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Energy literacy in elementary school textbooks in Mexico

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ABSTRACT

Recognizing the relevance of energy in our lives is essential for ensuring a sustainable future. The lessons offered by education systems could exert an impact throughout the lives of people. This study conducts a review of the content of elementary-level textbooks in Mexico to describe and analyze the scope of these materials and their depth from the perspective of energy literacy. Analysis considers the content of 44 textbooks published in 2014, and identifies 33 topics categorized based on the framework of energy literacy proposed by DeWaters (2011). The results show that energy-related issues were introduced to students earlier than expected by the government educational authority, energy-related contents were more extensive than expected across the textbooks, and offered a rich interdisciplinary perspective previously unrecognized by national educational guidelines. These findings suggest the need to update educational guidelines in Mexico to acknowledge the contents identified in this research, to support them with materials related to SDGs, and to understand better which energy education topics are being covered for future generations in other countries.

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Introduction

Similar to air, energy is indispensable to and used by humans throughout existence in the form of food for subsistence or as a necessary input for work performance. The current understanding of energy has revolutionized the world. In modern society, living as our ancestors did 200 years ago is nearly unacceptable. The complexity of transportation systems, water distribution and drainage, lighting, communication, among others, shapes modern societies that sustain the lifestyle of millions of inhabitants. However, such a complexity is jeopardized by the omission of a key piece of the puzzle – such as electricity, which serve as a reminder of the vulnerability of our infrastructure and the key role that energy plays in daily life.

As a country, Mexico enjoyed a sustained abundance of energy resources over previous decades. However, its competitive advantage exhibited a decline. In 2015, natural gas imports represented 30% of the total consumption in the country; in comparison, only 3% of natural gas consumed in 1997 was derived from imports (Gobierno de México 2015, 4). Oil revenues, which previously supported public finances, decreased their contribution to GDP from 10.3% in 2008 to 3.9% in 2019 (SHCP 2015, 192; 2020, 77). The outlook of the country looms at a critical moment where it can opt to embrace the tradition of known benefits or explore the

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transition to new sources of energy generation. Taking solar photovoltaic technology as an example, Mexico enjoys the advantage of receiving an annual solar radiation of between 4.4 kWh/m^2 and 6.3 kWh/m^2 with Chihuahua and Baja California as the two states with the highest solar radiation worldwide (Romero-Hernández et al. 2012). In turn, the discovery of one of the largest lithium deposits in the world in the state of Sonora ushers new opportunities for the country to take advantage of this mineral, which is key in the manufacture of electronic components and is indispensable for energy storage (Morales-Jurado 2019). To take advantage of this potential, an energy reform was approved in 2013 to open the energy market in Mexico to national and international private initiatives (Gobierno de México 2015). However, its opening led to extensive discussions among various sectors of society and government (Vargas 2015; Márquez 2019) and to heated debates on the decision on whether or not the country should restore the monopoly of the state over the electricity industry, which continues to this day (Redacción BBC Noticias 2021; Cullell 2021; O'Boyle 2022).

Beyond these events, Mexico has been affected due to the lack of energy, such as extensive blackouts (CFE 2017; Energy2121, 2021), with severe economic impact (Valle 2017); and at critical times, such as during the COVID-19 pandemic, when telecommunications were required to facilitate remote collaboration and work (Redacción Uno TV 2021). Addressing these issues, Ishiwatari and Surjan (2019) stated that 'Good enough today is not enough tomorrow', given that the risks to be addressed will remain latent as population and urbanization continue to progress. These incidents are examples of the concept that energy problems are not only dependent on technical and scientific personnel but also on the understanding of society and its leaders. As DeWaters and Powers (2013) point out, facing these challenges will also require the participation of people with a civic understanding of the aspects of energy.

In Mexico, elementary education is one of the most important stages of formal education, where children socialize and learn the basis for coexistence within communities. Thus, knowledge acquired at this stage, such as sustainable values, may be retained throughout their lives; therefore, they become equipped with important knowledge about potential challenges such as the effects of climate change and the importance of energy. To support the orderly provision of knowledge, the Ministry of Public Education (SEP 2017) distributes textbooks as the primary means of education for millions of children per year. According to recent data, the National Commission of Free Textbooks (CONALITEG 2020) program benefits more than 14 million elementary students; however, the extent to which the content and education provided to students facilitate the development of their understanding of energy issues is unknown. Therefore, this work studies the content of these elementary-level textbooks to describe and analyze the scope of these materials and their depth from the perspective of energy literacy.

We elaborated on the following questions to guide the exploration of contents related to the topic of energy in elementary-level textbooks.

1. How is the presence of the energy topic distributed by school grade, textbook, and pages?
2. What elements of the energy literacy framework of DeWaters (2011) can be identified in the textbooks?

Theoretical framework

Among the Sustainable Development Goals (SDGs) of the United Nations, goal seven *Affordable and clean energy* intends to encourage energy transition that focuses on the efficiency and implementation of renewable energy technologies in the electricity sector (UN 2015). The lack of access to energy can lead to multiple consequences, which lead to a low quality of life. Despite its importance to society and especially to individuals residing in a city, none of the

three objectives under goal seven prioritizes the relevance of the strengthening of energy education as part of their strategy. Consequently, the way in which education facilitates or presents difficulty in accomplishing this goal may remain unknown despite the potential influence of teacher training, school environment design, or educational materials, such as textbooks, on students.

In Mexico, the SEP establishes that students need to develop a set of competencies to equip them with values that ensure sustainability (SEP 2017, 107) through three curricular fields, namely, *Academic Training*, *Personal and Social Development*, and *Curricular Autonomy*. For each field, a group of domains presents the expected learning outcomes (i.e. mathematical thinking). In the case of Academic Training, the domain '*Exploration and understanding of the social and natural world*' intends to promote caring for the environment in an active manner among students. Moreover, it encourages the identification of problems related to the care of ecosystems and to the formulation of solutions involving the use of natural resources that considers responsibility, rationality, and commitment to the implementation of sustainable actions in the environment (SEP 2017, 98).

Figure 1 presents a visualization of the above-mentioned relationships between the fields and areas related to the learning outcomes of elementary education.

To achieve the goal of the domain '*Exploration and understanding of the social and natural world*', textbooks cover various courses, such as Geography and Natural Sciences, throughout elementary education. Each course produces themes, which are groups of related topics that intend to accomplish certain learning outcomes according to each year level in elementary school. For example, the Ministry of Education expects third-grade students to identify the sun as an indispensable source of light and heat for living beings under the theme *Matter,*

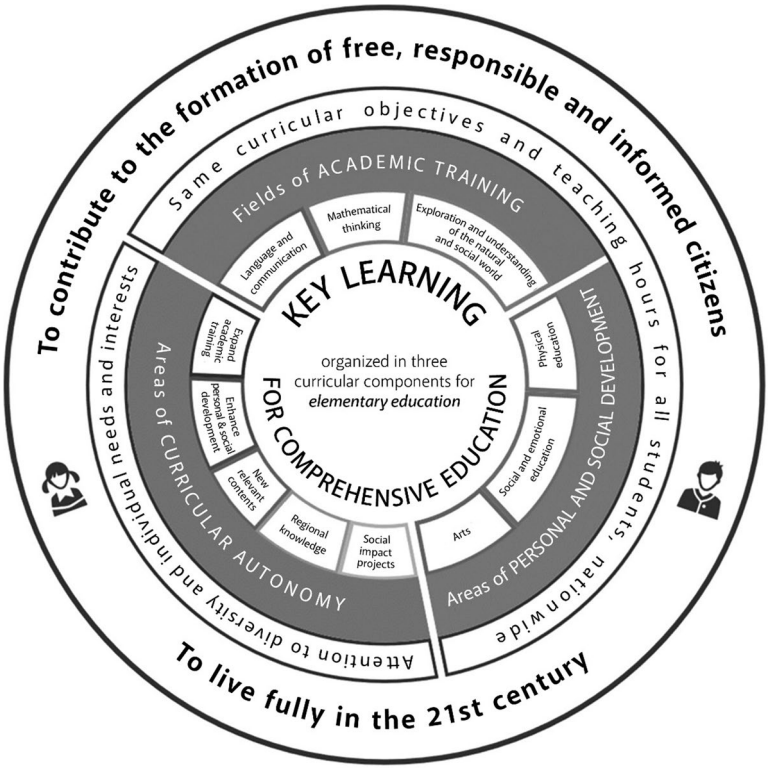

Figure 1. Three curricular areas/fields in elementary education with 11 domains (inner section of the circle). Source: SEP (2017, 109).

Table 1. Expected learning outcomes at the elementary level under the theme *Matter, energy, and interactions*.

Subject: Natural sciences	
Grade level (elementary)	Expected learning outcomes
First grade	No expected learning outcomes listed.
Second grade	No expected learning outcomes listed.
Third grade	Identifies the sun as the source of light and heat, which is essential for living beings.
Fourth grade	Identifies processes in the environment that produce light and heat, and are exploited by humans.
Fifth grade	Identify heat as energy and describe the changes it produces in matter.
Sixth grade	Identifies electricity as a form of energy, and recognizes and values its daily use.

energy, and interactions (SEP 2017, 368), as presented in detail in Table 1. Although energy could be integrated into or lead to implications within other subjects (e.g. Mathematics, Geography, or History), the SEP only documents its presence within a single subject, that is, Natural Sciences.

Energy education should not be limited only to the domains of the natural sciences. In contrast, energy is a concept with a multidisciplinary nature that integrates into daily life. Thus, its teaching should be facilitated through these experiences. Historically, energy education has been largely limited to those who interact with it professionally in its various forms, although the majority of the population possess sufficient knowledge for using and consuming energy. However, a successful shift to a stable future will not only depend on relevant professionals, but also on average citizens and their ability to understand it and make appropriate decisions on various aspects related to energy, such as transportation, consumption patterns and voting habits (DeWaters and Powers 2013, 38). These characteristics, which entail an understanding of energy from different perspectives, are referred to as *energy literacy*.

Over the two previous decades, researchers and institutions have developed different constructs of the nature of and knowledge to potentially learn from energy literacy. A few examples include the educational guide of the United States Department of Energy (DOE 2017) entitled '*Energy literacy – Essential principles and fundamental concepts for energy education*' and the online course of Webber and Glazer (2017) entitled '*Energy 101*'. However, only a few documents have provided a framework of the categories that compose energy literacy and set of questions for measuring energy literacy. In this situation, the framework of DeWaters (2011) has provided a common ground for other researchers in measuring and comparing the development of energy literacy in countries such as Japan (Akitsu et al. 2017; Akitsu 2018), Taiwan (Lee et al. 2015; Lee et al. 2017), and Mexico (Castañeda-Garza and Valerio-Ureña 2020).

DeWaters (2011) framework is composed of three levels. (1) The first level outlines the literacy domain (e.g. cognitive, affective, and behavioral) to which the measurement objective aligns, (2) the second level contains a set of broad characteristics (categories) within each of the three domains, and (3) the third level presents a set of measurable benchmarks or delineated objectives (aspects) for each category (p. 331). These characteristics of energy literacy were developed based on a review of educational curricula, literature, textbooks, educational standards, energy polls and surveys, which are mainly in the context of the United States (p. 169). Table 2 presents the categories corresponding to the cognitive subscales, which through 52 aspects of energy are grouped into eight categories of knowledge to deepen the different perspectives related to energy, such as the importance of energy in daily life, its impact on the environment, its economic and political factors, and basic concepts of energy, among others.

In this study, it is argued that a person has achieved development in terms of energy literacy when they are proven knowledgeable within the spectrum of these categories. Although the formulation of a specific definition is ongoing, this exercise enables a better understanding of how educational materials provide valuable information on energy literacy and assessment of the means to improve the quality of curricular contents.

Table 2. Categories under the cognitive subscale.

Categories (Cognitive subscale)
A.Knowledge of basic scientific facts.
B.Knowledge of issues related to energy sources and energy resources.
C.Awareness of the importance of energy use for individual and social functioning.
D.Knowledge of general trends in Mexico, and the supply and demand of energy resources in the world.
E.Understanding of the impact of the use and development of energy resources on society.
F.Understanding the impact of the use and development of energy resources on the environment.
G.Knowledge about the impact of energy use and development decisions at the individual and societal levels and their effect on the ability of societies to meet future energy needs in a satisfactory manner.
H.Skills.

Method

The current study identified similar articles that analyzed the content of textbooks. As an example, Guerra-Ramos and López-Valentín (2011) examined activities for elementary education in natural sciences, using a category approach and theoretical frameworks used in previous research to facilitate their analysis. In Mexico, Paredes-Chi and Viga-de Alva (2018) assessed the environmental education policy and content of the national curriculum for elementary education in Mexico by employing a five-category framework formulated by experienced researchers in Mexican curricular studies. A common aspect of these studies was the use of frameworks and categories for conducting analysis in an orderly manner.

This study aims to examine the contents associated with energy literacy in the textbooks of the SEP using the energy literacy framework by DeWaters (2011). To do so, this work focuses on a collection of free elementary school textbooks published in 2014. A total of 44 textbooks (excluding teachers' textbooks and scrapbooks) were identified.

The method used is content analysis, which denotes the subjective interpretation of content through a systematic pattern and a process of identifying themes (Hsieh and Shannon (2005) cited by Valerio-Ureña et al. 2015). The process was conducted using the following steps:

1. Index evaluation: the review was limited to the index of contents due to the length of the books and the inability to perform computer-assisted keyword searches in their digital versions.
    a. Elements associated with energy literacy were identified. Two researchers conducted the selection and reviewed the indexes of each book (one is an expert on education, and the other is an expert on energy education).
    b. Topics with words or contents related to sustainability, energy resources, electricity, energy, pollution, and climate change, among others, were considered for analysis.
3. Observation and compilation: the content of the relevant topics identified was reviewed and stored digitally for later analysis.
4. Evaluation: with the help of the cognitive categories of DeWaters (2011) framework, the presence of content associated with energy literacy within each page of the identified topic was evaluated.
5. Recording and summation: To quantify the findings, a record was made of the presence of energy-related topics per page. One point was assigned per page for each specific aspect of each corresponding category regardless of content concentration (e.g. mention, definition, emphasis, or a complete page cover or illustration).
    a. In the case of divergence, the researchers discussed a topic until an agreement was reached on how to record it.

Figure 2 and Table 3 provide an example of this procedure. Figure 2 illustrates one of the pages identified in a first-grade textbook. Within the page, we observe elements, such as a

reflection in text about the sources of light and heat in my community, the absence of electricity and sunlight, and the use of electronic devices (e.g. a lamp and a radio). When relating them to specific aspects of energy literacy (Table 3), we found that discussing the sources of light and heat falls under category (A) *Knowledge of basic scientific facts* and under specific aspect (2) *Forms of energy.*

After a specific aspect was identified within the page of a textbook, one point was assigned and recorded for the page in which the reference was found. In Table 3, six specific aspects fall under category (A) *Knowledge of basic scientific facts*, which help to understand the components of the category. Finally, records were classified according to the relevant pages associated with each one of the courses and school grades.

Results

To facilitate interpretation, the results are presented on the basis of each research question.

1. How is the presence of the energy topic distributed by school grade, textbook, and pages?

We identified 33 topics, with a total of 130 pages associated to energy contents in the elementary school textbooks from first to sixth grades (Table 4). The level of content increased across grades with its lowest presence identified in three pages of the textbook '*Exploration of*

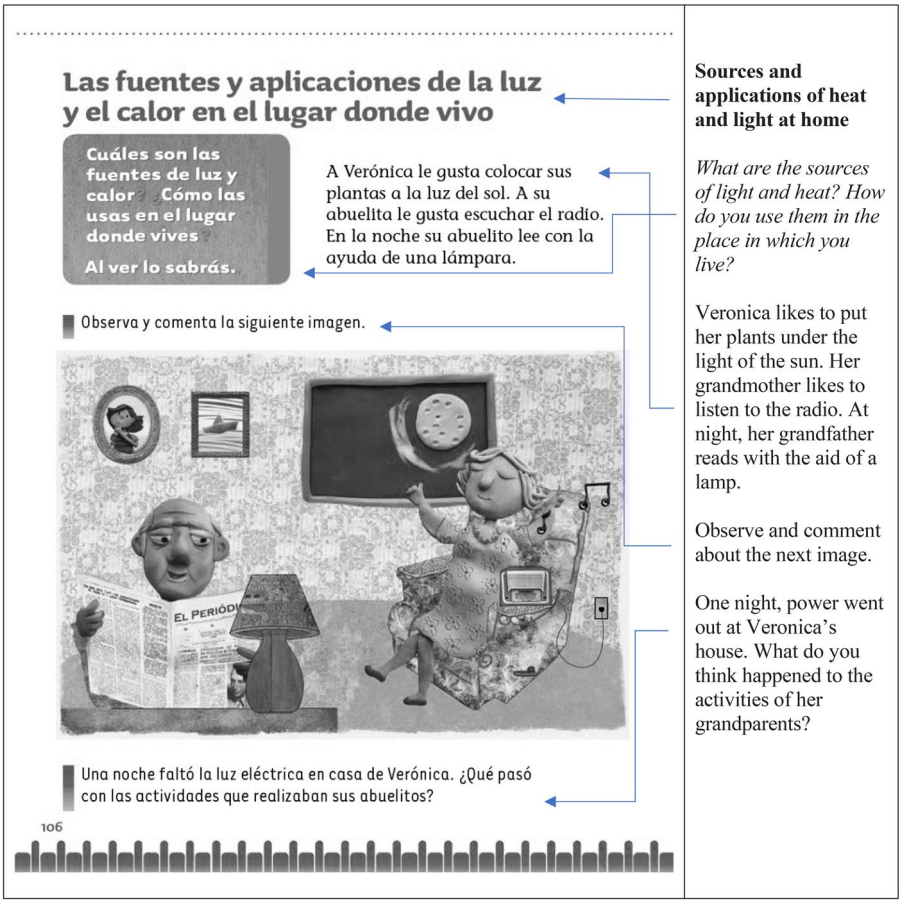

Figure 2. Example of illustration related to energy and text translations. Source: Exploring Nature and Society; First Grade (Martínez Luna et al. 2014, 106).

Table 3. Example of recording and summation of the presence of energy contents.

Category	Specific aspects	Sum	Subject: Exploration of nature and society
A. Knowledge of basic scientific facts	1. Definition of energy	0	
	2. Forms of energy	5	First grade: pp. 106, 107, 108 Second grade: pp. 108 and 109
	3. First and second laws of energy (e.g. concepts of conservation of energy and entropy)	0	
	4. Energy transfer mediated by living and non-living systems	0	
	5. Relationship between energy and power	0	
	6. Units of energy and power	0	

nature and society' in first grade. It was followed by eight pages in second grade, and seven pages in third grade with other courses, such as '*Civic and ethical formation*' and '*Natural sciences*'. In comparison with the upper grades, fourth grade exhibited 23 pages associated with energy in courses, such as *Geography*, *Natural Sciences*, and *the Atlas of Mexico*; 23 pages in fifth grade, which are covered by the majority of books (*Natural Sciences*, *Geography*, *Civic and ethical formation*, and *Atlas of the world*), and lastly, a maximum of 66 pages associated with *Geography*, *Civic and ethical formation*, and *Natural Sciences* in sixth grade. As a result, the first three grades of elementary school accumulate a total of 18 pages, whereas the upper grades include 112, which renders easily the observation of the greater proportion of contents from fourth grade onwards.

In terms of contents related to the topic of energy, textbooks with the highest number of references are (in ascending order): (1) *Exploration of nature and society*; (2) *Civic and ethical formation*; (3) *Natural sciences*; and (4) *Geography*, which includes the *Atlas of Mexico and Atlas of World Geography*. Alternatively, no references to stories, problems or activities related to energy were found throughout the textbooks for the *Spanish*, *Mathematical Challenges*, *Art Education*, and *History*. In the majority of cases, energy was found to be related to issues, such as the environment, sustainable development, and consumption, with increased emphasis on the oil industry. Although the textbooks highlighted renewable energy across the contents in selected topics, the information found was limited. Likewise, it did not highlight certain competitive advantages and challenges for the country, such as its location that is favorable for the generation of solar photovoltaic energy or strategies taken by the government to reduce dependence on fossil fuels, as discussed in the theoretical framework.

2. What elements of the DeWaters energy literacy framework can be identified in the textbooks?

The categories with greater coverage in the identified contents were characterized by the contemplation on the consequences of using certain natural resources. These categories were (A) *Knowledge of basic scientific facts*, (F) *Understanding the impact of the use and development of energy resources on the environment*, and (G) *Knowledge of the impact of decisions (…) on the ability of societies to meet future energy needs*. In contrast, those with lower coverage exhibited an increased inclination toward social issues, such as (C) *Awareness of the importance of energy use for individual and societal functioning*, (E) *Understanding of the impact of the use and development of energy resources on society and* (B) *Knowledge of issues related to energy sources and energy resources*. As an exception, the study did not consider category (H) *Skills*, because the measurement of a cognitive skill requires an evaluation of the capacity of students and not only through textbooks. Table 5 summarizes the overall results of the presence of these categories.

As previously described in Table 3, each of the categories in the cognitive subscale includes various specific aspects that help to measure the category in general. When examining these aspects, we found that the most frequent themes were related to the impact on the environment (F.1; Table 5), the relationship between fossil fuels and levels of carbon dioxide in the atmosphere (F.2), and the transfer of energy between living and non-living systems (A.4). In

Table 4. Distribution of contents related to energy in textbooks and its relationship between school grade and index topics per *course*.

School level	Textbooks and related subjects		
First grade (3 pages)	*Exploring nature and society* Unit IV: The sources and applications of light and heat where I live (pp. 106–108)		
Second grade (8 pages)	*Exploration of nature and society* Unit IV: Nature and its importance in everyday life (pp. 95–96) • Efficient use of electricity in daily life (pp. 108–109) 'How we celebrate: The oil expropriation' (p. 113–114)	*Exploration of nature and society* Unit V: Care for nature (pp. 131–132)	
Third grade (7 pages)	*Civic and ethical formation* Care for the environment and appreciation of our cultural diversity (p. 67).	*Natural sciences* Unit IV: Interaction of magnets and their utilization (pp. 120–125)	
Fourth grade (23 pages)	*Geography* Unit II: The riches of our country (pp. 127–131) Unit IV: The treasures of my country (pp. 159–165)	*Atlas of Mexico* Unit III: Electric power generation (p. 45) Unit IV: Oil and natural gas extraction (p. 58)	*Natural sciences* Unit V: Electrification of materials (pp. 111–113) • The effects of heat on materials (pp. 14–119)
Fifth grade (23 pages)	*Civic and ethical formation* Unit III. Care for the environment and appreciation of our cultural diversity (p. 106). *Geography* Unit IV. Primary activities (p. 115) • How do we reduce environmental problems? (pp. 160–163)	*Atlas of the World Geography* Chapter 4. Mining. Mineral and energy resources (pp. 96–97). • Industrial spaces (pp. 98–99) • Energy sources and consumption (p. 100) • World energy consumption (p. 101) Chapter 5: Environmental problems (p. 114)	*Natural sciences* Unit IV. The operation of the electrical circuit and its use (pp. 113–117). • Heat conduction and its utilization (pp. 119–123)
Sixth grade (66 pages)	*Geography* Unit II. Natural resources for life (p. 62) • Actions for sustainable development (pp. 67–73) Unit IV. Consumer societies (pp. 137–145) • Quality of life (pp. 149–157) Unit V. Local actions to preserve the environment (pp. 159–163)	*Civic and ethical formation* – Sustainable development (pp. 106–115)	*Natural sciences* Unit II: Relationship of air pollution to global warming and climate change (pp. 72–81) Unit III. Importance of temporary and permanent transformation of materials (pp. 98–99). Unit IV. Importance of energy, its transformation, and implications of its use (pp. 126–129). • Energy use (pp. 131–139)

contrast, we found the absence of presence for aspects of the framework of DeWaters (2011) associated with physics and economics of energy, such as the units of energy and power (A.6), the influence of energy supply and demand on geopolitical relations (E.1), or economic problems related to the scarcity of non-renewable energy resources (E.2).

Discussion

This study examined contents associated with energy literacy embodied in elementary-level textbooks in Mexico. Using the DeWaters (2011) framework, the study recognized the presence of categories and aspects associated with energy at each elementary school level. Thus, we found that students in the first and second years of elementary school are exposed to diverse topics, such as the sources and applications of light and heat, the efficient use of electricity, and the commemoration of Mexico's oil expropriation. Emphasizing the above-mentioned is

Table 5. Presence of themes related to energy within each category of the cognitive subscale.

Categories	Presence
A) Knowledge of basic scientific facts	40
A.4. Energy transfer mediated by living and non-living systems (19)	
A.6 Units of energy and power (0)	
B) Knowledge of issues related to energy sources and energy resources	20
B.6. Importance of fossil fuels to meet the energy demand of today's society and as components of multiple valuable products (6)	
C) Awareness of the importance of energy use for individual and social functioning	14
C.2. Energy uses in societies and households (8)	
D) Knowledge of general trends in Mexico, and the supply and demand of energy resources in the world	21
D.3. Use and management of the variety of energy resources in Mexico and globally (10)	
E) Understanding of the impact of the use and development of energy resources on society	17
E.1 Influence of energy supply and demand on geopolitical relations (0)	
E.2. Economic problems related to the scarcity of non-renewable energy resources (0)	
E.3. Impacts related to the use and development of energy resources (11)	
F) Understanding the impact of the use and development of energy resources on the environment	50
F.1. Impact of the use and development of energy generated with renewable and non-renewable resources on all spheres of the environment (18)	
F.2. Relationship between the combustion of fossil fuels and the increase in carbon dioxide levels in the atmosphere (18)	
G) Knowledge about the impact of energy use and development decisions at the individual and societal levels and their possible effects on the ability of societies to meet future energy needs satisfactorily.	26
G.3. Importance and effectiveness of personal actions and decisions to reduce energy consumption (8)	

Each category includes the specific aspect with the highest presence and the value of its contribution to the total of the category.

important, given that the official curriculum of the Ministry of Public Education identifies the beginning of the topic of energy from the third grade of elementary school solely within the subject *Natural Sciences* and only from the perspective of physics (Table 1). However, by changing the frame of reference of the understanding of energy, we find that other subjects apart from *Natural Sciences*, such as *Civics and Ethics, Geography*, and the Atlas collection, addressed its multidisciplinary nature, but not so for other subjects such as *Spanish* and *Mathematics*. If this is the case, then it may represent an opportunity for the Spanish course to promote stories (real or fictional) about the discovery of electricity or oil, the use of solar energy for aviation, or to imagine a world in which oil no longer exists. For older students, a critical opportunity emerges to reflect and debate on the advantages, disadvantages, and trade-offs associated with pollution and the extraction of rare minerals in relation to the clean energy industry.

In the case of *Mathematics*, the absence of problems associated with energy can be covered by calculations of electricity consumption or other resources. Examples of interesting exercises in *Mathematics* could be promoting curiosity to children in the upper grades by asking them to calculate their energy consumption through electronics in daily life and present it as a human right. Several questions may be asked, such as 'What would happen if every person on Earth had a smartphone?' and 'How much energy would be needed to toast a slice of bread?' With these types of challenges, children could endeavor in humorous and curiosity-arousing methods for understand the required elements to solve these issues. In addition, these exercises could provide an opportunity to rectify common misconceptions related to saving energy, such as the idea that turning lights off for 1 h will help to save our planet (WWF 2020), compared to the consumption of other appliances, such as a computer, an air conditioner, or a microwave oven. Although the intention of these type of advices is good, whether or not these actions promote better behaviors in the long run or only the belief of falsely contributing toward achieving goals oriented to climate change remains unclear. These types of activities also require students to become familiar with the measurement of energy, and the units used to measure it, such as kilowatt-hours and kilowatt ratings, which could help to increase their understanding

of category (A) *Knowledge of basic scientific facts* within the DeWaters' framework. Alternatively, a possibility exists for students in *Arts* to become familiar with the basic concepts of energy transfer, such as knowledge about batteries and conducting and insulating materials, as they create works of art using LED lights. An example of this activity could be a LED Christmas tree project, which could provide children with the opportunity to exhibit their personal styles and understand a few basic facts about current, voltage, resistance, and the manipulation of basic electronic equipment, such as switches, cables, capacitors, resistances, and batteries. In summary, these types of activities can create opportunities for students to exceed modular and curricular learning to motivate their interest and curiosity, which renders the topic attractive for children to learn and experience energy and develop interdisciplinary academic objectives simultaneously.

Employing the DeWaters (2011) framework for energy literacy facilitated the identification and analysis of categories and characteristics in energy education. However, the framework requires further analysis to be improved. As an example, studies that compared between the DeWaters framework with other frameworks for energy literacy are lacking. A suitable candidate for such comparative analysis in future studies would be the educational guide of the United States Department of Energy (DOE 2017) due to its design and set of organized categories, which are similar to those of DeWaters. Moreover, which aspects of the SDGs – which were announced in 2015 – are missing or present in the framework remains unclear. Future studies should address these concerns given that the original objective of the framework was to develop an assessment questionnaire instead of a guide for the appreciation of textbooks and other curricular materials.

When examining the relationship between the expected learning outcomes related to the objectives of the Ministry of Public Education in comparison with the findings of the current study in detail, we find notable differences between the expected learning outcomes and curriculum content in textbooks. A comparison between Tables 1 and 4 provides a clear view that energy is present in different courses and topics. Lastly, including Table 5 to this analysis, we find a greater concentration of topics that focus on caring for the environment but less on the relevance of energy to society. Despite several policy and technological changes that occurred over the previous decade, no significant ones were observed in the most recent versions of elementary textbooks, such as in *Natural Sciences* for sixth grade (Cevera Cobos et al. 2021) and other courses. This is observed despite UNESCO has promoted educational resources – as learning objectives and materials – as a component of their efforts toward achieving SDGs (UNESCO 2018). These findings could encourage educational researchers, teachers, and policy makers to require and observe for accountability in the development of our national educational materials.

This research has its limitations, which translates into a further need to refine these studies. First, the approach of limiting the search for energy-related topics through textbook indexes and not through an exhaustive review (as done by other works) implies a limitation in understanding the actual scope within textbooks. Thus, the possibility of performing keyword searches using computer commands was ruled out due to the nature of textbooks, which are available digitally only in image format. If electronic versions existed, then the frequency of words, such as *renewable*, *energy*, *environment*, and *electricity*, among others, could be examined to identify the content associated to discussions related to these terms, which sections in the books, and the extent of discussion. Finally, the decision to work with textbooks published in 2014 was derived from multiple changes that occurred on the CONALITEG website during the COVID-19 pandemic. Initially, this study was focused on reviewing textbooks published in 2017, which appeared to be the most recent edition on their website. However, the collection temporarily disappeared from the portal due to server changes in middle of the COVID-19 pandemic and was replaced by the 2019 and 2020 editions, which were unstable on the website due to multiple reconfigurations at the moment of the research, without the possibility to download the textbooks files. Therefore, observing that recent versions were subject to constant changes, we decided to examine only the collection of textbooks published in 2014 for research consistency.

An important aspect is that although the selected textbooks were printed in 2014, all of them were reprinted until 2018 – and some of them preserve most of their content until today, with minor or no changes.

A possibility for future studies is including the use of artificial intelligence applications to extract texts from textbook images, which can automate the collection of information from books that compose each annual collection. By doing so, a cross-sectional historical analysis (across years) can be performed and facilitated through text-to-picture searches to identify key words and sections in these educational materials. In turn, these ideas could ease the analysis of books on other topics of academic interest. Finally, the use of the DeWaters (2011) energy literacy framework proved useful for the analysis of features within textbooks. However, the possibility of reformulating and adapting it for a detailed visualization of the type of energy discussed (renewable or non-renewable) or used (oil, gas, coal, air, sun, others) is suggested.

Conclusions

Since the discovery of large oil deposits, Mexico has been privileged with one of the energy resources that defined the 20th century. However, the 21st century has been characterized by higher interest in sustainability and a rapid development of technologies for renewable energy. This new investment paradigm continues to challenge business models focused on fossil fuels, decreasing its value for the coming years, and marking the end of an era. Assuming constant values, estimations suggest that the reserve–production ratio of oil and gas reserves for the state company, Petróleos Mexicanos, is of 8.7 years (Chávez 2021), which provides the country with another decade of relative energy security. However, the question remains regarding whether it will be able to successfully make this transition on time or whether it will encounter difficulties amid public and political debates. Regardless of the scenario, the present offers an opportunity. To grab this opportunity, awareness of decisions should be increased regarding the role of education systems at all levels and the roles that individuals play in facing an important energy transition at the national and global stage.

The education of children in the next generations must answer as soon as possible to this need. Beyond the SDGs (UN 2015), Mexico can take a leading position in energy education. By adopting this strategy, a desirable scheme would be that future editions of textbooks will provide energy education using a clear and broad picture of addressing opportunities and weaknesses as a society and introducing children to debates that have concerned the country for more than a decade. These initiatives could help millions of students to become energy literate, which may gradually improve their decision making and critical judgment, as future citizens, regarding the use and understanding of energy. For this reason, adding content related to the benefits obtained from being in a convenient geographical position in terms of the generation of energy from renewable sources, such as wind, solar or geothermal, will be necessary. Another aspect to consider is the importance of the discovery of important deposits of lithium, which is an important mineral for the manufacture of electronic components, to the country. A topic of discussion could be whether or not this role should be considered only by educational institutions or should the experience of the private sector be contemplated in its realization. Finally, educational experiences may also start as a game, as in the case of Watt Watchers (University of Texas 2021), and could go further from generating a genuine and deep interest in energy issues, to help new generations identify early career interests (HISD 2020).

For the survival of any city, industry, or country, energy is the lifeblood that promotes the economic flow between the transportation of goods, public services, and electricity distribution for all sectors of the population. Likewise, how we decide – or not – to continue consuming energy will lay the groundwork on which difficult choices may be made. That is, focus on the protection of natural resources, biodiversity, and the environment; or take a delusive route that will serve as a reminder of why non-renewable resources are called as such. The need to further discuss its necessity is no longer needed. Instead, reflection on the meaning of the future of

energy dependence for future citizens and inhabitants of the country is more desirable. Needless to say, no work can be done without energy.

Declaration of interest statement

The authors report no competing interests to declare.

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Data availability statement

The data that support the findings of this study is available upon request to the corresponding author.

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