

Article

Revisiting Education for Sustainable Development: Methods to Inspire Secondary School Students toward Renewable Energy

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Abstract: Education is key to advancing a society that can achieve the Sustainable Development Goals (SDGs). One SDG is shifting energy consumption from fossil fuels to renewable energy (RE) sources to reduce environmental damage and prevent global warming. Awareness must be instilled among citizens at an early age (as early as secondary school) to motivate students to pursue higher education and careers in RE concepts and technologies. To analyze the current trends of existing education in RE concepts and education for sustainable development (ESD) in secondary schools, this study employed the Preferred Reporting Items for Systematic Review and Meta-Analyses method to systematically review 25 articles that were selected from the Web of Science and Scopus databases. The articles highlighted the availability of RE-targeted ESD in secondary schools and their impacts on students and society. However, they revealed a significant lack of curricula on RE concepts and ESD in secondary schools, reflecting the low knowledge, interest in, and awareness of RE and its concepts among students. The articles revealed positive impacts of introducing certain RE-targeted ESD courses/activities on students. Thus, we propose adopting new methods that include collaborative multidisciplinary and informal and non-formal and other factors as a means toward arousing secondary students' interest in RE education to achieve the SDGs.

Keywords: secondary school education; renewable energy; awareness; PRISMA; education for sustainable development; fossil fuel; environment



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1. Introduction

Investment in the renewable energy (RE) sector is a fundamental part of achieving the Sustainable Development Goals (SDGs), a collection of 17 interlinked global goals for achieving a better and more sustainable future for all, that were adopted by all member nations of the United Nations (UN) in 2015. However, a noticeable decrease was observed recently in the global investment in RE infrastructure. A 3% decrease was recorded in the global investment in RE technologies and infrastructure in 2017 [1]. This percentage might have increased in the last 2 years (during the COVID-19 pandemic), which presents a great concern for achieving the global SDGs. To cope with the economic effect of the pandemic, especially the disruption of the supply chain in the RE sector, most countries are relying on fossil fuels to manage their energy demands and revamp their economies. Furthermore, the global investments and government incentives toward developing the RE sectors have declined to cope with the economic effect of the pandemic, which may severely impact the global SDGs [2]. A survey by the Solar Energy Industries Association (SEIA) revealed that 55% of the workers in the sector have been dismissed or are suffering from the effect of the pandemic. The survey also revealed other pandemic-related issues, such as delays in supplying equipment, construction and supply-chain delays, and insufficiency in the workforce, in the solar energy sector [3].

Furthermore, there was a decrease in effort from many different countries in creating awareness and promoting education for RE and SDGs. Education is a fundamental tool to

help society achieve the SDGs; implementing RE education in various levels of education, such as secondary school, colleges and universities, will have a positive impact on the society [4]. Thus, the study aims to reveal the existing trends of education regarding RE in the secondary school level, analyze the shortcomings that are prevalent in the current trend, and come up with a suggested model based on factors that can influence the development and implementation of RE education in the secondary school curriculum.

1.1. Issues and Factors Related to Education for RE

The pandemic acted as a catalyst to expose the existing flaws in the infrastructure of the SDGs. One such flaw is the lack of RE-targeted education/courses at the secondary level. The lack of education in RE fields and technologies in secondary education (age 11–18 years old) accounts for the negative dissemination of RE technologies, design, and concepts, particularly among common people [4]. Different factors, such as socio-cultural, institutional, and technological barriers, persist among the public, owing to the poor dissemination of RE technologies education. Another barrier is the lack of creative methods for harnessing other RE sources and the high cost of harnessing the existing ones via available technology for the common people. Moreover, some of the existing technologies cannot satisfy the total energy needs of the public; thus, they are not cost effective either [5]. To overcome the barriers, new and creative technological advancements must be explored to harness energy from new sources by employing cost-effective technologies, thereby contributing significantly to meeting global energy needs. One strategy for meeting this objective is the introduction of RE concepts in the education spectrum from secondary school so that many future holistic citizens are informed of the grave necessity of RE technologies to motivate them to devise new creative and technological innovations in this field.

1.2. Impact of Secondary Education on RE

The subjects taught in secondary schools directly influence students' interest in particular courses at their tertiary and higher education levels. Previous studies in the field of education revealed that teaching secondary-level subjects in a structured, detailed, and interactive manner can enhance the students' interest in pursuing related fields. Students pursue particular courses in their higher studies based on their level of interest in that subject, as well as their anticipated success in the fields [6,7]. The availability of science, technology, engineering, and mathematics (STEM) subjects in secondary schools increases students' interest in STEM-based careers because of their early exposure to the basic knowledge, limitations or gaps, future implications, and career opportunities associated with the subjects [8]. The structuring of secondary school subjects or curricula with enhanced classroom experiences, detailed learning materials, and instruction methods, as well as interactive contents (projects, activities, etc.), directly contributes to inspiring students into pursuing STEM subjects at higher levels [9]. Most career paths at higher education levels are influenced by many different factors, including family background, family income, socioeconomic factors, and role models [9], although the availability of relevant subjects in secondary schools (ensuring the early exposure of students to the relevance, prospects, and implications of the subject in the global scenario) is also pivotal in encouraging students' pursuit of the subject at tertiary or higher education levels, thereby ultimately adopting it as a successful career path [10,11]. Thus, to ensure that future students develop interests in the RE sector, pursue STEM career paths, and opt to acquire knowledge and experience in RE technologies, they must be exposed to RE education from at least the secondary level education. With such an increase in the interests of future students in RE and STEM fields, more of them might pursue related career paths, and this would promote creativity and produce more skilled individuals in the sector to create, develop, maintain, and innovate RE technologies for their respective societies.

1.3. Public Awareness regarding RE Technologies and Concept

Public awareness represents the level of understanding of the general public regarding the implication, relevance, and necessity of a certain subject, topic, or activity. Public awareness has played a significant role in the achievement of most major goals of society. Similarly, public awareness can be key to achieving the Renewable Energy goals. Many countries have implemented different policies, such as developing sustainable energy infrastructure, to enable them to generate a percentage of their energy needs from RE sources; however, they failed to achieve their targets for various reasons, including people's lack of awareness regarding RE (this factor prevailed) [12,13]. The global implementation of RE technologies is significantly hampered by "economic barriers" (where there is no investment in the infrastructure of RE technology) and "social barriers," which comprise the lack of awareness, information, as well as technological literacy among people [13]. This lack of awareness regarding the concepts and benefits (financial and ecological) of implementing RE creates uncertainties and an information gap for the public. The social barriers to RE technologies exert significant negative effects on the realization of a nation's SDGs and cause a dearth of active participants in the sustainability projects and policies of such a nation [14]. Another adverse effect of the lack of awareness and information is the unavailability of a professional workforce in the RE sectors. Furthermore, the lack of early RE-centered education creates an awareness gap among the people, as well as a lack of motivation and knowledge among students and the prospective workforce. Consequently, prospective students fail to acquire technical knowledge on RE concepts, thus causing a shortage in the skilled workforce of a nation that can develop, innovate, and operate different RE and sustainable projects and infrastructure. The lack of awareness and early exposure to RE concepts at the secondary level of education directly influences the level of future competent technical professionals that a nation will produce, as well as how well a nation can develop and build sustainable energy infrastructure to harness their energy needs and achieve their RE targets. Another barrier that is closely linked to the social barrier is the technological one, which causes the shortage of new research and technological advancements and innovations in the RE sector [5,15–18].

2. Aim of the Systematic Review

The paper aims to conduct a systematic literature review to find out the existing trends of education regarding RE in the secondary school level, then analyze the shortcomings that are prevalent in the current trend, the educational strategies that are currently used to teach RE related topics and come up with a suggested model based on factors that can influence the development and implementation of RE education in the secondary school curriculum. For the systematic literature review, the preferred reporting items for systematic review and meta-analyses (PRISMA) method was employed to identify the existing research on the role of education in secondary schools in creating awareness regarding RE and sustainable development [18], as well as identifying the available education/curricula on RE/sustainable development in secondary level education (age 11–18 years old). In the analysis, the perspectives of different scholars were reviewed on the relevance of education in achieving RE SDGs and creating awareness, as well as the types of existing teaching and learning methods and educational strategies on RE particularly at the secondary education level.

3. Method

To address the aim of this paper a systematic literature review was done using the PRISMA protocol, which is a comprehensive procedure that allows us to clearly select relevant and high-quality articles and allows comprehensive analysis on the perspectives of different researchers/authors and combines them to answer specific questions, as well as identifying research gaps in the field. PRISMA comprises 27 checklists and a flow diagram (Figure 1) with which this study will select the articles to be analyzed.

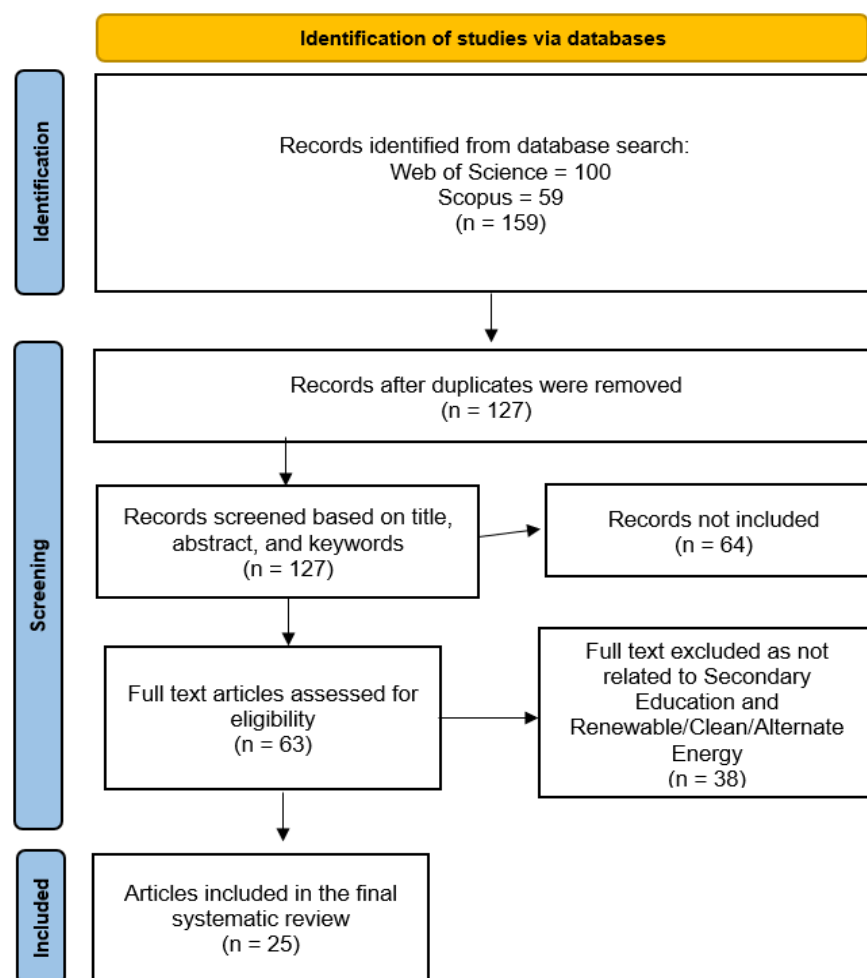


Figure 1. PRISMA flow chart.

Furthermore, this study searched for the articles to be analyzed using the Scopus and Web of Science (WoS) databases via selected search strings as the articles present in these two databases are of high quality and peer reviewed. Thereafter, the results were subjected to identification and screening phases, after which the final articles were filtered for analysis.

PRISMA consists of the following three stages for searching and selecting the articles/papers for analysis.

3.1. Identification Phase

Following the PRISMA guideline, the first step of this protocol is the identification phase. Two databases, WoS and Scopus, were selected to execute this phase; they were subjected to a search string based on carefully selected keywords that encompassed the aim of this study. Keywords, which were related to secondary education and RE and energy literacy and its other synonyms, were formulated and subjected to the Boolean search strategy; afterward, the databases were searched by employing the formulated search strings, and the results are presented in Table 1.

Table 1. Search string used for this study.

Database	Search String
Web of Science (WoS)	1: TS = (((“Secondary Education” OR “Secondary School” OR “Intermediate School”) AND (“Renewable Energy” OR “Alternate Energy” OR “Clean Energy” OR “Sustainable Development Goals” OR “SDG”)))
	2: TS = (((“Secondary School” or “Secondary Education”) AND (“Energy Literacy” or “Energy Education”)))
Scopus	1: TITLE-ABS-KEY (((“Secondary Education” OR “Secondary School” OR “Intermediate School”) AND (“Renewable Energy” OR “Alternate Energy” OR “Clean Energy” OR “Sustainable Development Goals” OR “SDG”)))
	2: TITLE-ABS-KEY (((“Secondary School” or “Secondary Education”) AND (“Energy Literacy” or “Energy Education”)))

3.2. Screening Phase

After retrieving the number of articles from the databases via the search string, we removed articles that appeared more than once. We removed a total of 32 articles that were present in both databases, bringing the total number of articles to 127, which were examined and screened based on their abstracts, titles, and keywords; only the articles that were related to secondary education and RE, environment studies and education for sustainable development with the theme of RE components were selected for further screening, bringing the total number to 63 (64 articles were removed at this stage). The remaining 63 articles were screened based on the inclusion and exclusion criteria, as directed by the PRISMA guideline (Table 2).

Table 2. Inclusion and exclusion criteria.

Inclusion Criteria	Exclusion Criteria
Studies conducted between 2013 and 2021	Studies conducted outside the selected range
Only peer reviewed articles from journals	Conference proceedings, book chapters, reports
Articles were written in the English language and related to energy education or energy literacy, RE, environmental education and education for sustainable development with theme of RE components, particularly the secondary level of education	Articles written in different languages and unrelated to secondary education and RE and ESD with RE components

After screening the articles based on the inclusion and exclusion criteria, we selected 25 articles for the final phase of PRISMA, and 38 articles were removed.

3.3. Inclusion Phase

The 25 articles, which were selected from the WoS and Scopus databases, were based on secondary education and RE, as well as sustainable development. WoS and Scopus databases were selected to ensure the quality of the papers and that they were peer reviewed papers. The included articles were thoroughly read and analyzed to find the author’s perspectives, results and opinions regarding the topic and also to find the gap in the research for the related topic. The summary of the articles that were selected for analysis is given in Table 3.

Table 3. Summary of the selected articles for analysis.

Authors	Title	Aim	Research Methodology	Educational Strategy	Findings
Miguel Ángel Queiruga-Dios, Emilia López-Iñesta, María Díez-Ojeda, María Consuelo Sáiz-Manzanares, and José Benito Vázquez Dorrio(2020) [19]	Citizen science for scientific literacy and the attainment of sustainable development goals in formal education	To propose the integration of a science project with the secondary education curriculum with citizens as the core focus, as well as to analyze the various changes in students' attitude toward technology and science and measure their literacy improvement in scientific processes for SDGs.	Experimental	Active learning, project-based learning, and interactive learning	The results of the study revealed a positive change in the interest and attitude of citizens toward science and technology. The integration of citizen science projects enhanced pupils' interest toward SDGs and contributed to changing their perceptions regarding environmental needs and their health.
Esra Çakırlar altuntaş, Salih Levent Turan (2018) [20]	Awareness of secondary school students about renewable energy sources	To analyze and identify the level of awareness on RE sources among secondary school students in Turkey.	Survey		The results revealed that their awareness about RE sources was at the intermediate level.
Mantu Kumar Mahalik, Hrushikesh Mallick, Hemachandra Padhan (2021) [21]	Do educational levels influence the environmental quality? The role of renewable and non-renewable energy demand in selected BRICS countries with a new policy perspective	To evaluate the roles and impacts of primary and secondary education levels on reducing carbon emissions and incorporating changes in renewable and non-renewable energy consumptions, as well as urbanization.	Survey		The study revealed that the presence of higher levels of education about RE and more investment in RE consumption reduced the emission of carbon from the studied countries. Thus, policymakers must focus on the investments in RE education and green-cities-driven urbanization to help the society adapt to the shift from non-RE to RE consumption.
Anas Zyadin, Antero Puhakka, Pirkkoliisa Ahponen, and Paavo Pelkonen (2014) [22]	Secondary school teachers' knowledge, perceptions, and attitudes toward renewable energy in Jordan	To investigate the attitude, knowledge, and perceptions of RE, as well as the neutral perceptions of the usage of RE technologies among secondary school teachers in Jordan.	Survey		The study revealed that the teachers exhibited very limited knowledge of RE and its usage. The teachers exhibited a positive interest in RE development, although they required personal training on RE concepts before the concepts could be fully introduced into the school curriculum.
Eva-Maria Waltner, Katja Scharenberg, Christian Hörsch, and Werner Rieß (2020) [23]	What teachers think and know about education for sustainable development and how they implement it in class	To clarify the necessity and relevance of education in the implementation of SDGs in Germany.	Survey		The results revealed that even though the teachers demonstrated high levels of sustainability awareness and interest in RE concepts for the protection of the environment, the policies regarding education for sustainable development (ESD) were ineffective. The teachers demanded support with more detailed and concrete teaching materials on ESD and more links to activities and extracurricular partnership facilities to acquaint students with the real-life applications.

Table 3. Cont.

Authors	Title	Aim	Research Methodology	Educational Strategy	Findings
Stamatios Ntanos, Grigorios L. Kyriakopoulos, Garyfallos Arabatzis, Vasilios Palios, and Miltiadis Chalikias (2018) [24]	Environmental behavior of secondary education students: A case study in Central Greece	To investigate the different environmental factors among secondary education students regarding a multiparametric analysis of the contributive roles of family and school curriculum, school environment, and procedures toward environmental awareness and participation.	Survey	Active learning and project-based learning	The result revealed a positive result on the students' awareness and attitude toward environmental safety, REs, and sustainable developments, although there was also a significant necessity to introduce more structured environmental education and courses in secondary education than what is currently obtainable since education and family will be key to assisting future students on tackling environmental issues.
Leire Agirreazkuenaga and Pedro Manuel Martinez (2021) [25]	Secondary students' perception, positioning, and insight on education for sustainability	To analyze and elucidate the perception of secondary school students in the Basque community about ESD in the Basque community.	Survey	Action-based learning and experiential learning	The results revealed that the students exhibited sufficient knowledge of the socio-environmental issues, but their actions did not correspond with their knowledge. To increase their interest and impact on their attitudes, environmental education or RE education must be present and experiential.
Judit García-Ferrero, Rosa P. Merchán, José M. Mateos Roco, Alejandro Medina, and María Jesús Santos (2021) [26]	Toward a sustainable future through renewable energies at secondary school: An educational proposal	To develop innovative educational activities on RE concepts and energy production in a real-life secondary education curriculum.	Experimental	Active learning, project-based learning, and collaborative learning	An educational proposal, which allowed students to engage in RE-production-related activities and projects to enhance their learning, innovation, creativity, and interest in SDGs.
A. McKinzie Sutter, Jenny M. Dauer, Tobias Kreuziger, Jan Schubert, and Cory T. Forbes (2019) [27]	Sixth grade students' problematization of and decision-making about a wind energy socio-scientific issue	To develop an instructional model for a local wind energy project to analyze how sixth-grade students framed, absorbed, reasoned, and decided to tackle the issue.	Experimental	Problem-based learning, Collaborative learning	The result revealed that the sixth-grade students' process of tackling the issues demonstrated their positive attitude toward socioscientific issues (SSI) even though they might not exhibit fully developed ideas about REs. The manner with which the students problematized and engaged in decision making on energy-related SSIs was key to tackling future global challenges, and their abilities to tackle SSIs are an essential component of their scientific and environmental literacy that would be pivotal to future global energy sectors.
Olugbenga Adedayo Ige, Loyiso C. Jita, and Thuthukile Jita (2019) [28]	Major personality traits influencing environmental knowledge: A case of urban learning ecologies	To investigate the impact and influence of the major personality traits of students in urban learning spaces on their environmental knowledge.	Survey		The results revealed that most of the personality traits of students were significant determinants of their environmental knowledge, and this must be considered by teachers and implemented in the environmental education curriculums of their schools.

Table 3. Cont.

Authors	Title	Aim	Research Methodology	Educational Strategy	Findings
Michael A. Cohen, Greg O. Niemeyer, and Duncan S. Callaway (2017) [29]	Griddle: Video gaming for power system education	To develop and test the impact of an interactive educational video game, “GRIDDLE,” which introduces secondary school students to the basics of power systems operations	Experimental	Interactive and game-based learning	The results revealed that the video game positively impacted the students by helping them comprehend key concepts about energy, as well as clarifying the effects of fossil fuels and the necessity of RE technologies.
Iwona Ocetkiewicz, Barbara Tomaszewska, and Anna Mróz (2017) [30]	Renewable energy in education for sustainable development. The Polish experience	To evaluate the experiences of upper secondary school teachers in Poland regarding ESD.	Survey		The results revealed that the teachers were not well prepared for the inclusion of RE and other key SDG issues into the school curriculum.
Dilek Çelikler and Zeynep Aksan (2015) [31]	The opinions of secondary school students in Turkey regarding renewable energy	To determine and analyze the secondary school students’ levels of awareness and knowledge regarding RE technologies and resources, as well as their opinions regarding RE.	Survey		The study revealed that 55.7% of the students learned about RE in their secondary schools and exhibit relatively good knowledge about the various RE resources. However, their limited amount of information regarding global warming, as well as their hesitant opinions to live near RE power plants indicated that additional educational steps were required to avail detailed information about RE and groom children with higher levels of awareness and knowledge.
Hazlee Azil Illias, Nabilah Syuhada Ishak, and Nurul Aini Mohd Nor Alam (2020) [32]	Awareness towards renewable energy among secondary school students in Malaysia	To assess the level of awareness among secondary school students regarding RE in Petaling Jaya city, Malaysia.	Survey		The result revealed that the education year, family attitude toward energy conservation and exposure to RE demands from the outside caused a significant difference in the students’ perception of RE. The results can be employed to develop and modify existing syllabi on RE in the curriculum of secondary schools in Malaysia.
Ibolya Markóczi Revák, Erzsébet Jász, Enikő Kovács, Károly Teperics, Judit Útő Visi, and János Máth (2019) [33]	Primary and secondary school students’ knowledge related to renewable energy and some of its influencing factors	To analyze students’ knowledge about RE resources and identify the differences in their knowledge based on their different grades and the correlation between RE knowledge and other influencing factors.	Experimental	Active learning, Project-based learning.	The result revealed that the students’ knowledge was poor and unstable. The factors that influenced the level of knowledge acquired by the students were their types of residents, family education levels, school curricula, textbooks, project works, and the media.
Omolade Adeleke and Mbonigaba Josue (2019) [34]	Poverty and green economy in South Africa: What is the nexus?	To investigate the relationships between a sustainable green economy and poverty in the South African context.	Survey		The results revealed the long-term effect of a green economy and sustainable development where secondary education is a significant indicator of poverty reduction and sustainable development in South Africa.

Table 3. Cont.

Authors	Title	Aim	Research Methodology	Educational Strategy	Findings
Tamas Beke (2016) [35]	A simple model for the energy supply of a stand-alone house using a hybrid wind–solar power system	To develop a project for secondary school students based on RE, particularly solar and wind energies.	Experimental	Project-based learning, active learning, and collaborative learning	The project increased the students' internal motivation toward the RE concept and promoted their awareness regarding their roles in environmental protection.
Knut Hjelleset (2020) [36]	The kids are all right: Lessons from recent changes in student preferences in Norway's oil-dependent regions	To examine the impact of formal education on successful climate-change education in Norway.	Experimental	Multidisciplinary project-based learning.	The study investigated the two types of climate education sources in Norway, namely nonformal (from the media and other environmental organizations) and formal education, as well as how they can be combined to develop more impactful climate-change education and develop a more active citizenry. The study reported that schools must adopt new types of curricula for sustainable solutions and RE in lower and upper secondary schools.
Eirini Ntona, Garyfallos Arabatzis, and Grigorios L. Kyriakopoulos (2015) [37]	Energy saving: Views and attitudes of students in secondary education	To investigate students' complex views on energy and their attitude toward the usage of energy in relation to the environment.	Survey		The result revealed the necessity of a drastic change in human behaviors toward the environment and SDGs, as well as the key role of environmental education in this regard.
Michael Danaher, Jiaping Wu, and Michael Hewson (2021) [38]	Sustainability: A regional Australian experience of educating secondary geography teachers	To investigate the usage of experiential activities and knowledge to analyze how tertiary level teachers can adapt these to help students understand and appreciate sustainability principles.	Experimental	Active learning and multidisciplinary	The result revealed the relationship between geography-based activity training and students' knowledge of employing geographical patterns to promote sustainability skills and knowledge embedded within Australian geography. The study also revealed the role of collaboration between university teachers of sustainability and school-based pedagogy to maximize the efficacy of ESD in schools.
Dimitrios Drosos, Grigorios L. Kyriakopoulos, Stamatis Ntanos, and Androniki Parissi (2021) [39]	School managers' perceptions towards energy efficiency and renewable energy sources	To investigate the perception of school managers (principals) on RE and the need for energy conservation and green energy.	Survey		The study revealed that school managers in Greece exhibited high sensitivity toward environmental protection and promoted energy-conserving behaviors in the school environment. They strongly believed that more education is required on RE sources in the education curriculum of schools. A positive relationship was also reported between the school manager's energy-saving and RE beliefs, as well as the students' and teachers' perception of the same topics in the same school environment.

Table 3. Cont.

Authors	Title	Aim	Research Methodology	Educational Strategy	Findings
Sen-I Chien, Chaochin Su, Chin-Cheng Chou, and Hsiou-Hsuan Wang (2021) [40]	Research Insights and Challenges of Secondary School Energy Education: A Dye-Sensitized Solar Cells Case Study	To investigate the impact of introducing a dye-sensitized solar cells (DSSCs) course in Secondary School Energy Education and how it influences the students' attitudes towards sustainability.	Experimental	Active learning, Action-based learning, and Multidisciplinary learning.	The result of the experiment showed that the students enjoyed learning via the strategies used and the results of the questionnaire highlighted an increase of students' motivation, experimental skills, and positive attitude toward sustainable development. Additionally, questionnaire focused on the teachers who participated in the workshop, showed that they all had a positive attitude and suggested that courses like this would be beneficial if integrated into the secondary school courses using the same teaching strategies.
Mageswary Karpudewan, Jamunah Ponniah, Ahmad Nurulazam Md. Zain (2015) [41]	Project-Based Learning: An Approach to Promote Energy Literacy Among Secondary School Students	To investigate the effectiveness of a newly developed Project-based learning energy education resources in increasing Malaysian secondary school students' awareness, attitudes and positive beliefs towards energy conservation.	Experimental	Project-based learning	The experiment showed a positive result in the students' perception towards energy conservation and increased their knowledge, attitude and behavioral factors toward energy literacy. The experiment also highlighted how project-based learning can be a great instructional method and teaching strategy towards implementing energy education in secondary schools in Malaysia.
Kuan-Li Chen, Shiang-Yao Liu, and Po-His Chen (2015) [42]	Assessing multidimensional energy literacy of secondary students using contextualized assessment	To investigate the existing energy literacy of Taiwanese Secondary students via a series of contextualized questions build into a computer-based test platform.	Survey		The result indicated that there is a discouragingly low level of energy literacy prevalence amongst the Taiwanese secondary school students and that there is a strong correlation between energy knowledge and behavior of the students towards energy preservation. The findings were suggested by the authors to be used to develop future energy-related educational curricula and materials to improve students' energy literacy and engagement.
Yoon-Fah Lay, Chwee-Hoon Khoo, David F. Treagust, and A. L. Chandrasegaran (2013) [43]	Assessing secondary school students' understanding of the relevance of energy in their daily lives	To investigate the levels of energy literacy amongst Malaysian Grade 8 students	Survey		The quantitative research used Energy Literacy Questionnaire (ELQ) and found that the levels of energy literacy amongst the students were very low, highlighting the fact that existing curriculum had failed to meet the intended impact. The authors also suggested to develop a context-based curriculum that emphasis on practical energy-related knowledge, decision making skills, ethical dimensions and personal responsibility related to energy consumption in Malaysia.

4. Findings

Education was identified as a key factor for achieving the RE education goals and SDGs and for driving society toward the required changes in environmental safety and harnessing of RE sources [25]. RE education is pivotal to creating awareness and promoting SDGs for RE, particularly the sustainable management of renewable resources, to shape a generation of future global citizens who would be more aware and concerned about environmental safety and global RE needs [30].

The selected 25 articles were analyzed comprehensively by reading through and finding out the authors perspectives, results from the experiments conducted and analysis of the surveys conducted. Based on the analyses of the selected articles, most previous research identified the lack of RE-concept-centered education and ESD at the secondary school level of education globally [20,23–25,31,33,39,42,43]. This lack of education directly contributed to the lack of awareness about RE and its concepts among secondary school students [21,34]. Although some students exhibited basic knowledge or had learned about RE sources and the basic concepts, their knowledge was insufficient, and most of the students were unaware of the serious role of RE concepts in environmental protection [33]. According to the study by Celikler and Aksan, which was conducted in Turkey, 55.7% of the students had heard about RE and exhibited some knowledge about the different types of RE sources, although their lack of sufficient systematic information about global warming and the relevance and necessity of RE technologies forced them to hesitate toward residing close to an RE power plant, highlighting a scary portrayal of how a lack of awareness and education could negatively impact future generations regarding RE [31]. Additionally, a lack of curricula on RE and ESD was visible; although the students exhibited knowledge about the existing socio-environmental issues in the world, their actions did not correspond to their knowledge because of their lack of interest and motivation regarding environmental issues. This could be overcome by introducing systematic curricula on environmental and RE topics from an early stage along with other STEM curricula to expose students to the various concepts of RE and other sustainable development technologies [26,39]. However, simply introducing the curricula would be insufficient if the teaching and learning approaches fail to explore active learning involving the community, home, and technological factors. The curricula must also feature multidisciplinary concepts [40,41] that integrate all the mentioned factors before introducing the curricula into the secondary education spectrum.

The analyses of the selected literature also highlighted another relevant factor that directly contributes to the lack of education on RE in secondary schools, as well as the lack of expertise and knowledge about RE and sustainable development among teachers [23,24,31]. Teachers play a pivotal role in how students can acquire the knowledge being transmitted; a lack of expertise and knowledge on the teacher's path would directly impact the student's knowledge, motivation, and interest regarding a particular subject [30]. The studies conducted in Jordan, Germany, and Poland revealed that the teachers exhibited very limited knowledge and experience in RE concepts and sustainable development [23,24,31]. It was observed that the teachers required personal training and detailed teaching materials on ESD and RE concepts, as well as environmental education [23,31]. The teachers also required access to facilities that facilitated activities and extracurricular partnerships to afford the students more practical-based real-life applications to introduce and have effective curricula on RE concepts and SDGs at the secondary school level [23]. Considering that these approaches and concepts were considered new to the teachers, pre-service and in-service training for teachers must emphasize these new approaches to increase their expertise in RE-targeted ESD and SDG.

Apart from teachers' influences, the other factors that also influenced student's knowledge about RE and SDG concepts were their family background and education level, as well as the types of available curricula in the school, the media, their families' attitudes toward energy consumption, and their attributes, which the researchers proposed to consider while developing a curriculum for RE and SDG concepts for secondary school education [25,29,33,34,37,38]. The majority of the research analyzed conducted survey on

students and few on teachers but lacked focus on parents' influences and attributes that may directly contribute to the students' perceptions and influence their attributes toward RE education.

Employing different educational strategies, some of the selected articles proposed and introduced different types of content, activities, RE projects, and sustainable development concepts into the secondary curricula of different schools to analyze the impact of such introductions on the student's levels of awareness, knowledge, motivation, and interest in STEM subjects and RE concepts. The educational strategies employed were active, interactive, game-based, project-based, experiential, action-based, collaborative, problem-based, and multidisciplinary learning strategies (Table 3). The results indicated that the introduction of such content on RE and sustainable development concepts increased the overall interests of the students in RE concepts and STEM subjects, motivated them to learn more about the environmental issues and how to address them, increased their knowledge about RE concepts, and increased their awareness about the necessity of environmental safety and the different strategies for harnessing green and clean environmentally benign energy [20,27,28,30,36,39–43].

Overall, the analyses of the selected articles revealed the significant necessity of secondary education in achieving the RE SDGs of society and highlighted the lack of secondary education in existing educational trends globally. The analyses revealed how secondary education and the introduction of different types of content and activities via different educational strategies can impact the student's perception regarding RE. Table 4 reveals that five articles among the selected ones directly highlighted the increase in the awareness of RE and SDG among the students when RE concepts and ESD were introduced into the secondary level of education [24,25,33,36,40]. Furthermore, five research works directly highlighted the increase in the students' motivation toward RE and SDGs [20,28,31,40,41]. Three of the articles highlighted the students' increased interest [20,23,27], and seven directly highlighted the increase in the students' knowledge about RE and sustainable development [26,30,32,34,39–41]. Out of the selected 25 articles, only 14 articles dealt with and reported the impact of RE education on students' personal attributes, which shows a lack of studies that can identify the more in-depth impact of RE education in the secondary education on the students' behavior and attributes and also focus on their interest and motivation toward pursuing higher education or careers in the RE fields.

Table 4. Impact of secondary school education about RE and SDGs on the students.

Impact of Secondary School Education on RE and SDGs on the Students				
Articles	Awareness	Motivation	Interest	Knowledge
[19]			✓	
[22]			✓	
[23]	✓			
[24]	✓	✓		
[25]				✓
[26]			✓	
[29]				✓
[31]				✓
[32]	✓	✓		
[33]				✓
[35]	✓	✓		
[38]				✓
[40]	✓	✓		✓
[41]		✓		✓

5. Discussion

Here, 25 selected articles were analyzed, and a model was designed to highlight the different factors that can influence the promotion or introduction of RE-centered ESD and their impacts on the students' general perceptions about RE and SDGs. This model can be employed as a conceptual framework for developing new methods toward RE education, as well as the promotion of RE among secondary school students.

Based on the views of the various researchers captured in this study, factors, such as teachers' roles and students' personal factors (family background, family income, and neighborhood), were key to promoting awareness regarding RE and ESD (Figure 2). These factors must be considered when developing and introducing curricula for RE education into secondary education [29,33,38]. The analyses highlighted a lack of teachers' expertise and knowledge on RE and sustainable development, which must be addressed via personal training for teachers [44] and the provision of detailed materials for teachers to utilize as content for teaching [23,24,31]. Finally, educational strategies, such as game-based, project-based, collaborative, and multidisciplinary learning strategies, were explored by researchers to implement projects, activities, and assignments in secondary schools, and the results revealed positive effects on the student's awareness, interest, motivation, and knowledge about RE and ESD; thus, these educational strategies can be explored to formulate new RE and ESD curricula and introduce them to the secondary education level [20,25,27,28,30,36,39–41]. The multidisciplinary approach achieved great success based on a study that was conducted in Australia, where the geography subject was combined with RE education to increase students' awareness and knowledge on RE sources and their implications [38]. Additionally, the multidisciplinary teaching strategy combined with other strategies, such as activity learning and project-based learning, showed great improvement in students' knowledge and interest toward RE education when incorporated in their curricula. One such example is the experiment of integrating the Dye-Sensitized Solar Cells Case Study (DSSCs) using computer-based and multimedia resources in a Taiwanese secondary school that showed a significant increase in students' awareness, motivation, and knowledge of RE education [40]. Additionally, another experiment conducted in Malaysia where project-based learning and multidisciplinary teaching strategies were used together to investigate the impact on students' knowledge, attitude and behavior showed an increase in all the factors once the course was integrated into their existing curricula [41]. With its recent advancement, technology influences the educational system, facilitating rapid transformations toward modern teaching methods, promoting the application of technology to teaching [45]. Among the other technologies, mobile learning was the most widely employed trend in recent times to address global educational challenges. Mobile learning also ensures quality education for all by availing opportunities for everyone to learn about new concepts and acquire knowledge about ESD [46]. Since this generation is more accustomed to mobile technologies, as evidenced in their everyday life [47], involving technologies, such as mobile learning or flipped classroom or interactive game-based learning [48] employing mobile technologies to facilitate RE-centered ESD would much more efficiently and effectively encourage this generation of students to pursue the curricula. Apart from the traditional formal learning approach, another educational strategy that could be proposed for RE-targeted ESD from this analysis is the non-formal learning approach in which external sources, such as the media, society, and external personnel links, can be employed to help the students acquire knowledge and awareness regarding RE and ESD [36]. Non-formal learning refers to the development of skills and knowledge from any source other than the traditional methods of learning, as well as where there are no formal assessments, such as exams [49,50]. A study, which was conducted by the National Science Foundation-funded LIFE Center, US, revealed that 70%–90% of human learning processes were derived from non-formal learning, which equates to a person spending one hour in a formal learning environment while spending four times more time in non-formal learning one [51]. Thus, combining multidisciplinary education or STEM-driven education [52] with non-formal learning and a technology-based approach for RE-centered ESD can be used

to develop new curricula on RE education and thus increase the impact of the developed curricula on the students' attributes, perceptions, and interest in environmental education and protection.

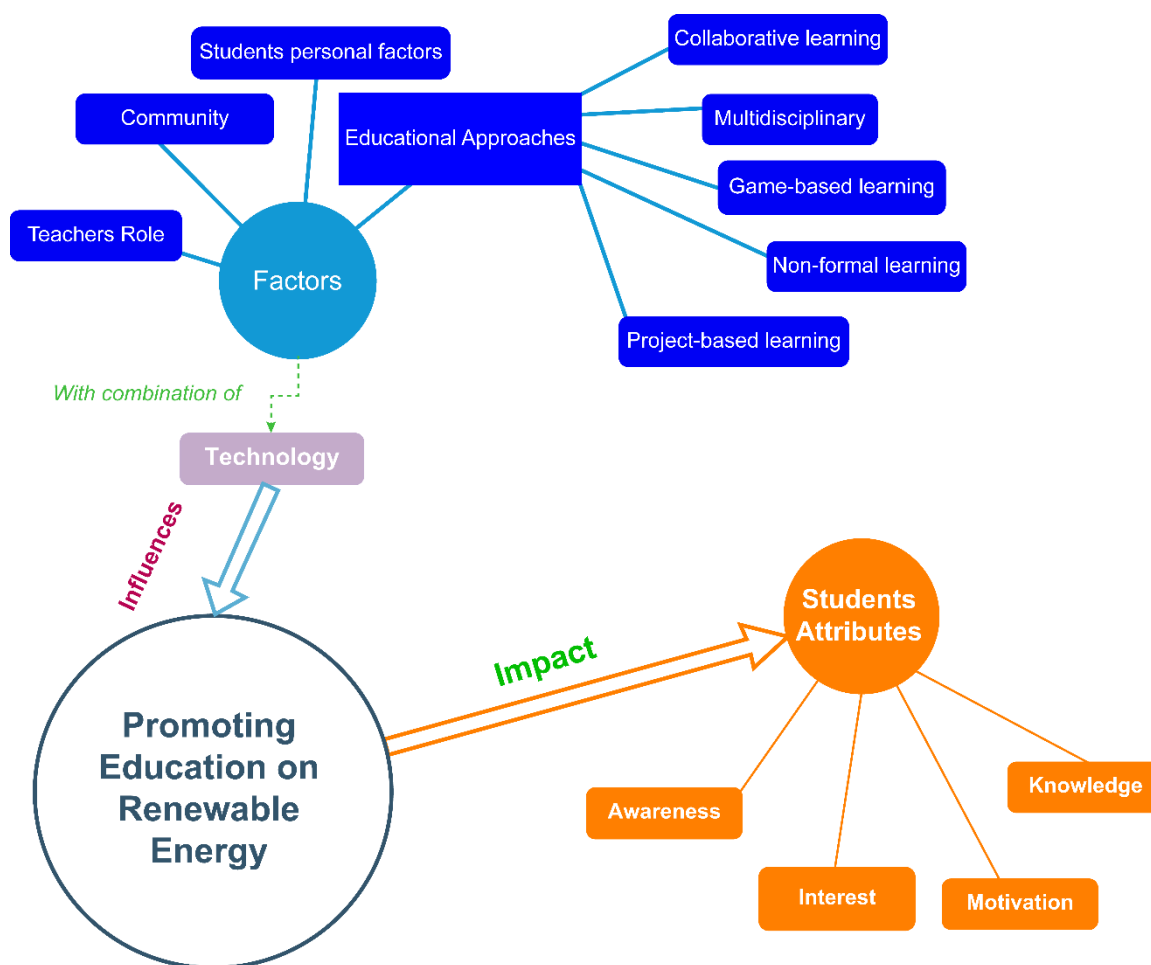


Figure 2. Suggested model for a comprehensive curricular development of RE education in the secondary school level.

These factors can be key to promoting or developing curricula for RE-targeted ESD, as well as introducing them into secondary schools in the future. Their impact on the students was positive, as analyzed in this paper. The articles of the various researchers in this study increased students' awareness regarding RE and ESD [24,25,33,36,40,41], acting as a catalyst to motivate students to pursue higher education and careers in the RE sector or STEM in general. Other impacts, such as increased interest and motivation, were demonstrated in the studies [20,23,25,27,33,36,41], which enabled society to develop more prospective students with interests in STEM career paths and the RE or sustainable development sectors, as well as shape future generations of students with adequate knowledge [26,30,32,34,39] regarding the importance and necessity of harnessing RE and environmental protection, thus developing a society whose citizens are aware of their duties and roles in environmental protection.

6. Limitations

This systematic review exhibited two limitations that must be addressed by academics who intend to further research this topic. First, this study relied on high-quality articles on the WoS and Scopus databases. Other articles with similar qualities are available in other reputed databases, including ERIC and Google Scholar, and subsequent researchers can explore more perspectives and outcomes from other research within the same scope. Second,

this research focused only on RE and ESD at the secondary level of education, as well as their impact on students' awareness, motivation, and interest in the said topics. Future academics can expand the research to include higher education and how the availability of RE-targeted ESD in secondary education can motivate more students into pursuing the related courses in their higher education.

7. Conclusions

The PRISMA protocol was adopted to analyze 25 articles related to secondary education on RE concepts and sustainable development, which were obtained from Scopus and WoS databases. The analysis was performed to investigate the existing availability of curricula on RE concepts, sustainable development, and environmental education in secondary education. Different studies worldwide involving different methodologies, educational strategies, and surveys, were reviewed to identify the current state of RE education in the selected topic in secondary education in the respective cities or countries of the researchers. Most of the researchers strongly identified the lack of available curricula for RE education in secondary schools, directly accounting for the lack of awareness, motivation, and interest of the students in RE concepts and environmental protection. This lack of awareness and knowledge regarding the harmful environmental effects of fossil fuels becomes an obstacle for a society that wishes to shift from harnessing fossil fuels to more RE sources. Additionally, many researchers developed different activities, projects on RE technologies, environmental education, and energy harnessing from renewable sources employing different educational strategies, including active, project-based, and collaborative learning, as well as game-based learning and multidisciplinary strategies. The introduction of these extra contents into the existing secondary school education system yielded positive outcomes for students regarding their interests in RE and environmental safety; their awareness of the existing environmental issues; and the need for RE concepts, motivation to pursue careers in RE and sustainable development fields as well as increasing their knowledge of the basic concepts of RE and sustainable development. The analyses also revealed the lack of knowledge and expertise among the teachers at secondary schools regarding sustainable development and RE concepts, and these must be addressed via personal training and structured content materials on the subjects. Owing to the lack of competence, skills, and knowledge among teachers regarding sustainable development, the implementation of curricula for RE and sustainable development concepts in secondary education would be arduous and might not achieve the desired outcome regarding students' increased awareness, motivation, and interest toward a STEM career. The selected articles for the analysis also exposed the lack of attention toward the technologies that are currently employed in the education system for RE-targeted ESD, which constitutes a big setback since the current generation of students is more accustomed to mobile learning and other technology-based learning strategies that can be introduced into the ESD and RE Education to increase their impact on the current generation of students.

The lack of secondary education curricula on RE concepts and sustainable development subjects negatively impacts a society or nation's goal of achieving the RE SDGs. Thus, it is of paramount importance to develop new or modified RE education curricula using different methods and factors showcased in the proposed model in this paper (Figure 2), and introduce them to the secondary school education, as well as train teachers to acquire the required skills, knowledge, and expertise to teach the students about these subjects through multidisciplinary strategies to rapidly improve the student's awareness and interest in RE concepts, thus encouraging them to pursue higher education and careers in the RE and STEM sectors and help society to protect the environment for future generations.

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