Exploring Challenges for Integrating Solar PV Technology in Secondary Schools' Education

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Abstract. This study seeks to examine the difficulties associated with incorporating solar photovoltaic (PV) technology into secondary school curricula. Solar PV technology is a popular renewable energy source, but its integration into secondary school education lacks research. The data used is secondary. This investigation utilises a literature review methodology. The literature search results, in the form of research articles, are compiled, analysed, and synthesised to draw conclusions about the literature. Insufficient knowledge and awareness, access and infrastructure, as well as learning methods and instructional resources of solar PV technology among secondary school students pose significant challenges to its integration. The review highlights the necessity for further investigation and funding to tackle the difficulties and capitalise on the possibilities of incorporating solar photovoltaic technology in secondary school instruction.

Keywords: solar PV technology, renewable energy technology, secondary schools' education.

1 Introduction

Renewable energy sources are gaining popularity around the world. In 2019, the total quantity of power generated from renewable sources was 6,963 TWh. These sources produced 361 TWh more power than in 2018, indicating a 5.5% increase [1]. The International Renewable Energy Agency (IRENA) reported that solar and wind power generation increased by 23% and 12%, respectively, in 2019. Both energy sources continue to dominate growth in the renewable energy sector, accounting for 71% of total growth since 2015. Solar PV technology can be used to harness the increase in solar energy generation for long-term electricity.

As in previous years, Asia continues to contribute to growth in electricity generation through renewable sources, with an increase of 245 TWh in 2019. Renewable energy generation in this region keeps rising, reaching 42% compared to the global level. This is followed by Europe and North America, each contributing 19% and 18%, South America (11%), and Eurasia (5%). Asia is also the largest contributor to the increase in solar energy generation, with a rise of 77 TWh out of the global increase [2]. The growth in solar energy generation can be harnessed for sustainable power using solar PV technology.

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The robust growth of the global photovoltaic industry cultivates a multitude of job opportunities, particularly within manufacturing, construction and installation, as well as operations and maintenance sectors. In China alone, employment prospects generated through the PV solar industry are anticipated to reach 3.52 million by 2035, a staggering 187% increase compared to 2020 [3]. With the decreasing costs of renewable energy and the continued growth of PV solar system installations, job prospects in this industry can be projected. Further, Liu et al. suggest that the number of job opportunities generated through the PV solar industry in China will gradually increase from 2020 to 2035 [3]. This not only has the potential to reduce poverty rates but also provides a visionary approach towards a future powered by cleaner and more sustainable energy. This notion is also supported by Fadlallah and Benhadji Serradj in their study in Sudan, where the growth of the PV solar industry can generate employment opportunities, alleviating poverty, and conserving energy use for future generations [4].

While job opportunities within the PV solar industry are plentiful, key constraints have been identified, such as the shortage of skilled workers for the installation, maintenance, inspection, repair, and evaluation of PV solar systems. Furthermore, a lack of fundamental knowledge among users (especially in rural areas of developing countries) can lead to issues such as overcharging of batteries, polarity reversal, and irregular usage. These factors can potentially result in damage to the PV solar system itself [5].

There is a consensus among past researchers that education on renewable energy technology should be introduced from the earliest school years through university level and other academic institutions [6]. Initiating renewable energy technology education at a young age is vital as today's students will grow into future decision-makers, policy makers, and authorities in the field of renewable energy technology, thus integrating it into their lifestyle. As with other environmental education topics, energy is also a crucial subject included in science curriculums across many countries. The efficacy of this topic is largely associated with how it is taught, whether through formal or informal education. Formal education involves structured programs within educational institutions, while informal education encompasses everyday life learning. However, formal education often merely provides theoretical information [7], making it challenging for students to fully grasp energy concepts.

Solar power is the most abundant and immediately recognised renewable energy source among students [6]. As a result, the incorporation of solar PV technology into secondary school curriculum is becoming a more relevant topic considering global climate change and the necessity for a shift to sustainable energy sources. Adoption of renewable energy technology such as solar PV has become critical as the globe strives to minimise the consequences of climate change and reduce greenhouse gas emissions. Secondary schools, by incorporating solar PV technology into their curricula, can play a critical role in moulding future generations' understanding of and engagement with renewable energy. Hence, the purpose of this review is to provide a systematic overview of the level of solar PV technology knowledge among secondary school students. The following research question will be the primary focus of the study: What are the issues inherent in enhancing the PV solar technology knowledge of secondary school students? In this review, the researchers will systematically investigate the knowledge level of secondary school students based on existing teaching strategies and analyze the issues encountered during the learning implementation. A thorough review of current material will be used to investigate the obstacles of incorporating solar PV technology into secondary school instruction.

2 Research Methodology

This literature review involves a systematic analysis of existing research through identification, assessment, evaluation, and interpretation. This approach enables a methodical review and journal identification process, adhering to established protocols [8]. The inclusion criteria for scientific articles as data are limited to articles published within the last 12 years, specifically from 2010 to 2022, and sourced from academic journals. At least 16 scientific articles were utilised as data. The article selection process in this study involved the following steps: Access the Web of Science and Scopus databases and input the search terms "renewable energy technology," "solar photovoltaic," and "secondary school student." The study retrieved 135 articles from the Web of Science database and 268 articles from the Scopus database using specific keywords. The subsequent stage involves validating the scientific articles by excluding those that do not align with the research objectives. Scientific articles are sorted by year. This method generates information on up to 16 scientific articles. The researcher will categorise articles on integrating solar PV technology into secondary school education. The researcher performed a comprehensive examination and evaluation of the article, with emphasis on the research findings presented in the discussion and conclusion portions. The researcher compared the study's findings and drew conclusions at the end.

3 Result and Discussion

The results of this study, based on existing research, suggest that the primary obstacles to incorporating solar PV technology in secondary school education are related to knowledge and awareness, access and infrastructure, as well as learning methods and instructional resources. There are research articles from Barbara Kaczmarczyk and Ilona Urych getting the results that secondary school students have limited knowledge on solar PV technology or renewable energy technologies [9]. Education pertaining to solar PV technology, or more broadly, renewable energy, must target the entire population of a nation. Consequently, within the context of this study, the main challenge identified is the insufficient coverage provided to educational content (curriculum structure) related to renewable energy technologies, particularly solar PV technology, at the secondary school level [10]. The deficiency in curricular coverage leads to a dearth of knowledge and awareness among secondary school students regarding solar PV technology [11]. Hazlee Azil et al. also reported that the lack of curricula for education related to renewable energy technologies indicates a necessity for new educational alternatives. They suggest that alternative curricula should encompass elucidating concepts of renewable energy technologies such as solar PV technology, demonstrations of solar PV power generation, and experiments pertinent to renewable energy technologies.

Moreover, there is a scarcity of information concerning career-oriented advice. Referencing the research conducted by Zyadin et al., who articulate that vocational training involving installation and maintenance of solar panels could facilitate students in probing future career trajectories [12]. Keramitsoglou also reported that the development of a curriculum related to photovoltaic technology, or renewable energy technology in general, assists students in exploring potential career pathways in the foreseeable future, thereby evolving into active utilizers of said technology [13]. This notion is further corroborated by Riyadi et al. state that vocational schools are the most conducive and appropriate secondary educational institutions to discuss job opportunities linked with renewable energy technology as they are practice-based, possess specific efficiencies, and employ technology [14].

In addition, the locale of schools, situated in both urban and rural areas, emerges as an issue in this systematic literature review. Schools located in areas with limited access to solar PV resources may find it challenging to procure necessary equipment or instruments for teaching. According to Chen and Lin, for students residing in rural regions, the perception of failure in project execution doesn't loom as large in their minds as do financial concerns, given that implementing more creative project activities requires substantial funding [15]. Such difficulties are not encountered by urban school students, as they have abundant and readily accessible resources [6]. Urban school students also exhibit superior knowledge concerning solar PV technology.

Subsequently, the allocation of financial resources is critical for the implementation of solar PV technology learning in schools. As Chen and Lin note, teachers need to request substantial funds to procure equipment when executing project activities. At times, teachers and students must be resourceful with available materials or borrow from relatives, peers, or NGOs to facilitate their learning [15]. This strategy is also employed by Machuve and Mkenda, who executed a project involving solar-powered motor toys created from low-cost materials during the learning process [16]. According to Buldur et al., the number of participants involved in the learning process is small over a ten-day period, as the cost of the expenditure is fully borne by third parties [17]. Without appropriate funding, students might miss opportunities to engage in PV solar-related learning. The restricted number of students during the execution of PV solar learning was also identified in studies conducted by Spangenberger et al. through a serious gaming approach [18], and Eliyawati et al. via multimedia learning [19]. Constraints on equipment, such as gadgets, are viewed as a significant factor influencing the number of students.

Furthermore, Bostan et al. limited the number of students partaking in PV solar learning as they focused on a group of students engaged in special training for national and international physics Olympiad competitions [20]. Restrepo et al. also limited their study to a group of just seven secondary school students involved in the production of solar cells in a laboratory [21]. Nevertheless, Bostan et al. suggested the potential for expanding PV solar-related learning across the entire secondary school curriculum.

Next, the timeframe for implementing solar PV technology education. Lin and Lu reported that the limited time available for executing project-based learning to construct insect traps utilizing solar PV technology is challenging in meeting the demands of school curricula [22]. Furthermore, students' practical assessments are not considered, which may lead to limitations in controlling their practical skills [23]. However, they also recommend allocating sufficient time during the design of project-based activities so that students have ample opportunity to complete their projects and reflect upon their own outcomes.

In addition, learning materials also constitute one of the primary issues and challenges in implementing solar PV technology education at the secondary school level. Numerous researchers have reported that a scarcity of reading materials, such as textbooks and reference books, impacts students' knowledge of solar PV technology [17]. According to Revák et al, the content of existing textbooks is dominated by merely presenting definitions, terms, and terminology, with little emphasis on attitudes toward the utilization of renewable energy technologies. Consequently, they propose integrating various elements, such as practical activities, data analysis, group work assignments, and project creation, into textbook content [24]. The cultivation of students' attitudes toward solar PV technology must be embedded in education to form a solid foundation of knowledge that can be applied in their daily lives in the future.

Lastly, Chen and Lin reported that a lack of equipment during learning activities renders student's incapable of putting their knowledge into practice [15]. The shortage of apparatus or necessary equipment to teach solar PV in schools can negatively impact students' learning. Without proper tools, students may struggle to comprehend the concepts taught or be unable to complete the required experiments or projects [6]. This could result in diminished understanding and a decline in knowledge of solar PV technology in the future.

4 Conclusion

Based on the results of the analysis of the literature review, it can be concluded that integration of solar PV technology in secondary schools' education presents several opportunities for curriculum enhancement, sustainability education, and cost reduction. However, challenges such as lack of funding, technical knowledge, and curricular integration must be addressed to maximize its potential. Future research should focus on developing innovative funding mechanisms, teacher training programs, and curricular resources to support the widespread adoption of solar PV technology in education.

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