Prisma Sains: Jurnal Pengkajian Ilmu dan Pembelajaran Matematika dan IPA IKIP Mataram
https://e-journal.undikma.ac.id/index.php/prismasains/index
e-mail: prismasains.pkpsm@gmail.com

July 2025. Vol. 13, No. 3
p-ISSN: 2338-4530
e-ISSN: 2540-7899
pp. 703-718

Exploring Indonesian Students' Views on Solar Panels and Fossil Fuels: Education for Sustainable Development Perspective

[1*]Ai Nurlaelasari Rusmana, [1]Putra Habib Dhitareka, [2]Rahmi Qurota Aini, [3,4]Yustika Sya'bandari

[1]Department of Science Education, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudi No.229, Bandung 40154, Indonesia
[2]Department of Biology, Middle Tennessee State University, Murfreesboro 37132, United States
[3]Department of Science Education, Kangwon National University, 1 Kangwondaehak-gil, Chuncheon-si, Gangwon-do 24341, South Korea
[4]Sekolah Bogor Raya, Jl. Danau Bogor Raya No.19, Bogor 16154, Indonesia
*Corresponding Author e-mail: airusmana@upi.edu

Received: May 2025; Revised: July 2025; Published: July 2025

Abstract

Understanding how young people perceive renewable and non-renewable energy sources is essential for aligning education with Sustainable Development Goals (SDGs). This study explores the perspectives of 748 Indonesian high school students on solar panel versus fossil fuels through an open-ended question. Different from previous studies, this work uses semantic network analysis to map the conceptual connections in students' understanding, which provides us a structural perspective on students' perceptions. Using semantic network analysis with NetMiner, 748 Indonesian students' responses were categorized into five ideas: Fossil fuels formation (G1), Solar panel role in sustainability (G2), Practical benefits of solar panels (G3), Non-renewable resource concern (G4), and Unsustainable fossil fuels use (G5). The findings indicate that students have a basic understanding of environmental and resource-related issues. Most responses remain surface level with limited demonstration of critical thinking. Furthermore, students' ideas primarily address the environmental and economic pillars of Education for Sustainable Development (ESD) while the social pillar is rarely discussed. These results highlight the need to improve ESD practices in Indonesia by explicitly integrating social dimensions into sustainability education. Empowering students to consider who is affected by sustainability decisions, and how they can contribute to fairer, more inclusive solutions can help to increase not only environmental awareness but also foster civic responsibility and empathy.

Keywords: Energy; ESD; High school students; Indonesia

How to Cite: Rusmana, A. N., Dhitareka, P. H., Aini, R. Q., & Sya'bandari, Y. (2025). Exploring Indonesian Students' Views on Solar Panels and Fossil Fuels: Education for Sustainable Development Perspective. *Prisma Sains : Jurnal Pengkajian Ilmu Dan Pembelajaran Matematika Dan IPA IKIP Mataram*, *13*(3), 703–718. https://doi.org/10.33394/j-ps.v13i3.15963

https://doi.org/10.33394/j-ps.v13i3.15963

INTRODUCTION

Moving from fossil fuels to renewable energy is now an important global project as we face the growing effects of climate change, environmental harm, and the loss of natural resources (Olujobi et al., 2023). Clean energy options including wind, solar, hydroelectric, and geothermal power provide eco-friendly substitutes for traditional fossil fuels such as coal, oil, and natural gas (Ewim et al., 2023). Those energy forms are required for combating climate change, enhancing energy independence, improving air quality, and driving economic growth via green employment and technological advancements (Esiri et al., 2023; Kabeyi & Olanrewaju, 2022).

The growing popularity of solar panel in Indonesia reflects the transition towards green and clean energy sources that is supported by country's geographical advantages, government policy, and technological advancements. As a country located in the equator line, Indonesia grants an average solar irradiance about 4.8 kWh/m² per day, making it one of the countries with significant potential for solar energy utilization globally (Laksana et al., 2021). The Indonesian government has recognized the potential of solar energy and is making substantial investments in solar technology as a key component of its broader renewable energy agenda. This commitment is outlined in the National Energy Plan (Rencana Umum Energi Nasional/RUEN), which sets ambitious targets for integrating Renewable Energy Technologies (RET) into the national energy mix 23% by 2025 and increasing to 31% by 2050 (Afif & Martin, 2022; Febrian et al., 2023; RUEN, 2017).

Despite these potential and commitment, the archipelago's primary energy needs are still dominated by fossil fuels, including coal, oil and natural gas, to meet electricity demand (Afif & Martin, 2022; Aprilianti et al., 2020), which has been growing at more than 6% per year since 2000 (ESDM, 2010). In other words, the abundant renewable energy resources in Indonesia have not been optimally utilized and the implementation of renewable energy technology (RET) has been slow (Alnavis et al., 2024; Langer et al., 2021). According to previous studies (Aprianto et al., 2024; Pambudi et al., 2023; Pambudi et al., 2024), the transition to renewable energy in Indonesia is challenged by high production costs, lack of infrastructure, variations in resource location, technological limitations, and low public awareness about renewable energy policies and benefits.

Public awareness refers to how much people know and understand about a particular issue, including its importance and why it matters. Public awareness has been a key factor in reaching many important societal goals. Therefore, the public awareness about renewable energy determines the success of the transition (Esiri et al., 2023). Studies have shown that societal attitudes towards energy sources can significantly influence the adoption and acceptance of renewable technologies (Sovacool, 2014). In Indonesia, despite the implementation of Education for Sustainable Development (ESD) in schools, the public's understanding of renewable energy, particularly solar energy, remains varied and often limited, with many still perceiving fossil fuels as more reliable or affordable sources of energy (Alnavis et al., 2024). There is a growing curiosity about sustainable energy among younger generations, particularly students, but this interest is often not matched by in-depth understanding or critical engagement (Takács-György et al., 2015). As youth represent the next generation of consumers, innovators and policy makers, it is important to explore how they perceive solar panels in comparison to fossil fuels. Moreover, Indonesia's current demographic profile, with 65% of its population under 35 (ESCAP, 2020), positions the young generations as important stakeholders in achieving the renewable energy targets outlined in the RUEN. Therefore, understanding the perspective of Indonesian students regarding renewable energy (i.e., solar panel) and non-renewable energy (i.e., fossil fuels) may provide valuable insights into societal readiness for a sustainable energy future and highlight areas where education and communication efforts need to be strengthened.

In connection with the topic, the student's perception about energy (solar panel and fossil fuels) should be clearly discovered. Prior studies (e.g., Ewim et al., 2023; Kishore & Kisiel, 2013; Pambudi et al., 2024) have primarily assessed factual knowledge or attitudes using interviews, multiple-choice tests, and Likert-scale questionnaires. While these approaches are informative, these approaches do not reveal how students structure their knowledge about energy concepts.

According to Siew (2020), knowledge is not merely an accumulation of disparated facts about particular topic, but rather a dynamic system of interconnected concepts. Understanding how learners connect these concepts is important in discovering the depth and coherence of their conceptual understanding. As noted by Aviv et al. (2003) and Siew (2020), techniques from network science, including semantic network analysis are particularly effective at capturing the relational nature of knowledge. By modeling students' understanding as networks, where nodes represent key terms and edges shows meaningful relationships between them, researchers can explicitly quantify and visualize the structure of students' thinking (Drieger, 2013). This network based approach provides insights into how ideas are organized and linked, offering a more comprehensive understanding than traditional method. In the context of Education for Sustainable Development (ESD), particularly energy, applying semantic network analysis (SNA) or language network analysis enables the identification of central key terms/concepts, the associations between them, and the overall coherence of students' perceptions of energy. Besides, SNA allows us to visualize the conceptual structure underlying students' language used to perceive energy, offering a unique perspective on their perceptions that traditional tools cannot capture. This is useful when investigating complex topics such as renewable versus non-renewable energy sources, where students often have fragmented or surface-level views. Therefore, SNA not only aligns well with cognitive perspectives that emphasize conceptual interconnectivity (diSessa, 2013; Hammer, 1996) but also fills a methodological gap by providing a structural and analytical view to study students' open-ended responses. Despite its potential, SNA has rarely been used in assessing students' understanding on energy, particularly in the context of ESD. Based on the background above, the present study addresses this gap by exploring the following research questions:

1. What are the common words that students use to describe solar panels and fossil fuels based on semantic network analysis?
2. How do high school students perceive of solar panels and fossil fuels related to ESD perspective?

Education for Sustainable Development (ESD) in Indonesia

Education is key to achieving sustainability (Walshe, 2013). Education plays a crucial role in fostering positive attitudes towards renewable energy among youth. As attitude alone may not lead them to informed decision-making, structured educational efforts are needed to build critical thinking, systems understanding and sustainability values. Education for Sustainable Development (ESD), as promoted by United Nations Educational, Scientific and Cultural Organization (UNESCO), emphasizes to equip learners with the knowledge, skills and attitudes needed to act for a sustainable future, including in energy use and environmental management (UNESCO, 2018). By developing knowledge, attitudes, skills, and values that enable individuals to participate in decision-making processes, both personally and collectively as well as locally and globally, Laurie et al. (2016) added that ESD aims to improve the quality of life in the present without damaging the quality of life in the future. To achieve that goal, students must develop certain sustainability competencies to think and act for sustainable development. These competencies include system thinking, anticipatory, normative, strategic, collaboration, critical thinking, self-awareness, and integrated problem solving (Eliyawati et al., 2023a).

Before the term "ESD" was introduced, environmental education focusing on green issues had already been implemented. Within the context of Indonesian schools, environmental education has been implemented since 2006 through a green school program known as the Adiwiyata program, which was initiated by the Ministry of the Environment (Suwarto et al., 2021). The program aimed to promote knowledge and awareness of environmental conservation efforts among students by encouraging environmentally friendly behavior (One Planet, 2015). Schools that have implemented the program are further called Adiwiyata schools. Suwarto et al. (2021) added that two models are commonly applied in the implementation of environmental education in Adiwiyata schools: 1) adding sustainable science content to the science and technology curriculum and 2) incorporating science education into ESD-driven school development. In conclusion, the science subject plays a central role in ESD integration in Indonesian schools.

On the other hand, Eliyawati et al. (2023b) stated that two main challenges are commonly present when integrating ESD into science learning. Firstly, the perception of science teachers and school science textbooks primarily view ESD as a content, therefore the action-oriented and interdisciplinary nature of ESD is often inadequately applied (Sinakou et al., 2022). Secondly, the three pillars of ESD (social, environmental and economic; Sinakou et al., 2019) are not fully integrated, as most science teachers emphasize only the environmental pillar when teaching ESD. In Suwarto et al.'s study (2021), in which the researchers analyzed science lesson plans in Adiwiyata schools, they also found that the social and economic dimensions of ESD were not mentioned at all in the lesson plans. Meanwhile, environmental awareness was emphasized many times throughout the learning process, from beginning to end. Teachers' strong orientation towards scientific thinking and limited openness to diverse perspectives makes it difficult for them to connect scientific topics with the social and economic dimensions of ESD (Borg et al., 2012).

This pattern reflects global concerns. According to the 2023 UNESCO Global Education Monitoring (GEM) Report, the implementation of Education for Sustainable Development (ESD) worldwide tends to marginalise social issues such as inclusion, equity and citizenship, therefore undermining the broader goals of sustainable development. According to Wals and Lenglet (2016) ESD paradigm should move away from transmissive, subject-bound instruction towards social learning. In this approach, learners actively engage in meaning-making, dialogue and critical reflection on sustainability challenges. Wals and Lenglet (2016) propose developing sustainability citizens where individuals capable of navigating complexity and participating in social change through collaborative and disruptive learning processes. From this perspective, science education should go beyond environmental literacy and cultivate the agency, values and social competencies required to shape fair and resilient futures. To support this transformation, Eliyawati et al. (2023b) also suggest a more comprehensive ESD frameworks that integrate holism, pluralism, and an action-oriented approach. This framework can bridge the gap between science and civic responsibility, encouraging the learners to connect knowledge with ethical, local, and global action.

METHOD

Participants

This study involved a total of 748 high school students in Indonesia. They were from general high schools (SMA) and Islamic high schools (MA) in three provinces in Indonesia: West Java, Central Java, and DKI Jakarta. Of 748 students, 230 were male (30.7%) and 518 were female (69.3%). In terms of grade level, 310 students (41.4%) were in 10th grade, 126 students (16.8%) were in 11th grade, 300 students (40.1%) were in 12th grade, and 12 students (1.6%) did not report their grade level.

Research Instrument

An online questionnaire was administered to students using Google Forms. The instrument included one open-ended question related to energy, specifically, solar panels and fossil fuels: "Why can solar panels be more important for sustainable development than fossil fuels?" This open-ended format allowed students to express their reasoning in their own words, providing deeper insight into their understanding and perspective on renewable and unrenewable energy. Although it is limited to one item, this format aligns with the goal of the study, which is to analyze conceptual structure using semantic network analysis. A focused question enables students to respond freely while ensuring that their responses remain within a meaningful scope for network mapping (Rusmana et al., 2021). Before being delivered to students, the question was reviewed by a science education professor and three science education researchers to ensure clarity and content validity. The wording was refined to reduce ambiguity and encourage substantive responses related to fossil fuels, solar panels, and sustainable development, avoiding overly broad or vague interpretations.

Data Analysis

Semantic network analysis was conducted using NetMiner to explore high school students' perspectives on solar panels in comparison to fossil fuels. NetMiner is a software tool designed for the exploratory analysis and visualization of patterns and structures in network data. The data analysis procedure using NetMiner followed the study of Rusmana et al. (2021) that analyze high school students' perception of species concept. Figure 1 illustrates the research procedure using semantic network analysis in the present study.

First, all student responses were originally written in Indonesian and translated into English using Google Translate function in a Google spreadsheet. To ensure accuracy and preserve the intended meaning, the researcher, native Indonesian speaker with C1-level English proficiency (advanced) carefully reviewed and validated the translated texts. Due to the large volume of data (748 open-ended responses) and the time-intensive nature of formal back-translation, it was not employed. Instead, the researcher thoroughly cross-checked the relevant to the analysis. This bilingual validation process was appropriate for semantic network analysis, in which consistency in meaning and conceptual relationships is important.

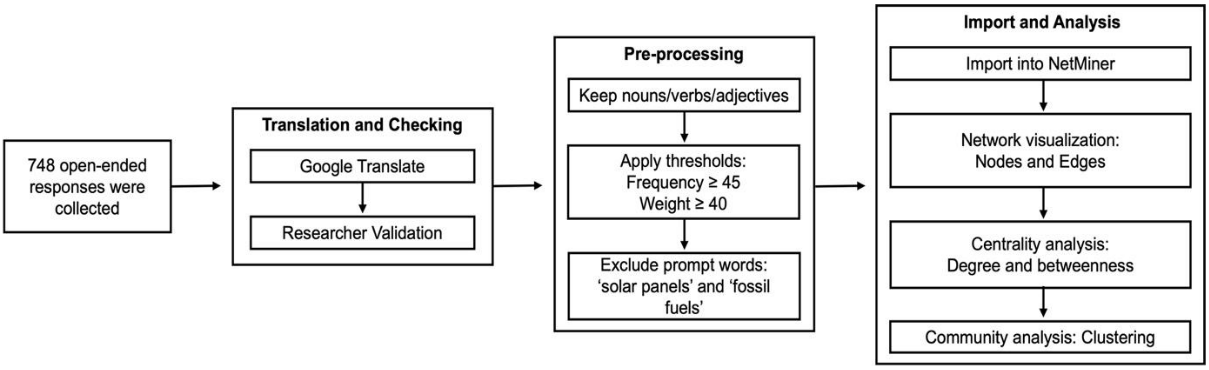

Figure 1. Research procedure of semantic network analysis

In the next stage, the pre-processing phase, only meaningful content words (nouns, verbs, and adjectives) reflecting students' ideas about solar panels and fossil fuels were included for analysis. Function words (e.g., conjunctions and articles) and irrelevant responses were excluded. Terms were filtered from the total word pool using two thresholds: a minimum word frequency of 45 and a minimum edge weight of 40 (i.e., the number of co-occurrence links a word has with others). These thresholds were determined through iterative trial and error and visual inspection to balance network readability and analytical depth. Lower thresholds resulted in dense, noisy networks with many peripheral, low-importance terms, while higher thresholds risked excluding relevant concepts. The selected cutoffs ensured that only frequently mentioned, highly connected terms were included, capturing the core conceptual structure of the students' responses without overwhelming the semantic network with noise (Segev, 2022). This filtering step enabled the resulting network to reflect the key cognitive patterns of how students relate solar panels and fossil fuels to sustainability issues. Additionally, words directly taken from the question prompt, such as "solar panel" or "fossil fuels," were excluded from network structure. Following this, the cleaned text data were imported and analyzed in NetMiner.

Students' perceptions were visualized through the number of nodes (words) and the edges (co-occurrence links) among them. The structural position of nodes within the network was shown by degree and betweenness centrality indices. Furthermore, the community analysis was applied to identify clusters of closely connected words, indicating thematic groupings in students' responses (Clauset et al., 2004). It should be noted that the clustering was automatically generated using the community detection algorithm embedded in NetMiner, based on the co-occurrence structure of the words. In this study, the modularity-based algorithm grouped words into clusters without manual coding. Therefore, no inter-rater reliability was conducted for the cluster formation itself, as it was not human-coded. Next, the researchers conducted the interpretation of these clusters qualitatively. This stage can be the most crucial and creative stage of semantic network analysis (Segev, 2022). To ensure meaningful interpretation, the researchers reviewed the central words and their co-occurrence patterns within each cluster and cross-checked them against the original responses. Then, descriptive labels (G1–G5) were assigned to reflect the dominant themes.

RESULTS AND DISCUSSION

The Most Common Words in Students' Responses about Solar Panels and Fossil Fuels

The semantic network analysis towards the students' responses resulted 39 meaningful words that students used to express their perception about solar panel and fossil fuels. Table 1 below shows the 15 most frequent words appeared in students' responses along with their in-degree centrality and nodes betweenness centrality scores.

Table 1. The top 15 most frequent words appeared in students' perceptive on solar panel and fossil fuels

No	Words	Frequency	In-Degree Centrality	Betweenness Centrality
1	energy	760	0.868	0.291
2	run out	465	0.737	0.123
3	use	363	0.921	0.076
4	fossil energy	331	0.842	0.093
5	coal	266	0.737	0.037
6	solar energy	235	0.605	0.013
7	petroleum	218	0.605	0.007
8	renewable	178	0.632	0.012
9	sunlight	163	0.684	0.014
10	future	139	0.526	0.037
11	resource	138	0.579	0.017
12	sustainable development	111	0.526	0.027
13	have	109	0.526	0.008
14	time	99	0.500	0.023
15	obtain	91	0.605	0.000

Based on Table 1, the words most frequently used in relation to solar panels and fossil fuels are 'energy' (760 times), 'run out' (465 times) and 'use' (363 times). The students were found to describe both solar panels and fossil fuels as sources of energy. They also used the word 'run out' to describe both. As the students defined both solar panels and fossil fuels as energy and thought that both could run out, they also perceived energy as something that could run out. In Kishore and Kisiel's (2013) study, students often held misconceptions about energy, particularly when they perceived it as being 'used up' or 'running out'. The researchers suggested that students' understanding of energy is complicated by its abstract nature (Kishore & Kisiel, 2013). The wide range of applications and connotations of the term 'energy' in everyday language also contributes to students' difficulty in defining it (Liu & Ruiz, 2008; Opitz et al., 2017; Pramesti et al., 2019). However, applying the term 'run out' to both energy sources could indicate a misunderstanding. Fossil fuels are non-renewable resources that can be depleted, whereas solar energy is continuously renewed. This confusion may stem from everyday language, where 'energy' is often discussed as a consumable commodity regardless of its source (Boyes & Stanisstreet, 1993).

Furthermore, when asked to compare solar panels and fossil fuels, students often name fossil and solar energy, as well as their respective resources (coal, petroleum and sunlight). In other words, high school students in the present study generally understand the natural resources from which solar panels and fossil fuels originate. This is reasonable, given that the concept of energy has been taught from elementary school level in the 3rd–4th grade, according to the Merdeka Curriculum (Kemdikbud, 2022). Pambudi et al. (2024) also found that students' awareness of energy increases with their level of education.

Another finding shown in Table 1 is that the word 'use' had the highest in-degree centrality value (0.921), followed by the words 'energy' and 'fossil energy' with values of 0.868 and 0.842, respectively. High degree centrality values show that these nodes are the most central in the network. The 'use', 'energy' and 'fossil energy' nodes had a high number of direct links to other words. This implies that, when students are describing their thoughts on the comparison between solar panels and fossil fuels, they were likely to include these three words. As can be seen in Figure 2, these three nodes have a wider diameter, showing their higher degree of centrality. Additionally, the 'energy' node had the highest betweenness centrality (0.291), acting as a link between the other nodes. Therefore, 'energy' is the main word used by students to describe solar panels and fossil fuels. The language that students use to describe things, such as solar panels and fossil fuels, is based on their learning capacity. This indicates that students use the term 'energy' as a general concept to make sense of solar panels and fossil fuels, reflecting their current level of understanding and familiarity with the topic.

The Students' Ideas about Solar Panels and Fossil Fuels

The community (modularity analysis) in semantic network resulted five ideas about solar panels and fossil fuels in students' responses as follows. Prior to discussing each cluster in detail, it can be generally observed in Figure 2 that lines (edges) are denser in clusters where the words with high degree centrality are located, such as 'energy' in G3, and 'use' and 'run out' in G5.

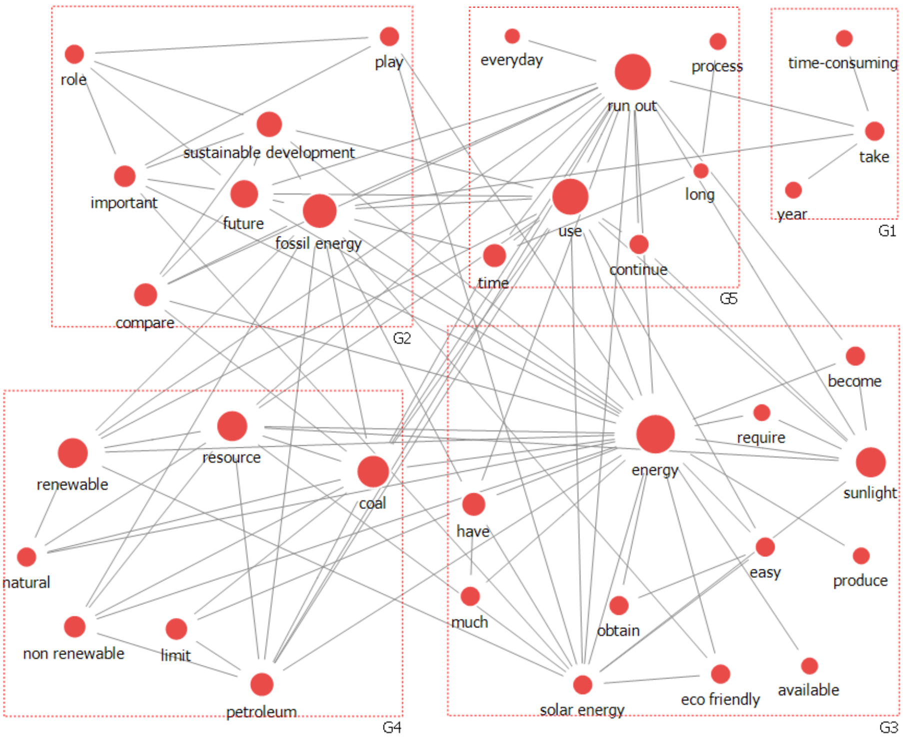

Figure 2. The semantic network of students' perception of solar panel and fossil fuels

The greater the number of incoming or outgoing edges or lines to or from a node, the higher its degree of centrality (Hoser et al., 2006; Steyvers & Tenenbaum, 2005). These words also appear to have betweenness centrality meaning they act as intermediaries or bridges between two nodes in the network (Erétéo et al., 2009). Figure 2 also shows that some nodes in particular cluster are interconnected to other nodes outside the cluster, indicating the probability that specific ideas coexisting with others. Therefore, some students' responses in this study may consist of more than one idea about solar panels and fossil fuels.

G1: Fossil fuels formation (Idea: Fossil fuels take year to form/time-consuming)

Seen in Figure 2 (G1), the first group idea consists of the fewest words, they are "time-consuming", "take", and "year". Node "take" links to the outside cluster, especially to the node "fossil energy". These words, therefore, suggest that students understand fossil energy source (i.e. fossil fuels) take millions of years to form. This idea was justified by Rule (2005) which stated that fossil fuels, especially petroleum is formed from ancient marine organisms. Over millions of years, the remains of these organisms were buried under ocean sediments and rocks. There, heat and pressure transformed them into petroleum. The oil then moved through cracks in the rocks and can now be found far from its original formation site. In this study, the researchers found that although many students discussed the length of time it takes for fossil fuels to form, few of them critically discussed how fossil fuels are actually created. Table 2 (Cluster G1) shows the sample of students' response about fossil fuels formation.

G2: Solar panel role in sustainability (Idea: Solar energy plays an important role for sustainable development in the future compared to fossil energy)

As shown in Table 1, "sustainable development" was listed as one of 15 most common word used in students' answers regarding solar panel and fossil fuels. This shows that many Indonesian high school students are starting to recognize the concept of sustainable development. Students' understanding of the sustainable development is valuable knowledge that can be used to develop ESD teaching and learning (Manni et al., 2013). Furthermore, as illustrated in Figure 2 (G2), the second group's idea consist of words such as "play", "important", "role", "sustainable development", "future", "compare", and "fossil energy". These words may represent students' recognition of the significant role that solar panels play in achieving sustainable development. Students seem to suggest that solar energy is more aligned with sustainability goals and will play an increasingly important role in the future, compared to fossil fuels. As seen in Table 2 (Cluster G2), students value solar panels over fossil fuels because it is renewable and unlimited, whereas fossil fuels are not. The availability of solar energy makes students believe that solar panels are an ideal resource for supporting sustainable development. This aligns with Maka and Alabid's (2022) study on the role of solar energy in sustainable development. They suggested that, due to the large availability of solar energy resources for converting sunlight into electricity through photovoltaics (PV) and concentrated solar power (CSP), we can transition to a sustainable energy system.

G3: Practical benefits of solar panels (Idea: Solar energy requires sunlight to produce and is easy to obtain, making it become an eco-friendly and much available)

In the third group, the idea consists of words such as "energy", "sunlight", "become", "require", "produce", "easy", "available", "ecofriendly", "solar energy", "obtain", "have", and "much" (see Figure 2 G3). This G3 idea reflects students' understanding of the practicality and benefits of solar panel. They seem to view solar panel as an easily accessible, abundant, and eco-friendly energy source that is readily available through sunlight (see sample responses in Table 2). The benefits of solar panels that students mostly mention in their responses rely heavily on the environmental pillar of sustainability (e.g., friendly to the environment). In the present study, researchers further investigated students' responses regarding the economic and social benefits of solar energy by searching the keywords such as 'economy', 'cheap', 'expensive' (for economic dimension) and 'society', 'justice', 'well-being', 'poverty', 'inequality', 'equity', 'safety', 'employment', 'welfare' referring to Maka and Alabid (2022) as well as Lourdel et al. (2007). As the result, we found only 18 students (1.6% of respondents) and 7 students (0.94%) discussed about the economic and social dimensions of sustainability, respectively. The following sentence are sample students' responses discussing the economic and social pillars about solar panels.

> *"Solar power is easy to obtain, **cheap**, and more efficient than coal and petroleum"* (Student#407) – **Economic dimension**

> *"…Solar power is eco-friendly compared to fossil fuels. Its use does not have a dangerous effect on the **safety** of living creatures."* (Student#191) – **Social dimension**

Other researchers have also found that the economic and social dimensions of sustainable development are rarely addressed in students' understanding and awareness of the issue (Lourdel et al., 2007; Panatsa & Malandrakis, 2018; Suwarto et al., 2021). Likewise, the interdependent relationship between the environmental, economic, and social pillars is often overlooked (Birdsall, 2014; Borg et al., 2014; Dyment & Hill, 2015). Zeegers and Clark (2014) discussed the possibility that this phenomenon is due to an ecocentric or enviro-centric view, in which individuals prioritize environmental well-being over human interests. Furthermore, individuals (including teachers and pre-service teachers) seem to understand or consider the social dimension the least important for sustainability among the three pillars (Borg et al., 2014; Fisher & McAdams, 2015; Panatsa & Malandrakis, 2018). Furthermore, the absence of integration between the environmental, economic and social dimensions suggests a lack of systemic thinking, which is an essential component of energy literacy (DeWaters & Powers, 2013), critical sustainability education (Ketschau, 2015) and youth agency frameworks (Hayward, 2012). These frameworks, moreover, advocate for the inclusion of power, justice and participatory citizenship in ESD. In the Indonesian context specifically, this phenomenon might partially because until recently, people's understanding of ESD was limited to environmental education and they might have some misconceptions about ESD itself. Consequently, sustainability is often associated only with the environment, limited to connect with social and economic components (Vasconcelos, 2012).

Moreover, the perception of solar energy as 'easy to obtain' may be shaped by idealistic assumptions rather than infrastructural realities. Even though Indonesia receives abundant sunlight, access to solar panel technology is unequal, particularly in rural areas, where installation costs, a lack of government support and limited infrastructure are still becoming big challenges (Handayani et al., 2019). Therefore, students' perceptions may reflect aspirational views of solar energy's potential rather than a grounded understanding of its socio-economic feasibility in different regions.

G4: Non-renewable resource concern (Idea: Fossil fuels come from limited and non-renewable natural resources, such as coal and petroleum)

As shown in Figure 2, students who have G4 idea have non-renewable resource concern. This idea consists of nodes such as "resource", "coal", "petroleum", "limit", "nonrenewable", "natural", and "renewable" (See Figure 2 G4). This fourth idea demonstrates students' awareness of the finite and non-renewable nature of fossil fuels (e.g. coal and petroleum) compared to renewable energy sources such as solar panels and their concern about the need to shift towards renewable alternatives for long-term sustainability. This concern can be interpreted through the lens of energy justice, particularly with regard to the principles of intergenerational equity. In the context of intergenerational equity, energy justice emphasises fair access to sustainable energy for all, including current and future generations (Jenkins et al., 2016). Therefore, from an energy justice perspective, students awareness on resource limits and the need for alternatives implicitly recognises that continued dependence on fossil fuels endangers future access to energy and environmental well-being. Their awareness aligns with the ethical responsibility to transitions toward renewable energy sources in order to ensure long-term energy security.

Table 2. Example of students' responses about solar panels and fossil fuels

Cluster	Idea	Sample responses
G1 (Fossil fuels formation)	Fossil fuels take year to form/time-consuming	*Solar power will never run out, unlike fossil energy such as coal and petroleum. Coal and petroleum themselves are formed from the remains of dead animals and plants which then become fossils and are buried for millions of years. Therefore, if coal and petroleum run out, it will take millions of years for these natural resources to be formed again* (Student#469).
G2 (Solar panel role in sustainability)	Solar energy plays an important role for sustainable development in the future compared to fossil energy	*Solar energy is a natural resource that is unlimited and always available, while fossils, coal and petroleum are natural resources that cannot be renewed and are already scarce, therefore solar energy is an important natural resource that will play an important role in sustainable development in the future* (Student#546).
G3 (Practical benefits of solar panels)	Solar energy requires sunlight to produce and is easy to obtain, making it become an eco-friendly and much available	*Solar power comes from nature and is very eco-friendly, it is an important asset for sustainable development* (Student#103). *Solar panels only require sunlight to produce electricity, which humans need today and will need in the future... Sunlight is always available and does not require the time-consuming search that fossil fuels do* (Student#706).
G4 (Non-renewable resource concern)	Fossil fuels come from limited and non-renewable natural resources, such as coal and petroleum	*Solar power is renewable, while fossil energy such as coal and petroleum are in limited supply* (Student#481). *Fossil energy is non renewable energy and is not eco-friendly/obtained by destroying the ecosystem* (Student#574).
G5 (Unsustainable fossil fuels use)	Continued and everyday use of fossil fuels for will make them run out	*Fossil energy resources such as coal and petroleum will run out if used continuously...* (Student#584). *Using solar panels can prevent the extinction of fossils such as coal and oil. If we continue to use fossil energy, then over time it could run out* (Student#605).

According to Maka and Alabid (2022), the world's rapidly growing population and increasing reliance on technology has led to higher energy demands. Since fossil fuels are limited, green technology has the potential to provide a sustainable energy supply. Although fossil fuels currently dominate large-scale energy production and will continue to do so in the foreseeable future, Maka and Alabid (2022) suggested that there is an urgent need to transition to cleaner energy sources to reduce greenhouse gas emissions and reach net zero.

G5: Unsustainable fossil fuels use (Idea: Continued and everyday use of fossil fuels for will make them run out)

The fifth group idea in Figure 2 (G5) contains nodes like "run out", "use", "every day", "continue", "long", "time", and "process". In this cluster, students express their concern about the continuous and unsustainable use of fossil fuels in daily life, leading to resource deficiency. They recognize that fossil fuels are being used every day, and while this process has gone on for a long time, it cannot continue indefinitely because these resources will eventually run out. Coal and petroleum are commonly used for energy in transportation and electricity generation (Maka & Alabid, 2022). Burning these fossil fuels, therefore, is considered the largest source of emissions when used for electricity generation and transportation. However, these energy resources are considered depleted because they are being consumed at an unsustainable rate (Sims, 2004). Moreover, continued use of fossil fuels leads to higher concentrations of greenhouse gases in the atmosphere, which leads to more climate disasters (Yáñez-Arancibia et al., 2013).

Students' view in this fifth cluster represents the alignment to the theory of energy justice (Jenkins et al., 2016). According to the principles of intergenerational equity, the unequal burden of fossil fuel externalities, such as pollution and climate disasters, often falls on vulnerable communities who contribute the least to these emissions. Intergenerational justice emphasises the ethical obligation to avoid depleting resources in ways that disadvantage future generations (Jenkins et al., 2016). By recognising that the use of fossil fuels is unsustainable, students are implicitly advocating for a fairer utilization and distribution of energy resources over time and across populations. However, regardless students' opinion about unsustainable fossil fuels use, currently Indonesia remains heavily reliant on coal, especially for electricity generation, due to its economic affordability, abundant reserves, and existing infrastructure (IEA, 2020; Handayani et al., 2019). In many regions, particularly outside major urban centres, renewable energy alternatives such as solar or wind power are still perceived as less accessible due to high initial costs and limited distribution infrastructure. In other words, while students understand the unsustainability of fossil fuels, their strong emphasis on 'running out' may also reflect the perception that they are locked into using fossil fuels because alternative energy options feel out of reach in Indonesian context.

CONCLUSION AND LIMITATION

Using a method of semantic network analysis, this study shows that Indonesian high school students have a basic understanding of renewable and non-renewable energy sources, such as solar panels and fossil fuels. Through semantic network analysis, the present study identified five clusters of ideas among students: fossil fuel formation, the role of solar panels in sustainability, the practical benefits of solar panels, concerns about non-renewable resources, and the unsustainable use of fossil fuels. Students' responses regarding solar and fossil energy remain superficial, with limited discussion representing critical thinking or deeper reflection. The researchers also found that social pillar of sustainability was addressed the least among the three dimensions of sustainability (environmental, economic, and social). Notably, the network structure shows a significant underrepresentation of the social dimension of sustainability. While students acknowledged environmental and, to some extent, economic considerations, social equity, justice and inclusivity were largely absent from their responses. This suggests that students' knowledge structuring is shaped by an eco-centric view, possibly reinforced by an education system that prioritises environmental protection over social transformation. Furthermore, integration among the three pillars was not evident in the students' responses.

This may be because Indonesian high school students view ESD as limited to environmental education, causing them to ignore integrating it to the other dimensions. These findings highlight the need to improve ESD practices in Indonesia by deliberately promote epistemological integration and critical thinking. Integrating social and ethical considerations into the understanding of energy, alongside environmental concerns, is crucial in developing students' ability to think systemically and act responsibly. Moreover, helping students recognise the interconnectedness of sustainability issues will improve their ability to address the broader goals of the SDGs, particularly those related to equity and inclusion.

Despite the novelty of using semantic network analysis with NetMiner to assess students' understanding of energy concepts, this methodological approach has certain limitations, particularly when working with Indonesian-language data. Currently, NetMiner software only supports Korean and English for text processing, which create significant challenges when analysing student responses originally written in Indonesian. Consequently, all open-ended responses had to be translated into English prior to analysis. Although these translations were reviewed and validated by the bilingual researcher to preserve meaning and interpretation, the researchers recognize that the absence of formal back-translation procedures and the use of on automated tools (e.g. Google Translate) may have introduced translation bias. Future research should consider using expert translators and formal back-translation procedures that improve the accuracy of cross-language data interpretation. Additionally, responses to a single open-ended question that used as the primary source of data may not fully capture the richness and depth of student thinking. Future research may involve triangulation with interviews or classroom observations.

RECOMMENDATION

The findings of this study highlight both the strengths and gaps in Indonesian high school students' understanding of renewable and non-renewable energy. While students demonstrate basic awareness of environmental and economic aspects of sustainability, their responses lack depth in critical thinking and rarely address the social dimensions of energy use. To better align education with the holistic goals of Education for Sustainable Development (ESD), the following recommendations are proposed for teachers, schools, and policymakers. For teachers, they should move beyond factual knowledge by integrating active learning strategies such as debates, case studies, and project-based tasks that encourage students to analyze the social and ethical implications of energy choices. Lessons should explicitly connect sustainability to equity, health, and community impacts, fostering a more nuanced understanding of the SDGs. Further, schools can model sustainable practices such as adopting solar energy while involving students in related projects. Collaborations with local government, including renewable energy initiatives or indigenous communities, can ground abstract concepts in tangible experiences. For policymakers especially curriculum designer, the national curricula should ensure balanced coverage of ESD's three pillars (environmental, economic, and social) across subjects. Moreover, teacher professional development program must equip educators with pedagogical tools to facilitate critical discussions on sustainability.

REFERENCES

Afif, F., & Martin, A. (2022). Tinjauan potensi Dan Kebijakan energi surya di Indonesia. *Jurnal Engine: Energi, Manufaktur, dan Material, 6*(1), 43-52. https://doi.org/10.30588/jeemm.v6i1.997

Alnavis, N. B., Wirawan, R. R., Solihah, K. I., & Nugroho, V. H. (2024). Energi listrik berkelanjutan: Potensi dan tantangan penyediaan energi listrik di Indonesia. *Journal of Innovation Materials, Energy, and Sustainable Engineering, 1*(2), 119-139. https://doi.org/10.61511/jimese.v1i2.2024.544

Aprianto, D., Laksmono, R., Sinambela, F. A. H., & Murtiana, S. (2024). Addressing indonesia's fossil fuel dependence: a path towards a sustainable future. *International Journal of Humanities Education and Social Sciences, 4*(3), 1518 – 1524. https://doi.org/10.55227/ijhess.v4i3.1200

Aprilianti, K. P., Baghta, N. A., Aryani, D. R., Jufri, F. H., & Utomo, A. R. (2020). Potential assessment of solar power plant: A case study of a small island in Eastern Indonesia. *IOP Conference Series: Earth and Environmental Science*, 599(1), 012026. https://doi.org/10.1088/1755-1315/599/1/012026

Aviv, R., Erlich, Z., Ravid, G., & Geva, A. (2003). Network analysis of knowledge construction in asynchronous learning networks. *Journal of Asynchronous Learning Networks, 7*(3), 1-23.

Birdsall, S. (2014). Measuring student teachers' understandings and self-awareness of sustainability. *Environmental Education Research, 20*(6), 814-835. https://doi.org/10.1080/13504622.2013.833594

Borg, C., Gericke, N., Höglund, H. O., & Bergman, E. (2012). The barriers encountered by teachers implementing education for sustainable development: Discipline bound differences and teaching traditions. *Research in Science & Technological Education, 30*(2), 185-207. https://doi.org/10.1080/02635143.2012.699891

Borg, C., Gericke, N., Höglund, H. O., & Bergman, E. (2014). Subject-and experience-bound differences in teachers' conceptual understanding of sustainable development. *Environmental Education Research, 20*(4), 526-551. https://doi.org/10.1080/13504622.2013.833584

Boyes, E., & Stanisstreet, M. (1993). The 'Greenhouse Effect': children's perceptions of causes, consequences and cures. *International Journal of science education, 15*(5), 531-552. https://doi.org/10.1080/0950069930150507

Clauset, A., Newman, M. E., & Moore, C. (2004). Finding community structure in very large networks. *Physical Review E—Statistical, Nonlinear, and Soft Matter Physics, 70*(6), 066111. https://doi.org/10.1103/PhysRevE.70.066111

DeWaters, J., & Powers, S. (2013). Establishing measurement criteria for an energy literacy questionnaire. *The Journal of Environmental Education, 44*(1), 38-55. https://doi.org/10.1080/00958964.2012.711378

diSessa, A. A. (2013). A Bird's-eye View of The" Pieces" Vs" Coherence" Controversy (From The" Pieces" Side of the Fence"). In S. Vosniadou (Ed), *International handbook of research on conceptual change* (pp. 31–48). Routledge.

Drieger, P. 2013. Semantic Network Analysis as a Method for Visual Text Analytics. *Procedia-social and Behavioral Sciences 79,* 4-17. https://doi:10.1016/j.sbspro.2013.05.053

Dyment, J. E., & Hill, A. (2015). You mean I have to teach sustainability too?: Initial teacher education students' perspectives on the sustainability cross-curriculum priority. *Australian Journal of Teacher Education (Online), 40*(3), 21-35.

Eliyawati, Widodo, A., Kaniawati, I., & Fujii, H. (2023a). *Penerapan ESD dalam pembelajaran IPA*. Bandung: UPI Press.

Eliyawati, Widodo, A., Kaniawati, I., & Fujii, H. (2023b). The development and validation of an instrument for assessing science teacher competency to teach ESD. *Sustainability, 15*(4), 3276. https://doi.org/10.3390/su15043276

Erétéo, G., Limpens, F., Gandon, F., Corby, O., Buffa, M., Leitzelman, M., & Sander, P. (2011). Semantic social network analysis: A concrete case. In *Handbook of research on methods and techniques for studying virtual communities: paradigms and phenomena* (pp. 122-156). IGI Global Scientific Publishing.

ESCAP. (2020). Energy transition pathways for the 2030 agenda: SDG7 roadmap for Indonesia. ESCAP.

ESDM. (2010). Indonesia energy outlook 2010. ESDM.

Esiri, A. E., Kwakye, J. M., Ekechukwu, D. E., & Benjamin, O. (2023). Public perception and policy development in the transition to renewable energy. *Magna Scientia Advanced Research and Reviews*, 8(2), 228-237.

Ewim, D. R. E., Abolarin, S. M., Scott, T. O., & Anyanwu, C. S. (2023). A survey on the understanding and viewpoints of renewable energy among South African school students. *The Journal of Engineering and Exact Sciences*, *9*(2), 15375-01e. https://doi.org/10.18540/jcecvl9iss2pp15375-01e

Febrian, H. G., Supriyanto, A., & Purwanto, H. (2023). Calculating the energy capacity and capacity factor of floating photovoltaic (FPV) power plant in the Cirata reservoir using different types of solar panels. Journal of Physics: Conference Series, 24981(1), 012007. https://doi.org/10.1088/1742-6596/2498/1/012007

Fisher, P. B., & McAdams, E. (2015). Gaps in sustainability education: The impact of higher education coursework on perceptions of sustainability. *International Journal of Sustainability in Higher Education*, *16*(4), 407-423. https://doi.org/10.1108/IJSHE-08-2013-0106

Hammer, D. (1996). Misconceptions or p-prims: How may alternative perspectives of cognitive structure influence instructional perceptions and intentions. *The journal of the Learning Sciences*, *5*(2), 97-127. https://doi:10.1207/s15327809jls0502_1

Handayani, K., Krozer, Y., & Filatova, T. (2019). From fossil fuels to renewables: An analysis of long-term scenarios considering technological learning. *Energy Policy*, *127*, 134-146.

Hayward, B. (2013). *Children, citizenship and environment: Nurturing a democratic imagination in a changing world*. New York: Routledge.

Hoser, B., Hotho, A., Jäschke, R., Schmitz, C., & Stumme, G. (2006, June). Semantic network analysis of ontologies. In *European Semantic Web Conference* (pp. 514-529). Berlin, Heidelberg: Springer Berlin Heidelberg.

Jenkins, K., McCauley, D., Heffron, R., Stephan, H., & Rehner, R. (2016). Energy justice: A conceptual review. *Energy Research & Social Science*, *11*, 174-182. https://doi.org/10.1016/j.erss.2015.10.004

Kabeyi, M. J. B., & Olanrewaju, O. A. (2022). Sustainable energy transition for renewable and low carbon grid electricity generation and supply. *Frontiers in Energy Research*, 9, 743114. https://doi.org/10.3389/fenrg.2021.743114

Kemdikbud. (2022). Capaian Pembelajaran – CP & ATP. Guru Kemdikbud.

Ketschau, T. J. (2015). Social justice as a link between sustainability and educational sciences. *Sustainability*, *7*(11), 15754-15771. https://doi.org/10.3390/su71115754

Kishore, P., & Kisiel, J. (2013). Exploring High School Students' Perceptions of Solar Energy and Solar Cells. *International Journal of Environmental and Science Education*, *8*(3), 521-534. https://doi.org/10.12973/ijese.2013.216a

Laksana, E. P., Prabowo, Y., Sujono, S., Sirait, R., Fath, N., Priyadi, A., & Purnomo, M. H. (2021). Potential usage of solar energy as a renewable energy source in Petukangan Utara, South Jakarta. *Jurnal Rekayasa Elektrika*, *17*(4). https://doi.org/10.17529/jre.v17i4.22538

Langer, J., Quist, J., & Blok, K. (2021). Review of renewable energy potentials in Indonesia and their contribution to a 100% renewable electricity system. *Energies*, *14*(21), 7033. https://doi.org/10.3390/en14217033

Laurie, R., Nonoyama-Tarumi, Y., Mckeown, R., & Hopkins, C. (2016). Contributions of education for sustainable development (ESD) to quality education: A synthesis of research. *Journal of Education for Sustainable development*, *10*(2), 226-242. https://doi.org/10.1177/0973408216661442

Liu, X., & Ruiz, M. E. (2008). Using data mining to predict K–12 students' performance on large-scale assessment items related to energy. *Journal of Research in Science Teaching, 45*(5), 554-573. https://doi.org/10.1002/tea.2023

Lourdel, N., Gondran, N., Laforest, V., Debray, B., & Brodhag, C. (2007). Sustainable development cognitive map: a new method of evaluating student understanding. *International Journal of Sustainability in Higher Education, 8*(2), 170-182. https://doi.org/10.1108/14676370710726634

Maka, A. O., & Alabid, J. M. (2022). Solar energy technology and its roles in sustainable development. *Clean Energy, 6*(3), 476-483. https://doi.org/10.1093/ce/zkac023

Manni, A., Sporre, K., & Ottander, C. (2013). Mapping what young students understand and value regarding the issue of sustainable development. *International Electronic Journal of Environmental Education, 3*(1), 17-35.

Olujobi, O. J., Okorie, U. E., Olarinde, E. S., & Aina-Pelemo, A. D. (2023). Legal responses to energy security and sustainability in Nigeria's power sector amidst fossil fuel disruptions and low carbon energy transition. *Heliyon, 9*(7). https://doi.org/10.1016/j.heliyon.2023.e17912

One Planet. (2015). Adiwiyata school program in Indonesia. One Planet.

Opitz, S. T., Neumann, K., Bernholt, S., & Harms, U. (2017). How do students understand energy in biology, chemistry, and physics? Development and validation of an assessment instrument. *Eurasia Journal of Mathematics, Science and Technology Education, 13*(7), 3019-3042. https://doi.org/10.12973/eurasia.2017.00703a

Pambudi, N. A., Firdaus, R. A., Rizkiana, R., Ulfa, D. K., Salsabila, M. S., Suharno, & Sukatiman. (2023). Renewable energy in Indonesia: current status, potential, and future development. *Sustainability, 15*(3), 2342. https://doi.org/10.3390/su15032342

Pambudi, N. A., Nanda, I. R., Alfina, F. T., & Syahrial, A. Z. (2024). Renewable energy education and awareness among Indonesian students: Exploring challenges and opportunities for a sustainable future. *Sustainable Energy Technologies and Assessments, 63*, 103631. https://doi.org/10.1016/j.seta.2024.103631

Panatsa, V. M., & Malandrakis, G. (2018). Student teachers' perceptions about the social pillar of urban sustainability: Attached importance and believed effectiveness of education. *International Journal of Sustainability in Higher Education, 19*(5), 998-1018. https://doi.org/10.1108/IJSHE-09-2017-0162

Pramesti, Y. S., Mahmudi, H. A. R. I. S., & Setyowidodo, I. R. W. A. N. (2020, April). Analyzing students' understanding of work-energy concept. *Journal of Physics: Conference Series*, 1521(2), 022016. https://doi.org/10.1088/1742-6596/1521/2/022016

RUEN. (2017). Peraturan Presiden Nomor 22 tahun 2017 tentang Rencana Umum Energi Nasional.

Rule, A. C. (2005). Elementary students' ideas concerning fossil fuel energy. *Journal of Geoscience Education, 53*(3), 309-318. https://doi.org/10.5408/1089-9995-53.3.309

Rusmana, A. N., Aini, R. Q., Sya'bandari, Y., Ha, M., Shin, S., & Lee, J. K. (2021). Probing high school students' perceptions of the concept of species: a semantic network analysis approach. *Journal of Biological Education, 55*(5), 472-486. https://doi.org/10.1080/00219266.2019.1707261

Siew, C. S. (2020). Applications of network science to education research: Quantifying knowledge and the development of expertise through network analysis. *Education Sciences, 10*(4), 101. https://doi.org/10.3390/educsci10040101

Sims, R. E. (2004). Renewable energy: a response to climate change. *Solar Energy, 76*(1-3), 9-17. https://doi.org/10.1016/S0038-092X(03)00101-4

Sinakou, E., Donche, V., & Van Petegem, P. (2022). Action-orientation in education for sustainable development: Teachers' interests and instructional practices. *Journal of Cleaner Production, 370*, 133469. https://doi.org/10.1016/j.jclepro.2022.133469

Sinakou, E., Donche, V., Boeve-de Pauw, J., & Van Petegem, P. (2019). Designing powerful learning environments in education for sustainable development: A conceptual framework. *Sustainability*, *11*(21), 5994. https://doi.org/10.3390/su11215994

Sovacool, B. K. (2014). What are we doing here? Analyzing fifteen years of energy scholarship and proposing a social science research agenda. *Energy Research & Social Science*, 1, 1-29. https://doi.org/10.1016/j.erss.2014.02.003

Steyvers, M., & Tenenbaum, J. B. (2005). The large-scale structure of semantic networks: Statistical analyses and a model of semantic growth. *Cognitive science, 29*(1), 41-78.

Suwarto, R. S., Sanjaya, Y., & Solihat, R. (2021). Implementation of education for sustainable development and pupils' sustainability consciousness in Adiwiyata School and ESD-based school. Journal of Physics: Conference Series, 1086(1), 012153, https://doi.org/10.1088/1742-6596/1806/1/012153

Takács-György, K., Domán, S., Tamus, A., Horská, E., & Palková, Z. (2015). What do the youth know about alternative energy sources–case study from Hungary and Slovakia. *Visegrad Journal on Bioeconomy and Sustainable Development, 4*(2), 36-41. https://doi.org/10.1515/vjbsd-2015-0009

United Nations Educational, Scientific and Cultural Organization. (2018). Issues and trends in Education for Sustainable Development Issues and trends in Education. UNESCO Publishing.

United Nations Educational, Scientific and Cultural Organization. (2023). Global Education Monitoring Report 2023: Technology in education: A tool on whose terms? UNESCO: Paris, France.

Vasconcelos, C. (2012). Teaching environmental education through PBL: Evaluation of a teaching intervention program. *Research in Science Education, 42*, 219-232. https://doi.org/10.1007/s11165-010-9192-3

Wals, A. E. J., & Lenglet, F. (2016). Sustainability citizens: Collaborative and disruptive social learning. In R. Horne, J. Fien, B. Beza, & A. Nelson (Eds.), *Sustainability citizenship in cities: Theory and practice* (pp. 52–66). London, UK: Routledge.

Walshe, N. (2013). Exploring and developing student understandings of sustainable development. *Curriculum Journal, 24*(2), 224-249. https://doi.org/10.1080/09585176.2013.781388

Yáñez-Arancibia, A., Day, J. W., Hall, C. A. S., & Reyes, E. (2013). Diminished resources, energy scarcity and climate change: unsustainable future development. In *Ecological dimensions for sustainable socio economic development* (p. 557-574). WIT Press.

Zeegers, Y., & Francis Clark, I. (2014). Students' perceptions of education for sustainable development. *International Journal of Sustainability in Higher Education, 15*(2), 242-253. https://doi.org/10.1108/IJSHE-09-2012-0079