Building Ecological Literacy in Mining Communities: A Sustainable Development Perspective

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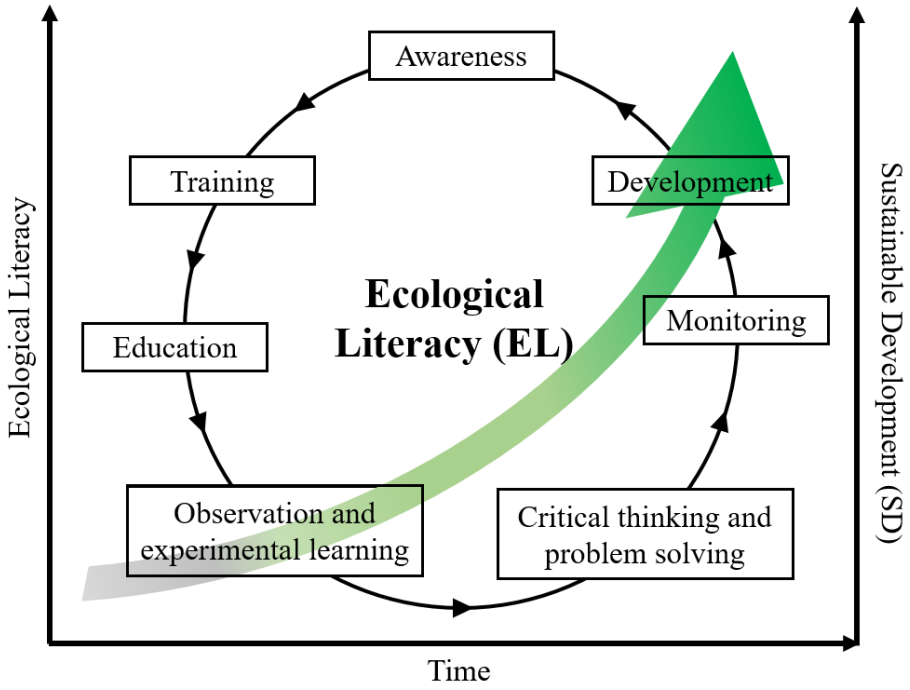
Abstract

Ecological Literacy (EL) is understanding and applying ecological principles to environmental issues. It involves recognizing the interdependence of living organisms and ecosystems and the impacts of human actions on the environment. EL individuals possess knowledge of biodiversity, ecological processes, and sustainability, enabling them to make informed, environmentally responsible decisions. This knowledge is essential for addressing ecological challenges and promoting sustainable development in all industries and communities. EL is a new concept in the mining industry introduced in this paper. Mining has a direct impact on ecology. This paper provides an overview of EL and its application in the mining industry, examining the potential benefits of EL for achieving sustainable and responsible mining. Results show that prioritizing EL Training (ELT) in the mining communities for countries with many mines has a higher priority than other industries. Also, in mining communities, ELT to workers, engineers engaged in mining, and government managers have a higher priority than other sectors in mining, respectively.

Keywords: ecological literacy, sustainable development, mining industry, mining communities

Graphical Abstract



1. Introduction

Before delving into the concept of sustainable development, it is necessary to clarify two fundamental elements: development and sustainability. Sharpley notes the potential conflict when juxtaposing development with sustainability [1], indicating potential counterproductive impacts. However, neoclassical economists, such as Matović, Lović Obradović, and Denda, argue that there is no inherent contradiction between sustainability and development [2]. Sachs asserts that sustainability and development are inextricably linked, asserting that no meaningful development can be achieved without sustainability, and vice versa [3]. As a general rule, development refers to the constructive changes that society undergoes over time, including federal and non-federal agencies' plans, policies, programs, and activities. The Human Development Index (HDI), a well-recognized development indicator, captures various socio-cultural, economic, ecological, and political categories [4]. Sustainability, in its literal sense, is the ability to maintain an entity, outcome, or process over time without depleting the resources upon which it depends [5]. The general understanding applies to all human activities and business processes; however, relying solely on it poses risks. Such an approach would likely overlook ecological constraints and the need to adapt human activity systems to existing natural systems [6]. In addition to supporting human activities, natural systems are essential for human survival. Therefore, addressing sustainability without considering ecological aspects is challenging [5]. As part of the discourse on sustainable development, ecological sustainability forms a foundational framework for addressing socio-cultural and economic sustainability.

Among the three components of sustainable development are socio-economic development aligned with ecological limitations, the redistribution of resources to meet human needs and ensure quality of life, and the possibility of long-term resource use for future generations. Fundamental principles of sustainable development include fulfilling human needs, protecting present and future generations, improving overall life quality and equality, preserving the environment and biodiversity, conserving natural resources, and judiciously using renewable and nonrenewable resources [7].

Figure 1 illustrates the relationships between different sustainable development indicators [8]. This study aims to add to the current conversation on sustainable development and the guiding ideas covered in the literature by making these links.

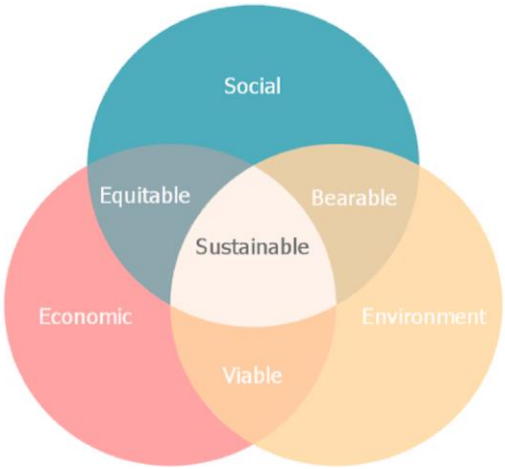


Figure 1: Relationship between sustainable development indicators [9]

Given the circumstances, it is clear that ecological challenges and sustainable development indicators are explicitly linked. Modern education strongly emphasizes the importance of people's moral and spiritual development, viewing it as a core component of the educational process. This aligns with the guidance and socialization purposes of spiritual and moral cultivation. Fundamental national values are ingrained in family customs, culture, and socio-historical contexts. One of the most important national values is nature, which includes Earth, evolution, natural reserves, native lands, and ecological literacy (EL) [10]. As an environmental science, ecology sheds light on how living things coexist in distinct physical environments.

On the other hand, EL refers to the ability to understand how natural systems work and how all living things are interrelated. In Persson, Andrée, and Caiman's work, EL is characterized as a tool that heightens our awareness and knowledge of the principles and processes governing natural systems. It extends our understanding of how these systems sustain life on Earth and prompts us to live in greater harmony and integration with them [11]. This approach strengthens the relationship between environmental problems, EL, and the larger sustainable development framework. This viewpoint is consistent with ongoing discussions in the literature, which highlight the critical role that ecological literacy plays in promoting sustainable development by recognizing Nature as a fundamental national value and the significance of EL.

The issues mentioned above underline the importance of enhancing EL in mining industries. Mining has the potential to significantly affect progress toward SDGs, both positively and negatively, as follows:

- Direct positive impact:
    - SDG 1 - No Poverty: Mining can support local economic growth and aid in the reduction of poverty by creating jobs and revenue for the community.
    - SDG 8 - Decent Work and Economic Growth: The mining sector has the power to boost local infrastructure and industry development and provide jobs and economic progress.
    - SDG 9 - Industry, Innovation, and Infrastructure: New infrastructure, such as energy facilities and roads, are frequently built as a result of mining operations, which is advantageous to the community as well as the enterprise.
- Indirect positive impact:
    - SDG 7 - Affordable and Clean Energy: To achieve this goal, mining corporations can also build new infrastructure to facilitate access to reasonably priced and dependable energy sources.
    - SDG 13 - Climate Action: we must be mindful of the potential indirect benefits of mining for minerals vital to renewable energy technologies like solar panels and wind turbines.
- However, it's important to also recognize the negative direct impacts as:
    - SDG 12 - Responsible Consumption and Production highlights how mining can deplete resources and harm the environment, leading to ecosystem damage and biodiversity loss.
    - SDG 6-Clean Water and Sanitation can be negatively impacted by mining because it can contaminate water sources with trash and dangerous chemicals, which can impact local communities and aquatic ecosystems. Finding a balance between encouraging renewable energy sources and making sure that mining operations are ethical and sustainable is essential.

- And negative indirect impacts
    - Mining can have a negative impact on the environment and nearby communities, particularly on SDG 3 and SDG 15. Inadequate mining techniques can cause adjacent people to be exposed to dangerous substances like asbestos and mercury, which can have a negative impact on their health. In the meantime, mining-related deforestation, habitat degradation, and soil erosion might impair land-based ecosystems and disturb biodiversity, which would hinder the achievement of SDG 15.

Achieving sustainable development requires finding a balance between the advantages and disadvantages of mining. This can be accomplished by using ethical mining methods, practical laws, and active community involvement to make sure the advantages outweigh the disadvantages. In this regard, these industries play an essential role in the training and expansion of EL due to their direct interference with Nature through mining and their relationship with educational organizations [12]. One of the major responsibilities of these organizations and mining companies is to cultivate positive feelings, values, and attitudes toward the surrounding world by enhancing "EL". Therefore, by training engineers and workers, mining companies should have a strong sense of duty to promote EL as one of the most fundamental challenges in the world's socio-environmental index of sustainable development.

Thus far, it has been elucidated that one of the most vital social and environmental sustainability issues is developing and implementing relative EL in communities. EL has not received much attention or developing SDG (Sustainable Development Goals) assessment tools in the mining industry. Regarding SDG analysis tools for the mining business, it should be noted that while there are many SDG evaluation tools available, not all of them are specific to the mining sector. However, general SDG evaluation instruments can be tailored to the mining environment with a few tweaks. Here are several SDG assessment frameworks and methods that the mining industry can use to support sustainable development:

1. UN SDG Compass: Mining companies can use the UN SDG Compass as a comprehensive guide. It helps companies match their plans to the Sustainable Development Goals. This tool can help mining businesses assess how their operations such as community participation, environmental procedures, and responsible sourcing, affect particular Sustainable Development Goals [13].
2. Global Reporting Initiative (GRI): The GRI provides sustainability reporting standards that mining companies commonly adopt. These standards can easily be incorporated into the mining industry to aid in the assessment of sustainable development [14].
3. The Sustainable Development Goals Impact Assessment (SDGIA) is an essential tool that makes it possible to assess a project's, initiative's, or business's contribution to the SDGs in detail. It can be customized to meet the unique requirements of the mining sector, enabling a comprehensive analysis of the sector's influence on a number of SDGs, from community development to responsible mining practices [15].
4. The International Council on Mining & Metals (ICMM) has devised a set of Mining Principles that serve as a standardized framework for promoting sustainable mining practices. These principles are in alignment with several SDGs, including responsible environmental stewardship and community well-being. As such, mining companies can utilize these principles as a means of self-assessment [16].

5. Sustainable Mining by the Earth Institute: The Earth Institute, which provides the mining industry with a wealth of tools and information, is at the forefront of advocating sustainable mining methods. For mining businesses working toward sustainable development, these resources are crucial since they frequently include assessments and evaluations that help ensure sustainable practices [17].
6. Explore and Utilize Local and Global Sustainability Protocols: When it comes to sustainability, different regions may have their own set of standards, while others apply on a broader scale. For instance, mining companies can make use of both local and international sustainability standards. Notable examples include ISO 14001, focusing on environmental management [18], ISO 26000 for social responsibility [19], and ISO 45001 for occupational health and safety. These established standards serve as a helpful framework for evaluating alignment with the SDGs [20].

It should be noted, therefore, that the best framework or assessment instrument may differ based on the particular goals, circumstances, and scale of the mining operation. To properly adopt sustainable practices and conduct a thorough assessment of the mining industry's impact on the SDGs, it may also be advantageous to integrate a variety of techniques and methodologies. In any case, EL ignorance is more evident in developing communities and countries as they prioritize economic growth and ignore the SDG.

To the best of the researcher's knowledge, no study has been conducted on the effects of EL on mining activities and sustainable development indicators. For this reason, the difference between this article and other articles in the field of EL is that this article can be the first (or one of the first) manuscripts that examine EL in the field of mining (The author's belief, according to the background of the studied research, this article will introduce the concept of "*Ecological Literacy*" in the mining community for the first time).

Therefore, this study explores the necessity of EL in the mining industry to achieve a more sustainable community. To this end, EL is initially clarified as a relatively new mining concept. The relationship of EL with sustainable mining is then explicated. Afterward, a method is introduced to prioritize various sectors of communities and mining companies for Ecological Literacy Training (ELT) to achieve more sustainable communities and mining. Ultimately, the discussion and conclusion are reported.

2. EL in the sustainable mining industry

Embedded within the foundational principles of modern society are core values such as the human nature of education, the prioritization of human life and health, individual rights and freedoms, the genuine and free development of individuals, mutual respect training, hard work, respect for Nature and the environment, and rational nature management [11]. These principles underscore the importance of instilling values that promote harmonious coexistence between human activities, particularly within industries that have a direct impact on the environment. Traditionally, Ecological Literacy Training (ELT) has focused on instilling respect for Nature, imparting skills necessary for working in natural conditions, cultivating emotional-value attitudes toward wildlife, and providing knowledge, skills, and abilities in ecology [21]. In the context of mining, an industry fundamental to the economic growth of many nations, the impact on the environment is inevitable. The various stages of mining operations, including exploration, extraction, loading, transportation, closure, and reconstruction, inherently interfere with and alter natural systems, leading to environmental pollution [22]. Recognizing the

indispensable role of the mining industry in economic development, industrial growth, and employment in numerous regions worldwide, it becomes imperative to transform mining practices into responsible, environmentally conscious endeavors. Achieving responsible mining involves leveraging existing technologies to minimize environmental impact. A promising avenue for achieving this objective is through the enhancement of Ecological Literacy (EL) among workers, engineers, employees, and managers engaged in mining processes [23]. Drawing on the insights from the preceding sections, it becomes evident that continuous training, coupled with regular field visits, emerges as the most efficient approach for imparting Ecological Literacy. By aligning practical experiences with theoretical knowledge, this approach equips mining professionals with the understanding and skills necessary for sustainable mining practices. This synthesis of education and practical application forms a crucial bridge between theoretical concepts and on-the-ground environmental responsibility, contributing to the broader discourse on responsible mining in the existing literature.

ELT and personality development should be among the focal concerns in educational organizations and all organs and organizations connected with the environment and ecosystems. One of the major difficulties of this training is to teach a generation purposefully so that they can make changes in their surrounding areas without violating the principles and laws of Nature. The foundations of ecological culture, like those of other cultures, are cultivated throughout life. The formation and development of EL is a long-term process and should be considered from various angles. In the training process, EL is shaped by acquiring certain environmental knowledge and improving emotional sphere and practical skills to establish environmentally effective interaction with Nature and the community [24]. Zverev, a Russian ecologist, defines the following tasks for ELT [25]:

- Training: The formation of knowledge about the Nature of ecology, Nature, and their mutual relationships; the development of a system of skills to promote the ecology of the environment.
- Education: The education required to act following the laws and norms of Nature.
- Development: development in intellectual, emotional, and volitional areas, a tendency to improve and partake in practical issues to care for and preserve the environment.

In the realm of Ecological Literacy Training (ELT), a crucial shift in mindset is underscored—the need to reshape prevailing notions of human supremacy over nature. This transformative education, as articulated by Sarbassova et al., advocates for a paradigm shift, fostering an understanding that views Nature not merely as a means to fulfill human needs but as an integral entity where Nature and humanity coexist [26]. Central to ELT is the imperative of continuity across all educational stages, encompassing schools, families, workplaces, universities, and preschools. Sarbassova et al. emphasize that the enduring impact of ELT on future citizens and the younger generation necessitates consistent training throughout their educational journey. Mere comprehension of the essence of ecological literacy is insufficient; it demands proactive identification and resolution of challenges through the application of requisite technologies [26].

Recognizing humans as active agents with the power to shape the environment, it becomes paramount for each individual to possess a certain level of Ecological Literacy (EL). This places environmental information at the forefront of vital knowledge acquisition. Prioritizing

environmental education in schools and extending it across all community sectors, especially through early childhood education, is identified as a crucial step by Orr. Orr also calls for scientific organizations to define human-nature interactions meticulously, investigating and evaluating the intricate relationship and dependence on the environment [27].

Direct observation and research are deemed indispensable for practical EL, requiring the exploration of objects, phenomena, and natural relationships to establish cause-and-effect connections. Cutter-Mackenzie and Smith highlight the significance of regular and continuous investigations of Nature as fundamental requirements for achieving EL. Further, raising awareness about natural preservation responsibilities necessitates the creation, induction, and highlighting of the beauty of the environment in people's minds. Engaging individuals through thought-provoking questions in various forums is identified as an effective strategy for instilling a sense of responsibility toward nature conservation [28].

In the context of mining, situated at the heart of Nature, continuous field visits have gained prominence among mine workers due to their direct and effective impact. However, challenges persist in the educational domain due to a shortage of qualified experts [28]. The temporary and symbolic nature of existing training, as noted by Chua, underscores the need for a more substantial and practical approach [29]. The presence of experienced individuals with sufficient Ecological Literacy becomes pivotal for effectively transferring EL concepts to mine workers, addressing a critical weakness in the current educational landscape. The most significant issues that should be trained to convey EL to mine workers are as follows:

- They are raising ecological awareness about the destructive effects of mining on Nature and the necessity of responsible extraction. Humans are propelled to extract minerals for survival and development. To reduce the negative impacts of mining, it should be carried out to cause the least environmental damage. Therefore, one of the responsibilities of EL is to raise awareness about environmental damage and help minimize it.
- Raising ecological awareness about the impacts of responsible mining operations on plant and animal species
- Creating a sense of responsibility in mine workers about the ecological challenges posed by mining
- Teaching mine workers about responsible behaviors toward Nature
- Raising awareness about the necessity of applying skills from the given ELT
- Giving proper perspectives to mine workers on the positive effects of applying the given ELT
- Underscoring the importance of mine workers' transferring the given ELT to their family members and, on a larger scale, to society

Both sustainable development and EL are significant and interrelated matters. Sustainable development is directly associated with EL. If the EL of mine workers is fostered, its direct effects on social and economic indicators will be observed. In the social indicator, EL would promote the personal knowledge of mine workers, raising a sense of duty about Nature and environment preservation in mine workers. Moreover, since the given training is likely to be conveyed to families, a suitable platform is created for cultural formation in EL [30]. The application of the given training would also elevate the health of society. As for the environmental indicator, by creating a sense of responsibility for environment conservation in people, EL can hinder further environmental damage caused by mining operations and boost

the survival of plant and animal species. As a result, it is highly required to apply EL in mining communities and develop this knowledge among people working in mining complexes.

3. Prioritization for ELT in mining countries

It has been argued that nowadays, EL is one of the most vital human needs to have a healthier life and environment. Due to mining activities, mining countries directly threaten the environment and endanger native animal and plant species [31]. Since most mining countries are underdeveloped or developing regions, little attention has been devoted to EL at the macro and operational levels. Short-term and discrete training has usually been offered in this field. Moreover, due to the preference for the economic indicator in these countries, the environment of these communities has been facing serious challenges because of mining activities [32, 33].

Since there is a lack of serious and continuous training on ecological issues and the provided training has almost been ineffective, it is necessary to plan ELT and implement these plans in these mining communities, particularly due to the nature of mining activity [29].

The term *ecology* is not well known to many people in mining, especially those in undeveloped or developing communities. Therefore, it is initially essential for academic professors and people who make macro-policy decisions in social responsibility, the environment, and mining to understand this area well [34]. In the next step, by using expert opinion and prioritization tools and considering society's policies, different sectors of society should be identified and put in order of priority to transfer EL to people at the community level. Then, detailed and large-scale planning at the community level should be made based on the identified priorities. Finally, experts should implement this planning step by step over a certain period to convey EL to society (Figure 2). The most efficient technique to improve the perception and effectiveness of EL in a real sense is to provide continuous training and establish rules for applying the taught knowledge in the real environment [35].

Considering the necessity of prioritizing the transfer of EL to the community, as thoroughly discussed above, this study aims to evaluate the priority of different community sectors in mining countries for ELT (Figure 2) using the Fuzzy Delphi Method (FDM). This method was first introduced in the early 1950s in a project carried out in the US Air Force under the supervision of Dalkey, an academic researcher from the Rand Cooperation, in order to examine the opinion of experts about the extent of damage caused by the explosion of a Soviet atomic bomb in the United States [36]. This project is known as the Delphi project, and consequently, this method is widely recognized as the Delphi method to include expert opinions in research. Based on this method, experts judge the issue under investigation when insufficient and unsatisfied knowledge is available. The purpose is to reach the most reliable expert consensus on a specific issue. This method is implemented by taking opinion polls from and/or administering questionnaires to experts [37].

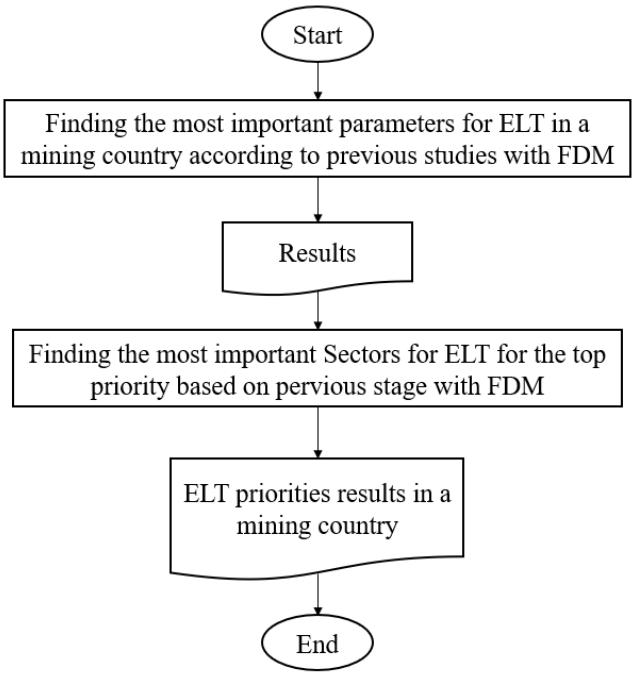


Figure 2: Framework of prioritization for ELT in mining countries

The Fuzzy Delphi method, as an extension of the Delphi method in management science, was propounded in 1988. It is appropriate for complicated and confusing settings because it combines expert opinions with fuzzy logic to resolve uncertainty and ambiguity in forecasts. It offers qualitative insights that are especially useful for long-term estimates and scenarios where expert opinions are vulnerable to subjectivity. On the other hand, multicriteria analysis provides an organized, quantitative method by comparing options according to predetermined standards and producing numerical results. It thoroughly evaluates a variety of factors, meeting the needs of decision-making scenarios where accuracy and numerical comparison of options are critical. The nature of the decision problem, the data at hand, and the decision-desire maker's accuracy and detail in the outcomes all influence which of these approaches they choose. In the Delphi method, the predictions made by experts are expressed through definite numbers. However, by using definite numbers for long-term predictions, the obtained results may be far from reality [38]. The steps to implement this approach are as follows:

In the first step, the fuzzy numbers are calculated as follows (equations 1 to 5):

$$a_{ij} = (\alpha_{ij}, \delta_{ij}, \gamma_{ij}) \quad \text{(Eq. 1)}$$

$$\alpha_{ij} = Min(\beta_{ijk}), k = 1 \dots \dots \dots n \quad \text{(Eq. 2)}$$

$$\delta_{ij} = \left(\prod_{k=1}^{n} \beta_{ijk}\right)^{1/n}, k = 1 \dots \dots \dots n \quad \text{(Eq. 3)}$$

$$\gamma_{ij} = Max(\beta_{ijk}), k = 1 \dots \dots \dots n \quad \text{(Eq. 4)}$$

$$\alpha_{ij} \leq \delta_{ij} \leq \gamma_{ij} \quad \text{(Eq. 5)}$$

where β_{ijk} denotes the relative importance of parameter i over parameter j from the point of view of expert k. The fuzzy triangle's minimum, average, and maximum numbers are symbolized as L, M, and U, respectively. The number of experts is represented by n.

Then, this method determines the weight of controlling parameters in the created two-dimensional matrix. In this regard, firstly, a questionnaire was constructed with the intended parameters and was sent to the experts. The experts then rated the importance of the parameters in the indicators. In the next step, the weight of each parameter was calculated and normalized to 10.

The fuzzy triangular numbers on a 7-point scale were used to estimate the importance of controlling each parameter (Table 1).

Table 1: Description of fuzzy triangular numbers on a 7-point scale

linguistic expression (Abbreviation)	linguistic expression	Fuzzy Number
EI	Extremely Important	(0.9, 1, 1)
VI	Very Important	(0.75, 0.9, 1)
I	Important	(0.5, 0.75, 0.9)
MI	Medium Important	(0.3, 0.5, 0.75)
U	Unimportant	(0.1, 0.3, 0.5)
VU	Very Unimportant	(0, 0.1, 0.3)
EU	Extremely Unimportant	(0, 0, 0.1)

After the expert opinion matrix was formed, the following equations were utilized to compute the weight of each parameter (equations 6 and 7).

$$F_{AVE} = \frac{\sum l}{n}, \frac{\sum m}{n}, \frac{\sum u}{n} \quad \text{(Eq. 6)}$$

$$\tilde{F} = (L, M, U) = Then\ F = \frac{L + M + U}{3} \quad \text{(Eq. 7)}$$

Where F denotes the average

Since mining communities directly affect their surrounding environment and the mining areas' ecology, the conveyance of EL to these communities seems critical. By training these communities and encouraging them to employ the taught knowledge, it is feasible to promote responsible mining and create a better environment and a more sustainable society. Thus, the present study attempted to prioritize various sectors of mining communities and countries for ELT. Given the direct influence of mining operations on the mining regions' ecology, the human force's priority in different sectors of the mining industry for EL was also assessed in more detail.

4. Priority of different sectors in the mining community for ELT

Given the need to increase ecological awareness in all communities, especially mining communities whose mining operations directly impact the environment, this study was designed to prioritize various sectors of a mining community for ELT. To do this, a questionnaire was initially created, assuming there was no ELT in the mining communities or

that the training was cross-sectional and had a minimal effect. After that, the 7-scale FDM survey forms (Table 1) were prepared and administered to 20 qualified experts (only one of these experts worked in the mining industry). Six experts with the characteristics listed in Table 2 completed these forms.

Table 2: Characteristics of experts prioritizing four sectors in a mining community for ELT

Skill	Education	subject	Number
Academic member	Ph.D	Mining engineering	1
		Environmental engineering	2
Non-academic member	Ph.D	Environmental engineering	1
		Risk Management	1
Student	MSc	Environmental engineering	1

Table 3 reports the results of the expert opinions. These results were analyzed to identify the priority of four sectors for ELT: mining complexes, academia (undergraduate or graduate students), schools (students at all elementary, middle, and high school levels), and preschool.

Table 3: Expert opinions on the priority of four sectors in a mining community for ELT

	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6
Mining (C1)	EI	VI	EI	EI	EI	VI
Academica (C2)	VI	I	VI	EI	VI	VI
The school (C3)	VI	I	I	VI	VI	I
Preschool (C4)	VI	EI	VI	EI	EI	VI

Table 4 indicates the fuzzy form of the expert opinions in Table 1.

Table 4: Fuzzification expert's opinion on four sectors in a mining community for ELT

	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6
C1	(0.9,1,1)	(0.75,0.9,1)	(0.9,1,1)	(0.9,1,1)	(0.9,1,1)	(0.75,0.9,1)
C2	(0.75,0.9,1)	(0.5,0.75,0.9)	(0.75,0.9,1)	(0.9,1,1)	(0.75,0.9,1)	(0.75,0.9,1)
C3	(0.75,0.9,1)	(0.5,0.75,0.9)	(0.5,0.75,0.9)	(0.75,0.9,1)	(0.75,0.9,1)	(0.5,0.75,0.9)
C4	(0.75,0.9,1)	(0.9,1,1)	(0.75,0.9,1)	(0.9,1,1)	(0.9,1,1)	(0.75,0.9,1)

Table 5 shows the defuzzification and prioritization of the fuzzy numbers of the expert opinions on the priority of the abovementioned sectors in a mining community for ELT.

Table 5: defuzzification and prioritization of four sectors in a mining community for ELT

	Average	Result	Rank
C1	(0.85, 0.97, 1)	0.94	1
C2	(0.73, 0.89, 0.98)	0.87	3
C3	(0.71, 0.83, 0.95)	0.83	4
C4	(0.83, 0.95, 1)	0.93	2

Based on the results, in mining communities where ELT is not given or is very limited and ineffective, the order of educational priority is as follows: the mining sector, preschools, academia, and schools (Figure 3).

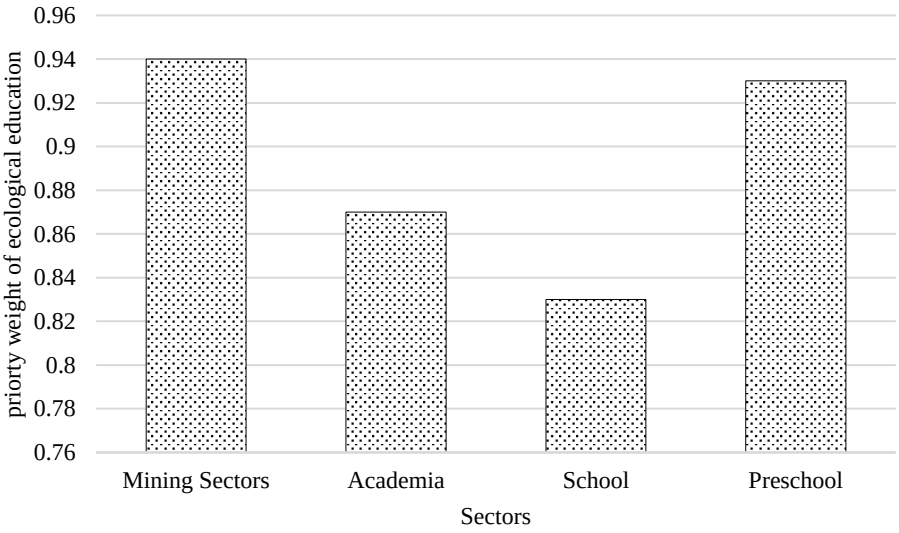


Figure 3: Priority of four sectors in a mining community for ELT

The ELT of people in the mining sector is the top priority because it directly brings about significant natural changes. Due to the nature of this industry, environmental pollution caused by mining operations has been fully confirmed [39]. Therefore, given the considerable ecological impacts of this industry on the environmental and ecological health parameters, it is possible to significantly reduce environmental pollution induced by mining activities by providing ELT for people involved in this industry. The effects of ELT would be immediately observed in communities in which no special attention has been devoted to this issue. In these communities, mining, a leading industry closely related to ecological issues, can be an overriding priority for ELT. In this way, the environment's health would increase, directly raising the health of the communities.

Preschools were ranked second for ELT in mining communities. The efficiency of education on children during childhood has been verified. Consequently, continuous ELT for preschool children and recreational camps to raise awareness about ecological problems and their effects on the environment and human health can substantially enhance the EL of the future working generation.

As the third priority for EL, university students would enter the working community quickly (some students are even employed while studying). As a result, it is paramount to promote their EL to create a proper perspective on the impacts of mining activities on the community and environment. The provision of ELT for students at schools is also very important. However, due to the lack of literacy mentioned for the other three sectors of the mining industry, universities, and preschools, this group was ranked fourth (It seems that considering the great capacity of people at younger ages to learn, ELT should start from preschools and continues up to high schools in order to accomplish the process of ELT at schools).

5. Priority of Human Resources (HR) in a mining complex for ELT

The results indicated that in a mining community whose economy partly relies on mining and where ELT has not been provided or has been limited, people in mine complexes were prioritized over people in other groups for environmental training. At this stage, another questionnaire was constructed to determine the priority of the human force within a mining

complex for ELT. To do this, a mining complex was first divided into six groups, namely, government employees involved in mining activities (government employees), the employees of mining companies (private employees), mining engineers, mining workers, government managers involved in mining activities, and the managers of mining companies (private managers). The prioritization of these groups for ELT was investigated. The prepared forms were sent to 15 qualified experts, and eight experts with the characteristics listed in Table 6 completed the forms.

Table 6: Characteristics of experts evaluating the priority of HR in a mining complex for ELT

Skill	Education	Subject	Number
Academic member	Ph.D	Mining engineering	3
		Environmental engineering	1
Non-academic member	Ph.D	Mining engineering	1
Student	Ph.D	Environmental engineering	1
	MSc	Mining engineering	1
		Environmental engineering	1

The data obtained from the expert-opinion survey were analyzed to rank the abovementioned groups in the order of priority for ELT, and the results are presented in Table 7.

Table 7: Expert opinion on the priority of HR in a mining complex for ELT

Expert	1	2	3	4	5	6	7	8
Private employees (MC1)	I	I	VI	VI	MI	VI	VI	EI
Government employees (MC2)	VI	EI	VI	I	VI	I	VI	I
Engineers (MC3)	I	VI	VI	EI	VI	EI	EI	EI
Workers (MC4)	VI	VI	EI	EI	EI	EI	EI	EI
Government managers (MC5)	I	I	VI	VI	I	VI	EI	EI
Private managers (MC6)	MI	VI	VI	EI	VI	VI	VI	VI

Based on the results in Table 1, the experts' opinions were transformed into fuzzy numbers, as shown in Table 8.

Table 8: Fuzzification expert opinions on the priority of HR in a mining complex for ELT

Expert	1	2	3	4	5	6	7	8
MC1	(0.5,0.75,0.9)	(0.5,0.75,0.9)	(0.75,0.9,1)	(0.75,0.9,1)	(0.3,0.5,0.75)	(0.75,0.9,1)	(0.75,0.9,1)	(0.9,1,1)
MC2	(0.75,0.9,1)	(0.9,1,1)	(0.75,0.9,1)	(0.5,0.75,0.9)	(0.75,0.9,1)	(0.5,0.75,0.9)	(0.75,0.9,1)	(0.5,0.75,0.9)
MC3	(0.5,0.75,0.9)	(0.75,0.9,1)	(0.75,0.9,1)	(0.9,1,1)	(0.75,0.9,1)	(0.9,1,1)	(0.9,1,1)	(0.9,1,1)
MC4	(0.75,0.9,1)	(0.75,0.9,1)	(0.9,1,1)	(0.9,1,1)	(0.9,1,1)	(0.9,1,1)	(0.9,1,1)	(0.9,1,1)
MC5	(0.5,0.75,0.9)	(0.5,0.75,0.9)	(0.75,0.9,1)	(0.75,0.9,1)	(0.5,0.75,0.9)	(0.75,0.9,1)	(0.9,1,1)	(0.9,1,1)
MC6	(0.3,0.5,0.75)	(0.75,0.9,1)	(0.75,0.9,1)	(0.9,1,1)	(0.75,0.9,1)	(0.75,0.9,1)	(0.75,0.9,1)	(0.75,0.9,1)

Table 9 indicates the defuzzification and ranking of the fuzzy numbers of expert opinions on the priority of HR in a mining complex for ELT.

Table 9: defuzzification and ranking of priorities of HR in a mining complex for ELT

	Average	Result	Rank
MC1	(0.65, 0.83, 0.94)	0.807	6
MC2	(0.68, 0.86, 0.96)	0.833	4
MC3	(0.75, 0.93, 0.99)	0.89	2
MC4	(0.86, 0.98, 1)	0.947	1
MC5	(0.69, 0.87, 0.96)	0.84	3

MC6	(0.71, 0.81, 0.97)	0.83	5

As the results showed, ELT in the mining sector had a high priority in the mining community, where mining was a basic industry, and planning and prioritizing all mining sectors for ELT were necessary to accelerate educational processes and achieve high educational efficiency. The results indicated that the workers and engineers working in mines were the priority for EL. Government managers dealing with mining activities, government employees involved in mining operations, private managers in mining companies, and private employees working in mining companies were ranked third to sixth, respectively (Figure 4).

As illustrated in Figure 4, mining workers and engineers had a higher educational priority than other groups since they are directly and closely involved in the mining environment. It is essential to teach ecological issues to mining workers, given that these people carry out the main production operations. Training mining engineers were placed in the second rank. These engineers are responsible for managing mining workers and projects in the mining areas; therefore, they can effectively monitor the implementation of ELT by mining workers in mines.

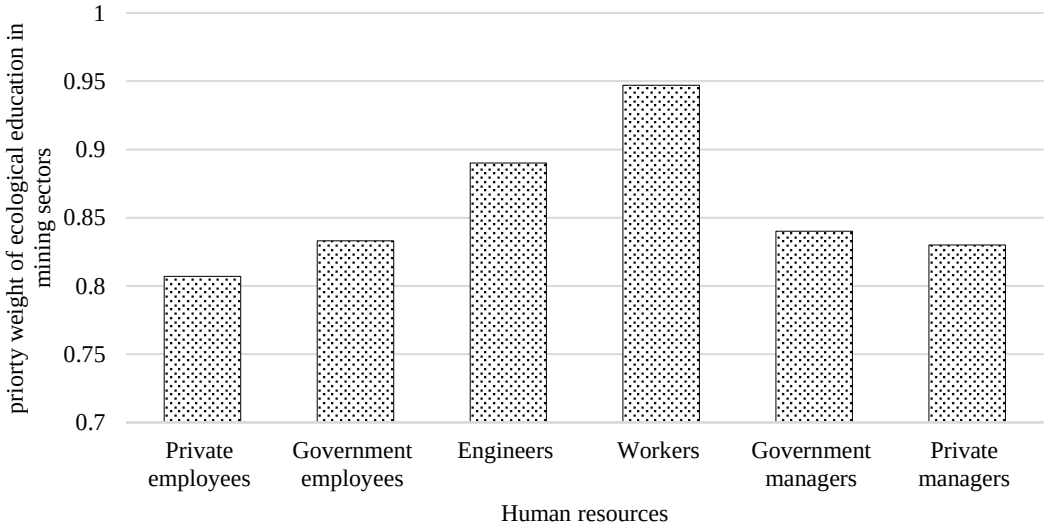


Figure 4: Priority of HR in the mining industry for ELT

Ranked in third place were government managers involved in mining activities. These managers can set new policies, regulations, and laws. Hence, new environmental laws and regulations for mining activities can be established by providing ELT for them. When government managers take a proper view of EL and recognize the importance of this issue, the expansion of this knowledge in the mining sector will significantly be accelerated. Government employees are responsible for implementing instructions and new laws created by government decision-making organizations and monitoring their implementation in the real environment. Thus, raising ecological awareness to understand better the issues related to this field can positively influence the implementation of these instructions and laws in mining.

Furthermore, by having higher levels of EL, government employees can provide more effective and accurate reports on ecological issues and problems in the real environment. Mining managers can also know about ecological challenges in more detail by reading these reports and creating more detailed instructions with greater precision based on them. The managers of

private companies are ranked in the fifth place probably because they are not directly involved in the mining environment and have much less relationship with the mining sectors than government managers and employees. It is worth mentioning that ranking private managers as the fifth priority does not mean that ELT is inconsequential for these people. It is required to provide ELT to all people in the community, but they are fifth in order of priority considering the current conditions).

6. Discussion

Nowadays, EL is one of the most basic requirements of having a healthy life and environment. In underdeveloped and developing countries, the number of human activities damaging the health of society and the natural environment is substantially increasing. Therefore, the absence of environmental education or the underestimation of the importance of ELT due to the preference for income maintenance and economic growth would destructively affect these countries. The communities that regard the mining industry as one of their major wealth-producing industries would experience more negative environmental effects than other communities because of the direct interference of this industry with Nature. Most communities considering mining the main income-generating industry are undeveloped or developed countries. These countries prioritize income maintenance and economic development over environmental and social matters. Hence, EL has been either ignored or provided in a cross-sectional manner, which has not profoundly influenced the growth of EL in these communities.

To start ELT in a mining community, it is practically impossible to develop the necessary infrastructure and have enough experts to extensively and effectively implement this type of education for the whole community simultaneously. Efficient ecological education in these communities entails step-by-step planning to establish and expand infrastructure and train experts who function as ecological tutors in the future. Other significant results of this study are as follows:

- The most vital factor in the effectiveness of ELT is the continuity of training. It is paramount to devise an integrated program for continuously training people in the community to promote EL and observe the consequences of such training at the community level. Along with training, field visits and the implementation of applicable training on the field and the real environment can stabilize ecological knowledge in people.
- Training all people in that community is important to achieve sustainable EL in a community. When all community members understand the importance of this issue and the necessity of complying with the associated laws, one can declare that the community has achieved sustainable EL.
- Establishing sustainable ecological laws and regulations by government organizations and making the execution of these laws and regulations mandatory for people working in industrial units can improve environmental pollution, which boosts the community's health. Furthermore, in communities where ELT has been ignored or received little attention, the formation of appropriate laws, instructions, and guidelines can promote their ecological conditions locally and superficially.
- It is required to augment the EL of educational, industrial, and mining decision-makers to raise awareness about the importance of ecological issues and their effects on the community. The decision-making organizations in education, industry, and mining should closely interact with each other to design an integrated educational program and provide

continuous and efficient training for people from young to older ages. In this way, the community can achieve EL.

7. Conclusion

The study, using the FDM method, identified the priority areas for Environmental Literacy Training (ELT) in mining communities. Results indicate that immediate impacts are best achieved by prioritizing ELT for mining companies (0.94 weight), followed by training for preschool children, university students, and school students (0.93, 0.87, 0.83 weights, respectively). Among mining companies, training mining workers and engineers takes precedence due to their direct involvement in mining operations and the environment (0.94 and 0.89 weights, respectively). Next in priority are government managers (0.84), government employees (0.83), mining company managers (0.83), and private employees in mining companies (0.80). The study emphasizes the effectiveness of continuous Environmental Literacy Training (ELT) and real-world ecological awareness to enhance Environmental Literacy in mining communities. From the sustainability perspective, applying EL in communities greatly impacts sustainable development. The most important effects of sustainable development on the sustainability goals are as follows:

1. Promoting Sustainable Mining Practices: EL can guide individuals and mining companies to comprehend the environmental impacts of mining and advocate for sustainable practices, like using renewable energy and minimizing waste.
2. Conserving Biodiversity: EL emphasizes the significance of biodiversity conservation in mining areas, aligning with SDG 15. It promotes understanding and adopting practices that minimize mining's impact on biodiversity.
3. Promoting Sustainable Communities: EL addresses the social impacts of mining, urging awareness on land use, displacement, and water access. It supports SDG 11 by encouraging sustainable mining practices that benefit local communities and economic development.
4. Supporting Responsible Consumption and Production: EL educates mining stakeholders on the environmental impact of mining activities. It emphasizes responsible consumption and production (SDG 12) by promoting practices that minimize waste and enhance resource efficiency.
5. Reducing Greenhouse Gas Emissions: EL underscores the need to reduce greenhouse gas emissions in mining, aligning with SDG 13. It encourages the adoption of sustainable mining practices, including the use of renewable energy sources and minimizing energy consumption.

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