energy applications, the authors presented to the students an interactive and non-formal structure: from laboratory experiments to real solar energy systems operation, both demonstrations being performed in the Scientific and Technological Institute of Multidisciplinary Research (ICSTM) - Energy Environment Research Department of Valahia University Targoviste, Romania.

3. Theoretical foundation

In accordance to the constructivist paradigm explained by Kozulin in [7] - "*learning is a dynamic, participatory and interactive process between the learner and his social environment*" the authors of this paper have projected a structure of a non-formal activity developed in the frame of the National week: "*School in Another Way: To know more, to be better!*", characterized by two key levels:

1) *First level - the proximal development* - in which the student is able to do alone the primary non-formal activities - investigations and researches in the field of solar energy conversion, with an educational and experimental solar junior kit. Consequently - *how to use* -, it was analyzed the possibility of working with the students, in the individual mode, to use an educational solar kit for photovoltaic conversion demonstration.

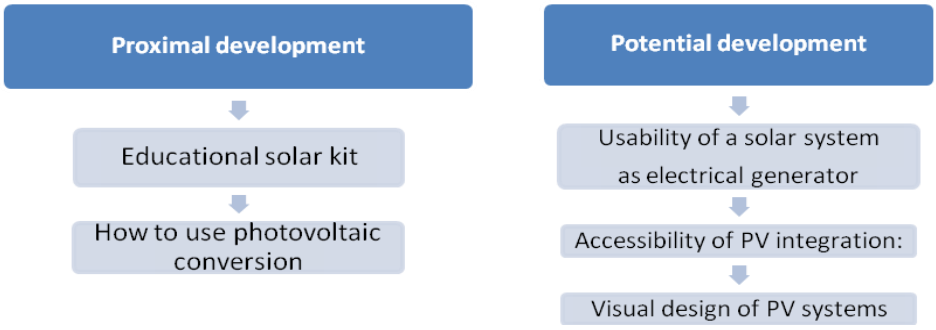

Figure 1. The key levels of non-formal activities in the solar energy area

2) Second level - the potential development - in which the student would proceed to more gradual steps of knowledge with the respect of responsible research and innovation - in the real world of solar systems operation, with the help of adults: researchers in the field of electrical engineering, chemistry and physics, specialists in education and class teachers. For this level the

process was focused on the development of qualitative information and effective mechanisms to describe, through non-formal education, the usability and technical options for realizing photovoltaic systems:

- Technical options for the entire solar energy system;
- Storages technologies and transmission technology related to the electrical network;
- Architectural solutions for building integration of solar panels;
- Monitoring;
- Environmental aspects, including combination with other renewable energy technologies (wind energy, solar hydrogen as a solar storage solution);
- Innovative researches and business models based on locally systems integrated into ICSTM building.

4. Research Methods

In order to achieve essential learning, non-formal activities were organized on a structure of participants, as fallow: 130 of students from pre-university educational levels (30 - primary, 50 - lower secondary, 50 - upper secondary) and 15 members of the Community of Learners (7 - Science teachers; 3 - Educational experts, 5 - Researchers). The students started the activities with a visit to the solar energy systems located on the ICSTM terrace, where teachers and researchers introduce and discussed with students the following issues:

To evaluate the existing information in-line with the concepts of the using of renewable sources;

To broaden the students' horizons and gain insight into the problem of green energy usage;

To discuss and analyze relevant information regarding the solar energy conversion;

To provide a solid background and theoretical foundation through a non-formal activity with an experimental kit of solar energy;

To familiarize themselves with the responsible research and innovation and latest developments presented in the institute laboratories, in the field of solar energy;

To identify the benefits of the existing research results and to establish the needs for a profession in this area.

The researchers explained to students which are the emerging scientific and technological trends and future practices, in the field of renewable energy, for the smart cities of the future. In that context, they

presented the Scientific and Technological Institute of Multidisciplinary Research (ICSTM) building from the Campus of Valahia University Targoviste, as an intelligent building.

The types of solar systems integrated into the ICSTM building, - grid connected photovoltaic system, stand alone photovoltaic system and solar thermal system - were also described to students.

a). ICSTM façade

b). Students in Campus of University

c). Students in front of the PV system

d) Students near the solar collectors and wind turbine

Figure 2: a, b, c, d. Students visiting the solar energy systems integrated into the ICSTM building and terrace. Photos made by Gabriela Măntescu. Source: personal galleries of the authors. Permission given by the participants for taking pictures during the activities

4.1. Accessibility of solar systems integration in real world

Following the guidelines of building integration of solar technologies

in a real application - the ICSTM building -, the students became familiar with the PV system components integration as electrical and architectural elements - PV sun shadows, PV curtain wall, and PV terrace systems.

a. b. c.

Figure 3-a,b,c. Solar panels integrated into the ICSTM building as electrical and architectural elements. Photos made by Gabriela Măntescu. Source: personal galleries of the authors.

4.2. Visual attention

With a simple perception, the students evaluated the *Photovoltaic Panel Prototype Lab* of ICSTM, and discussed on the advantages or disadvantages of using of different technologies related to solar cells and concerning materials, colors of cells versus the building environment, frames of solar panels, and different electrical connections between the solar panels and different other components of the solar systems. Those criteria offered important issues for the students' debates due to the fact that they were not accustomed using all different technologies in the same place - a building.

a. b.

Figure 4-a,b. Students in the laboratories of ICSTM: a). identifying the technological steps of the solar panels fabrication; b). visual inspection and testing. Photos made by Gabriela Măntescu. Source: personal galleries of the authors. Permission given by the participants for taking pictures during the visits

4.3. Graphical demonstrations

Students participated to several demonstrations: silicon solar cells operation versus interactive evaluation of 33.15kWp photovoltaic grid connected system with modules of monocrystalline silicon, polycrystalline silicon, amorphous silicon and thin film of CIGS.

5. Experimental results versus interactivity with monitoring results

5.1. Photovoltaic Solar Cells: interpreting, understanding, measuring

It is better known that a photovoltaic system convert the sun radiant light directly into electricity and the I-V Characteristic Curves show the current and voltage (I-V) characteristics of a particular case of solar cells, panels giving a detailed description of its solar energy conversion ability and efficiency. In that respect, the students experimented in the "*Building Integration of Renewable Energy Systems*" laboratory from ICSTM, different issues:

- solar cells operation, as energy converter;
- open circuit voltage and short circuit current with varying irradiation intensity;
- short circuit current of a solar cell with varying angles of incidence of the light;
- series and parallel connection of solar cells/shading;
- Current - Voltage (I-V) characteristic line of a solar cell.

a. **b.**

Figure 5-a,b. First level: investigations and researches with an educational and experimental solar kit made by IKS Photovoltaik GmbH. Photos made by Gabriela Măntescu. Source: personal galleries of the authors. Permission given by the participants for taking pictures during the experiments

Figures 6 and 7 illustrate the I-V Characteristic Curves and Power Curves, for a series connection with four solar cells. The students tested different irradiations, without and with shadow elements.

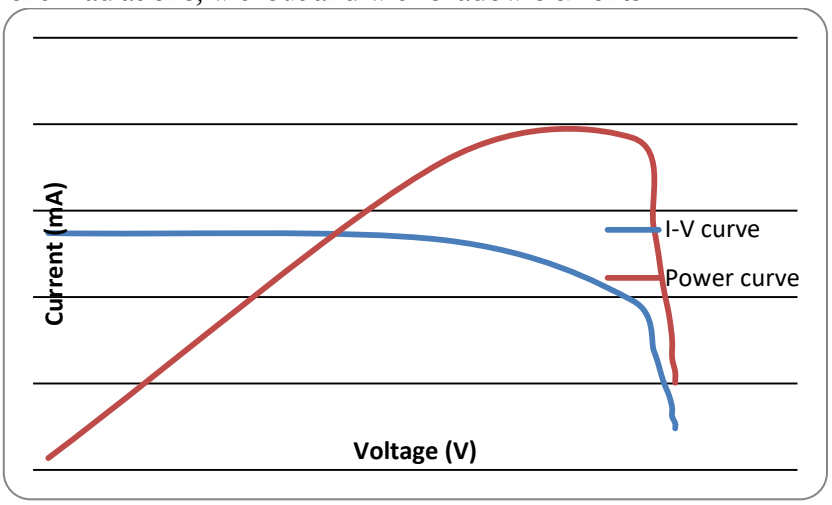

Figure 6. I-V Characteristic curve and power curve for four solar cells series connection - results obtained at irradiation of 1000W/m2, without shadows elements.

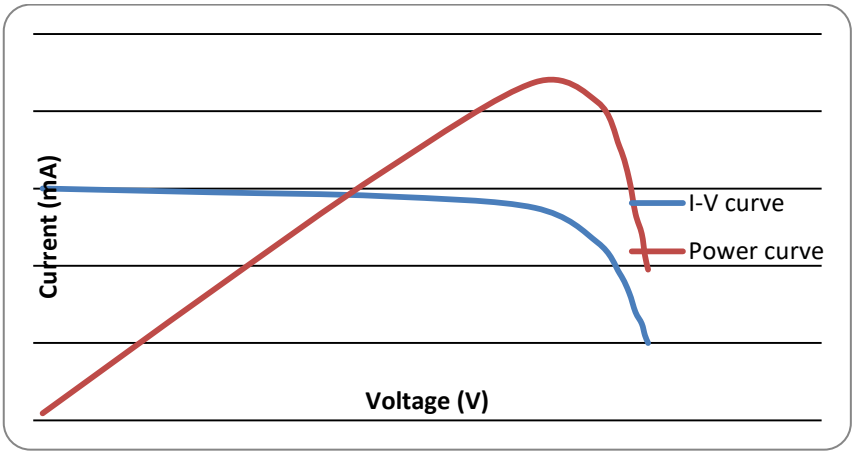

Figure 7. I-V Characteristic curve and power curve for four solar cells series connection - results obtained at irradiation of 1000W/m2, with 2 shadows elements.

5.2. Interactivity of the PV systems monitoring and data acquisitions

This criterion is related to the way that the student, with the support of researchers and teachers, interacted directly with the interface of PV systems control. The student, as an active part of the PV systems control,

was able to evaluate the results, having the possibility to import and analyze the graphical evolutions of photovoltaic solar grid connected systems, integrated on the ICSTM terrace (ICSTM - PV system), as follow:

- PV system power: 33.150kWp
- Annual Production: 39,614 kWh (1,195 kWh/kWp)
- CO_2 avoided: Approx. 27.7 tons per annum
- Energy and power
- Total yield
- Daily, monthly and annual report.

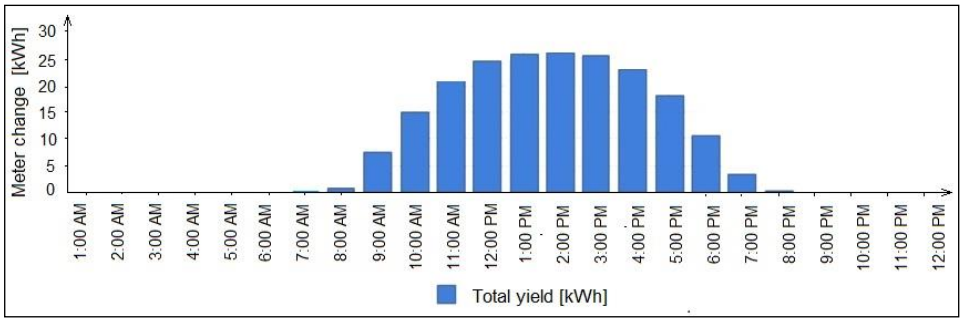

Figure 8. Daily yield of PV system – 03.04.2017

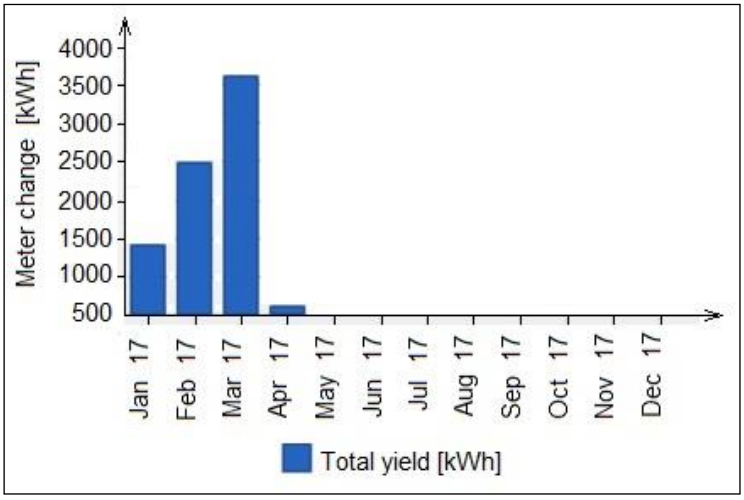

Figure 9. Total yield of PV system, monthly reported

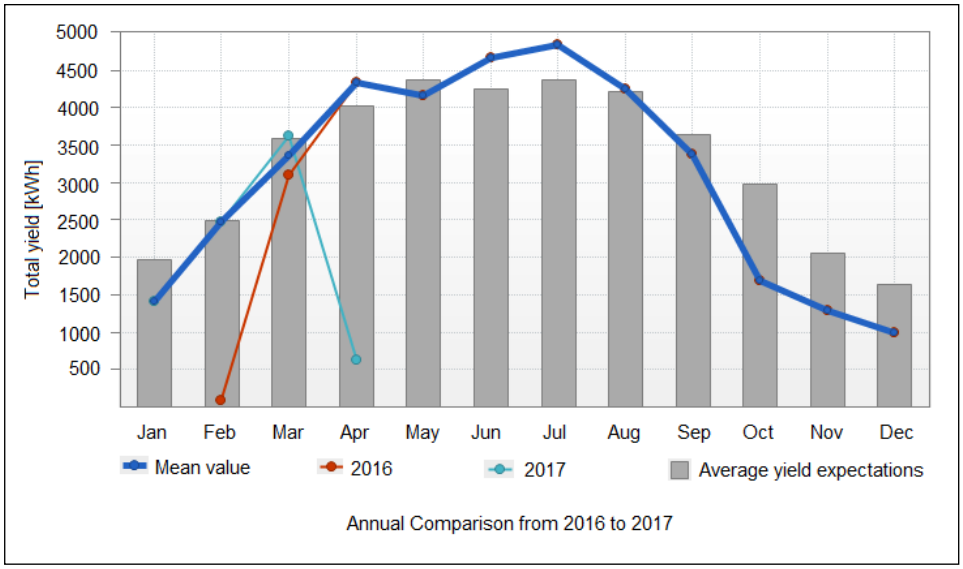

Figure 10. Annual comparison, from 2016 to 2017, of total yield

With the graphical demonstrations, experimental determined and interactive observed via PV system monitoring, researchers, teachers and students were led into a technological land that redefines the nature of constructionist learning environments.

6. Conclusions

Direct access to the scientific results and exchange of views with the educational and research experts stimulated the communication and students' acceptance of solar energy as future and sustainable green solution.

Even informal and non-formal educational activities are not new issues, the design for such activities in the way in which the interactive knowledge is transferred to students, was important and produced a powerful impact. In this respect, it can be considered that such activities - especially those ones organized during the National week: "*School in Another Way*" were a real success, answering also to the actual society challenges, having solar energy as main thematic area, in an environment of responsible research and innovation, which can inspire the young students to integrate new energy solutions in their life, that generate new value in the society.

In the respect of the responsible research and innovation, the question "*How can we make the use of solar energy more attractive for the following generations?*" comes as a burden for new non-formal activities, both for experts and students.

Acknowledgement

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