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Students Prior Knowledge about Sustainable Design Perspectives of Solar Cells

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Abstract

To make scientific research projects on renewable energies accessible to the non-formal and formal education sector, we aim to develop appropriate teaching materials. Referring to the model of educational reconstruction, we therefore carried out a literature review on preconceptions related to the working principles of solar cells and a preliminary study investigating students' knowledge about sustainability perspectives. Both revealed a considerable lack of knowledge about these relevant topics. Most of the students did not have a basic understanding about the processes happening in a solar cell. Furthermore, many sustainable design aspects like reparability or the substitution of critical materials were not mentioned at all.

Keywords: *Solar cells, preconceptions, survey, energy conversion, public outreach*

1. Introduction

As part of a science outreach project of the Collaborative Research Center 1073, teaching materials are developed and disseminated to make the corresponding scientific research projects on energy conversion accessible to the non-formal and formal education sector. For the latter, we refer to the model of educational reconstruction and relate perspectives of scientists and students to each other in order to develop curricular valid and learning effective materials [1]. To implement this in a structured and evidence-based way, it is pivotal to have an accurate knowledge of students' ideas about the corresponding topics. In this contribution, we focus on students' prior knowledge about photovoltaic energy generation. For this, a literature review of international studies on preconceptions related to the working principles of solar cells and a preliminary study concerning students' knowledge about the design criteria of these modules from a sustainability perspective were carried out [2]. The latter include not only technical aspects such as efficiency and durability, but also considerations like recyclability and reparability originating from the model of circular economy or the use of low-cost and non-critical materials [3,4].

2.1 Literature review

To gain an understanding of students' prior knowledge about the working principles of solar cells, international literature about prior knowledge studies on this topic was analysed. Ideally, these should involve students attending university-preparatory types of schools. A detailed and comprehensive study on students' perceptions of solar cells was found, conducted in 2013 by Kishore and Kisiel [5]. Students were asked both open and closed questions about solar cells and their working principles. This study is supplemented by a study from 2007 by Nguyen, who investigated the prior knowledge of students in a closed questionnaire study [6].

The results of both studies revealed that there is only a poor level of understanding about solar cells among the students surveyed. For example, in the study by Kishore and Kisiel, only 3 % of the students were able to correctly describe in detail the working principles of a solar cell. Furthermore, basic knowledge was also often lacking among the students. For instance, 17 % mentioned the conversion of light energy to electrical energy as a process in a solar cell. Additionally, only 41 % of students stated light energy plays any role in solar cells at all. Questions about relevant factors for the output power of solar cells also revealed major deficits among the students. For example, 58 % stated that not only light energy but also thermal energy positively influences the output of a solar cell. 13 % of the students mentioned only thermal energy as a performance factor. 3 % of students correctly named increased temperature as a negative influence on solar cell performance. Similar results to this were provided by Nguyen's study, where 5 % correctly identified this correlation.

In contrast, most answered that high temperature had a positive effect or no effect on solar cell performance. Lastly, it should also be noted that only 35 % of respondents knew that semiconductor materials are used in solar cells.

This short excerpt from the two studies shows that most of the students surveyed are not familiar with the working principles of solar cells. To a large extent, they even lack a basic understanding of the processes that take place. However, the data available regarding this specific prior knowledge can only be described as incomplete. The two studies presented show clear results, but they are from the years 2007 and 2013. Nowadays, due to the strong increase in the relevance of solar cells for energy generation in the last 10 years, the topic is much more prevalent in everyday life and schools. Accordingly, it is possible that students today know significantly more about solar cells and their working principles than they did 10 years ago. In addition, more specific knowledge about the working principles of solar cells such as the formation of excitons in semiconductors or the need for a p-n junction in silicon based solar cells was not investigated at all. Also, no recent studies can be found on students' prior knowledge of non-silicon-based novel solar cells such as perovskite solar cells. This shows a gap in research, which should be addressed in the future.

2.2 Sustainability perspectives and preliminary study results

Apart from obtaining an understanding of students' prior knowledge about the working principles of solar cells, we also wanted to determine what knowledge students hold concerning the design criteria that should be considered for the fabrication of solar cells from a sustainability perspective. This includes sustainability aspects that go beyond technical aspects such as efficiency, production cost or durability. The growing waste problem of end-of-life solar modules shows that these aspects are also essential for the design of future solar cells. Photovoltaic modules have a lifetime and the question arises how they are processed once they can no longer be efficiently operated. More and more commercially installed solar cells are approaching their end of life, and at the same time an increasing number of solar modules are being installed as part of the energy revolution, therefore the amount of potential future electronic waste is also increasing [7]. In addition to the effective processing of these materials, the goal for the future must be to move on from the typical linear economy to a circular economy that not only focuses on production (and recycling), but also considers the dimensions of reuse, repair and remanufacturing (figure 1) [7]. These criteria should of course already be considered in the design of solar cells in order to effectively establish such an economy. In addition to these aspects of the circular economy, there are also other sustainability aspects, such as the use of non-critical or non-toxic materials.

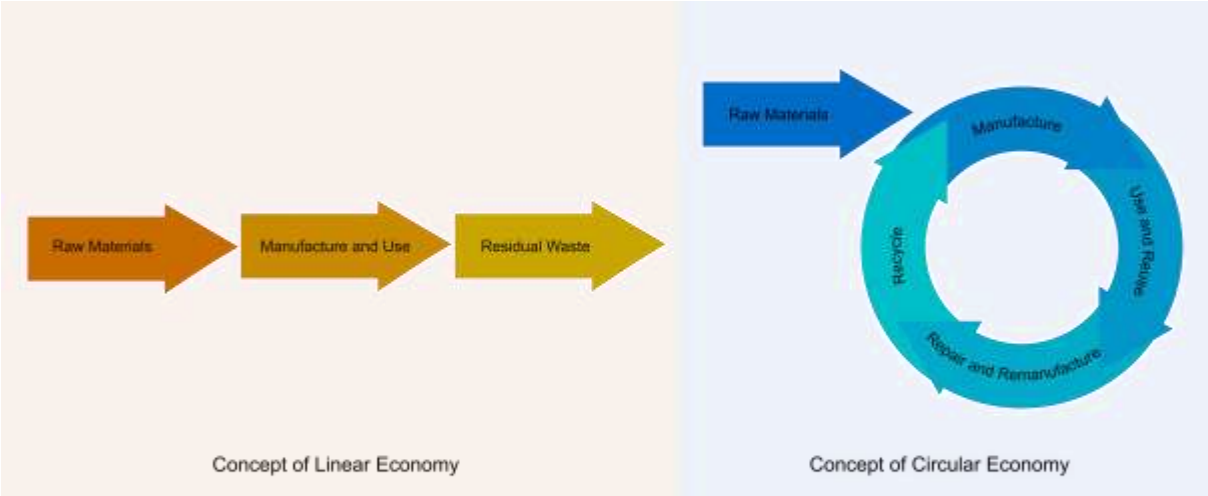

Figure 1: Concepts of Linear Economy (left) and Circular Economy (right).

In order to generate initial data of the extent to which students think about such sustainability dimensions in relation to the development of solar cells, we conducted an explorative paper pencil study in which we asked students which criteria they consider to be important in the development of a solar cell. The question followed an experiment involving solar cells in which they already received input about the working principles of a solar module. A total of 58 high school students between the ages of 15 and 17 participated in the study.

A large proportion of the responses related to technical aspects of solar cell development. The optimization of efficiency, either by minimizing energy losses or maximizing energy absorption, was a particulary frequent answer. Examples of these responses are the following two student statements:

“[The solar cells should] release as little energy as possible to the environment”
“[The solar cells should] be able to capture as much energy as possible”

These answers show that although basic ideas about solar cell efficiency are present among the students, these are superficial and not fully developed. For example, no specific technical terms are used, nor is it explained in more detail what exactly these energy losses are and how they occur.
In addition to these statements regarding efficiency, more technical aspects, such as the longevity of the modules and cost minimization in production, were mentioned. Only very occasionally were specific aspects with a sustainability dimension part of the students’ answers. For example, a few students noted that care should be taken in the design to use as few rarely occurring raw materials as possible:

“Less rare materials should be used [in the production of solar cells]”

Another student wrote that the recyclability of the solar cells must be ensured. However, answers referring to sustainability were rare and many aspects such as reparability, reuseability or the avoidance of critical materials were not mentioned at all.

3. Conclusion and Outlook

Overall, the results presented here show that there are large gaps in the students' knowledge of solar cells. The literature study revealed that a large part of the students do not even have a basic understanding of the working principles of a solar cell, and more advanced knowledge is almost completely absent. As already mentioned, these studies are not recent and it is possible that the situation of prior conceptions on this topic has changed. In the area of sustainability perspectives for the design of solar cells, the preliminary study showed that here a large part of the students seem to have only little knowledge, too. Although some aspects were mentioned, the main part of the answers remained on a purely technical level of design. We want to explore both the prior conceptions of the working principles and the sustainability perspectives in more detail in further work.

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