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Framing citizen science and sustainable education development

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Abstract The world is now changing on a multidimensional scale, and citizens are calling for sustainable development to deal with economics, society, and the environment. Citizens of the twenty-first century must contend with socioeconomic and environmental development, as well as degradation growth rates. Sustainable development is a key term for living in balance. This study employed a literature review method to frame citizen science and sustainable education development. A systematically high number of academic articles were retrieved from the ERIC database, identifying a gap between the literature and sustainable educational development. The findings revealed that citizen science can communicate, be scientifically informed, socially connected, and respectful of diversity. Sustainable educational development should foster an understanding of a holistic perspective for all learners. Science is a key subject for explaining two prongs in the current of modern scientific development. It teaches about the relationship between local and global contexts. To ensure the existence of a sustainable environment, education should be considered at all educational levels. Educational policy should incorporate a balance among economics, society, environment, and culture into the curriculum and pedagogical practices. Thus, sustainable education development should be integrated with citizen science, multiculturalism, and a holistic approach to learning behavior.

Keywords: citizen science, global citizenship, sustainable development

1. Introduction

The modern world in the era of sociocultural borderlessness calls for participation and social justice. The United Nations and 193 countries endorsed the 2030 Agenda for Sustainable Development and Sustainable Development Goals, or SDGs, with the purpose of seeking a balanced approach to global cooperation and development (UNESCO, 2015). Seven teen goals are a framework for the development and balancing of natural resources based on sustainable social, economic, and environmental development (Pais and Costa, 2020). The goals are also aimed at not leaving anyone behind by 2030. It consisted of 169 SDG targets for creating internationalization, connection, and support in each other. The SDGs make their linkage in 5 dimensions, or 5Ps, i.e., people, planet, prosperity, peace, and partnership (Goren and Yemini, 2017; Sant et al., 2018).

The Asia-Pacific Centre of Education for International Understanding (APCIEU) aims to build teachers' understanding of sustainable development goals. In 2012, the United Nations (UN) announced that education should be more than paving the way for a career. However, it must be a force that creates sustainable development in the future and creates a better world. Education policy must therefore support all people in learning how to live with others, in their environments, and in peace (Ho, 2018; Goh and Deutschman, 2020; Veugelers, 2021). Furthermore, education should instill in our children respect for humanities as well as environmental stewardship. Education must not only be readable, written, and mathematical but also shape humans to live together in all patterns of peace, and it should be an open society for multiculturalism and diversity (Chanchitpricha et al., 2019; Sagala et al., 2019; Janmaimool and Khajohnmanee, 2020).

The new paradigm of scientific learning and teaching in the 21st century not only focuses on subject topics or science content but also enables learners to comprehend the learning process of science and literate science in relevant circumstances and make contributions to the lesson. Learners need to acquire the abilities essential to exploring knowledge, which will enable them to comprehend the dynamic natural circumstances and surroundings that surround them, as well as the role that science plays in the process of social development (Wongchantra and Nuangchalerm, 2011; El Islami et al., 2018; Listiana et al., 2019; Duncan et al., 2021). By being exposed to a wide variety of educational opportunities, they are able to independently produce and distribute information. Information technology breaks down barriers to learning and paves the

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way for borderless education. Users of this technology are able to compile and analyze data and deploy relevant knowledge while making rational choices (Juhji and Nuangchalerm, 2020; Nuangchalerm, 2020; Khajornkhae and Nuangchalerm, 2021).

Learners need to understand that the majority of natural occurrences follow a specific pattern and that this pattern can be predicted. The scientific method allows for the explanation and verification of hypotheses using the resources and information at hand. Learners need to be aware that science, technology, society, and the environment are all interconnected and cannot be considered independent of one another in the context of human activity (Herman et al., 2018; Herman et al., 2020). Learners of science are encouraged to think and behave more like scientists, as well as to possess their traits. It is able to use the process of seeking knowledge, planning, collecting, analyzing, summarizing, and presenting in a scientific way based on the idea that learners are engaged in action to find their own knowledge based on interests or needs. This idea allows it to use the process of seeking knowledge in a scientific way (Siribunnam et al., 2014; Foulk et al., 2020). It is important for educators to take into account the maturation of their own learning styles, the state of modern education, and the preparedness of their learners to inquire.

A reductionist view can be used to look at science, technology, society, and the environment in the modern world. Information technology has made it possible to study anything anywhere in the world. This used to be impossible before the development of information technology. Literate learners are able to use science to maximize the conditions in which they find themselves in real life, and they are also able to go beyond this to address citizenship issues that science and sustainable development are attempting to balance. The comprehensive approach of scientific literacy and global citizenship education was the primary topic of this essay. Additionally, an overview of the conceptual framework of sustainable development was examined to facilitate a concrete conversation.

1.1. Scientific knowledge is power

People need to learn science so they can know, understand, use, and be used to living in and interacting with the world from an ecological point of view. This is a very important goal. Despite the fact that scientific information is shared globally, it is found to be most useful when used regionally (Weyl, 2021). Learners are expected to know about science on both a global and a local scale. Learners are expected to use their deep understanding of scientific principles in their everyday lives, to learn from both facts and arguments and to judge events and processes that are happening now and will happen in the future. Then, they can use scientific information to address both scientific and nonscientific problems (Rosenberg and McIntyre, 2019). Furthermore, a holistic approach to science encourages all learners to participate in citizen science and environmentally sustainable development, to engage in literate practices through science education and to develop a growth mindset in relation to science, technology, society, and the environment (Jax et al., 2018; Prachagool and Nuangchalerm, 2019).

The scientific knowledge that is being generated explains things by definition of science. In nature, as a cornerstone of scientific progress and social development, science is a cultural tool for researching and explaining phenomena in the trajectory accepted by science (Hartikainen, 2008). The language of science is simplified by the educational process, and curriculum and pedagogical practices can make connections from science to the public. Learning science requires the theory of learning, which helps explain human behavior. Learning science is not exactly like finding scientific knowledge because learning science helps learners enter into the knowledge that scientists experiment with. When scientists create new scientific knowledge, it can be said that knowledge is created. By applying what scientists have discovered, we can expand the understanding of learners more easily and enhance science for all (Henderson et al., 2015; Vincent-Ruz and Schunn, 2018). The process of finding scientific knowledge is as follows:

- Asking questions and defining problems: what happens and what exists, why does it happen? and how do we know?. These questions are the beginning of our curiosity about natural phenomena that scientists use as the beginning of their proof or experiment.
- Developing and using models: makes a form of scientific exploration that explains more easily to others. Good teaching and learning, teachers must adhere to the philosophy and nature of science. The development of the teaching model is mainly based on the development of teaching and learning innovation.
- Planning and carrying out investigations: the success of scientists is not just someone with academic knowledge, but they have a good plan for investigation. Knowledge is the basis for the extension of new knowledge. Planning to conduct experiments and collect systematic data will help them to speed up learning and avoid wasting long trial and error to achieve goals.
- Analyzing and interpreting data: Scientists will use the data once they have been received to perform an analysis by using existing knowledge or may analyze statistical data. They should be fulfilled in terms of data analysis ethics and a straightforward interpretation of the experiment by not inserting personal opinions or bias into the data analysis results.

- Using mathematical tools: Scientists sometimes need to use mathematical formulas to calculate them to form a universally symbolic descriptive equation. In teaching science, it is important to define the symbols used to convey meaning to understand and create a matching science classroom activity.
- Constructing explanations: a much-needed skill for scientists is effective representation and communication. When discovering new knowledge, it is inevitable to show that information to the public. Communication is an important tool to convey needs in emotional expressions, feelings toward individuals and the environment.
- Engaging in argument from evidence: scientific explanation may be flawed, citing is supporting reasons from testimony that allows to make informed decisions, especially information that can be observed. However, in modern times, the information is so widely unnoticed for a limited time. Learning that learners are aware of enough information can help them think and make decisions quickly and reliably.
- Obtaining, evaluating and communicating information; if lacking in reading science, it is like a dumb person. Learners need to develop understanding into scientific communication. Science teaching also needs to develop learners to know scientific literacy through presentations to communicate in a scientific way.

All learners can be empowered by scientific knowledge to understand and apply science in this manner. Global and local knowledge can be met in the balance by the scientific method and its process to reveal natural phenomena. Social development needs science as a driver to lead us in the negotiation arena between science and nonscience dilemmas. However, scientific knowledge has the power to shape our economic, environmental, social, and technological development (Fritz et al., 2019; Patterson and Gray, 2019; Lee et al., 2021).

1.2. Bridging science to education

Science is one of the fields that is designed for school curricula, and especially in the modern world, it cannot be reduced to a reduction of pedagogical practices. Due to science, both subject matter and the process of knowledge construction can be explained (Cole, 1992; McComas et al., 1998; Bell and Lederman, 2003). The rules and procedures are hypothesized, tested, and organized into genuine practices. In addition, science can be claimed as a culture in the modern world when all societies must learn and understand that science is an important tool for improving quality of life. Therefore, the management of education and teaching of science must be nurtured to allow learners to understand deeply and see science as a way of life (Sinakou et al., 2019; Kopnina, 2020).

Science cannot be separated from our social activities or social movements; we should not think fragmentarily that science differentiates and divides humans into supernatural but rather raises awareness that science is subject to the laws of nature. Sustainable development should use science to coexist with nature in a balanced way (Frantzeskaki et al 2019). When we understand it, as mentioned above, it causes science literacy, in which knowing science is about the impact of science on society. The evolution of scientific knowledge from research chambers to information technology. The decision to apply science to improve the quality of life of oneself and society (Garrecht et al., 2018; Rieckmann, 2018; Chowdhury et al., 2020).

Knowing science will help us develop an understanding of the importance of science as a culture and something that reflects human thinking abilities. The science teaching process promotes the nature of science by providing learners with the opportunity to prove it. Experiment and communicate rational discoveries between science and social science (Laugksch, 2000; Roth and Lee, 2002; Yacoubian, 2018; Aristeidou and Herodotou, 2020). The nature of science is methodically accessible and explained clearly, based on testimonies that can be proven or experimented with through the senses. It is also a body of knowledge that is widely studied and offered in educational institutions. Teaching science in pursuit of knowledge and understanding of the nature of science will allow learners to connect the relationship between science, technology, society, and the environment (Holbrook and Rannikmae, 2007).

Thus, scientific literacy for all is a concern for all sectors. Every society needs to develop people who understand the nature of science, scientific development, and systemic thinking. In general, scientific knowledge subject to change is empirically based on observations and concerns technology, society, and the environment. It cannot be separated from social and cultural dimensions (Yacoubian, 2015; Karisan and Zeidler, 2017). Science is therefore meaningful as long-standing knowledge, and it is also a process that develops rational ideas for research. Systematic troubleshooting can be determined using a wide range of data and verifiable testimonies (Foster and Huber, 1999).

The American Association for the Advancement of Science (AAAS), 1990, presented three issues related to the nature of science: scientific worldview, scientific inquiry, and scientific enterprise. The *scientific worldview* is the concept of the methodology of phenomena that occur in nature. Things in the universe have absolute stereotypes. If studied carefully, humans can discover phenomena and understand that they occur by patterning. Scientific knowledge gained from observations leads to the creation of theories to explain the phenomenon, and it is possible that the emergence of new phenomena cannot be explained by the original theory. *Scientific inquiry* is the pursuit of scientific knowledge and is a guide or method for building knowledge. The pursuit of knowledge must be based on observational testimonies, and scientists must control the conditions that affect their observation. The effects of observations are conditional without the influence of other conditions. However, if scientists cannot control the conditions of what's studied, they're not. Scientists need to study

the phenomenon enough to continue to summarize references. *Scientific enterprises* are complex social activities because science infiltrates the way of life, and everyone applies almost all science. In addition, science is classified as a separate material and is open, teaching in educational institutions and agencies. Scientists are both scholars and members of society who exist in society as part of society.

Considering the environment around us, science and social science are connected to the nature of living in many ways, i.e., education, politics, economics, culture, and so on. Therefore, science education focuses on teaching and learning that is consistent with the perception and understanding of the nature of science (McComas et al., 1998; Cofré et al., 2019). When science and education enter the learning arena, they play a role in determining the direction of social development. Curriculum and teaching activities should allow learners to learn what is happening in science and how to change it, rather than bringing only what scientists have discovered or telling learners experimental stories (Queiruga-Dios et al., 2020).

1.3. Citizenship in science education development

In 2015, the education goal will focus on access, creating equality, quality of education, education for all, and sustainable development of education. The United Nations launched the Sustainable Development Goals (SDGs), which are significant goals. Specifically, Target 4.7 recommends that by 2030, all learners can acquire the knowledge and necessary learning skills required to promote sustainable development, including among others, through education for sustainable development. This target also needs to promote sustainable lifestyles, human rights, gender equality, a culture of peace and nonviolence, global citizenship, and an appreciation of cultural diversity and of culture's contribution to sustainable development.

Global citizen education (GCED) increases international cooperation to enhance the quality of education for all. It entails achieving all 17 global goals by 2030 to lead global society into equal colearning. It is intended to develop learning skills, values, and attitudes to be a healthy citizen and live a good life, to be environmentally and socially aware, and to make decisions based on reason and appropriate principles, with a commitment to quality education. A citizen should also be responsible for locality and globality. All learners will gain knowledge, skills, understanding of human rights, gender equality, participation in creating a culture of peace, not using violence to solve problems, respect for multiculturalism, and a sustainable development culture (Pandeeka and Maneekul, 2019).

Hence, learning management for sustainable development objectives (Caiado et al., 2018; Malik, 2018) assists individuals in acquiring knowledge in a manner that is both integrated and founded on how to respond to occurrences that take place in society. The concepts that underlie effective learning management may be broken down into three categories: cognitive, socioemotional, and behavioral. Learners are better prepared to acquire information and an awareness of local, national, and global goals thanks to the cognitive dimension (Strachan, 2018). They are aware of the links and linkages between things, although individuals and countries are distinct from one another. They also have acquired critical thinking as well as the abilities necessary for critical thinking (Shulla et al., 2020).

Learners will be better prepared to gain experience with fundamental human rights, learn about diverse values and responsibilities to society based on human rights, develop understanding toward others, and respect the differences that come with multicultural diversity if they pay attention to the socioemotional dimension of education. Learners will be better prepared to conduct responsibly in their local and global obligations if they focus on the behavioral dimension. They should be encouraged to engage in global efforts to make peace and in sustainable development if we take a comprehensive approach (Rieckmann, 2018; Kioupi and Voulvoulis, 2019).

Sustainable development goals are clearly correlated with understanding; they give learners the opportunity to learn about the issues that arise in local and global society (Nuamcharoen and Dhirathiti, 2018; Kopnina, 2020; Uppamaiathichai and Roueangrong, 2021). It encourages learners to develop new skills such as critical thinking, changes in self-behavior, and reflection. An important learning process must lead learners to the decision-making process on the basis of reliable information, scientific reasoning and argumentation, and environmental education. Teachers serve as an important target drive mechanism in lifelong sustainable education. Teachers, who are a model for globalization and are able to create education for peace, respect human rights, embrace diversity, and have a sustainable development goal to manage learning, create learning for learners based on principles to deal with a friendly environment, coexist, adapt, and understand the diverse needs of all learners (Lüsse et al., 2022).

To achieve sustainable development goals, citizenship in science education and development can work together by educating people holistically. This article must answer the research question of how citizen science is related to sustainable education development. The critical review can be used for investigation and elaboration into science education in Thailand.

2. Methodology

This study employs a literature review method on citizen science relevant to sustainable education development. Based on the holistic approach and critical overview for sustainable development, an efficient writing audit was utilized. A scholarly education database was a significant source for review through the ERIC database, which collected research articles

and reviews in the field of education between 2018 and 2021. Keywords were generally defined in terms of “sustainable development”, which was found in 1,881 titles; “sustainable education”, which was found in 2,355 titles; “scientific literacy”, which was found in 1,022 titles; “science literacy”, which was found in 2,243 titles; “global citizenship”, which was found in 604 titles; and “global citizenship education”, which was found in 578 titles. A systematically retrieved high number of academic articles in the database was studied. The identification of gaps between the literature and sustainable education development to provide reliability and possibility regarding science citizenship and sustainable development. The review process is shown in Figure 1.

Articles that were relevant to the scope of the study were analyzed; some articles were excluded and classified for a conceptual overview. Citizen science and sustainable education development were concluded and presented in descriptive and narrative reports.

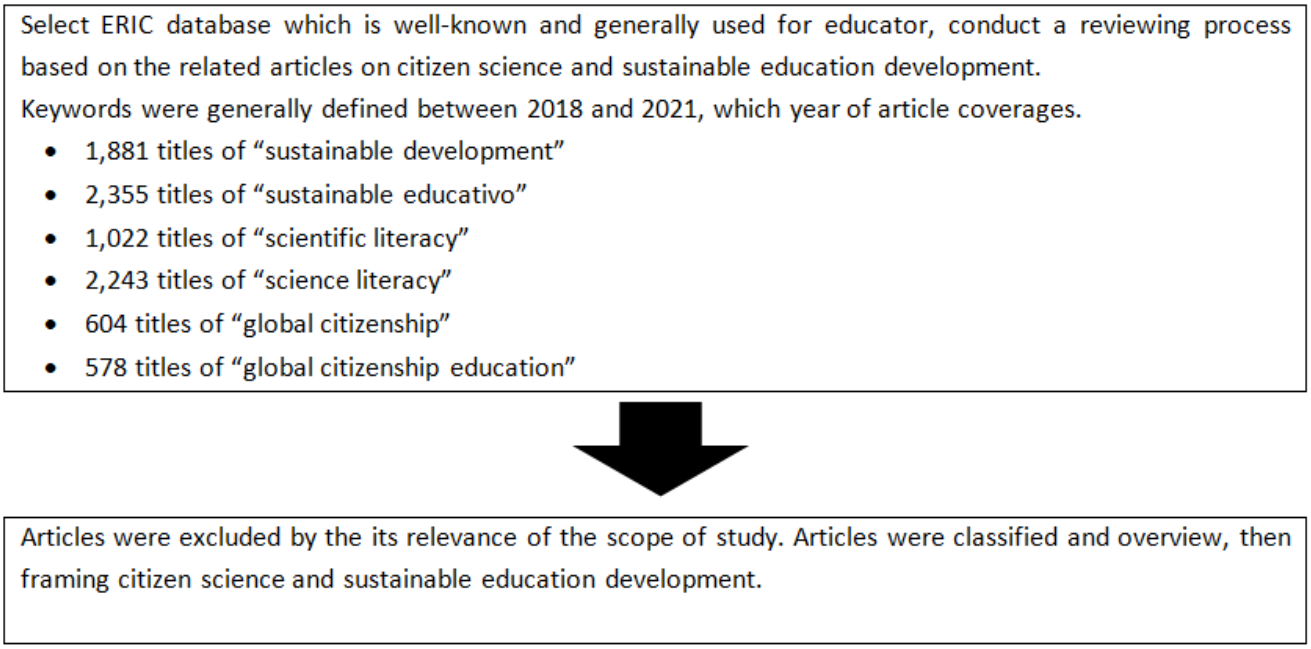

Figure 1 Method for reviewing articles.

3. Results

Citizen science can communicate, be scientifically informed, socially connected, and respectful of diversity. Sustainable educational development should foster an understanding of a holistic perspective for all learners. The world can be linked through global and local paradigms by accepting our diversity and differences in human rights and social responsibilities. We can share our appreciation for culture, language, religion, gender, and other differences. Beliefs and values in the local community can be explained by scientific concepts, but some are not. Citizens must accept and respect beliefs that have been passed down from generation to generation. However, education can engage science in social decision-making, perceptions of social justice, and civic engagement in a variety of ways.

Citizen science has the potential to make a large difference in efforts to move forward with sustainable development. The term "citizen science" refers to the participation of those who are not scientists in the conduct of scientific research, data collection, and analysis. This strategy could involve and give power to the people in the area in regard to monitoring and fixing environmental problems and promoting sustainable development. One way that citizen science helps the field of sustainable development is by keeping an eye on the quality of the air and water. The environmental monitoring systems in many developing nations are either insufficient or nonexistent, leaving local residents vulnerable to the effects of dangerous contaminants. The practice of citizen science has the potential to offer communities an efficient, low-cost method of monitoring the quality of their air and water and locating possible sources of pollution.

Science is a key subject for explaining two prongs in the current modern scientific development. It teaches about the relationship between local and global contexts. In addition to social media movements, learners should cultivate attitudes of care and empathy for others. With these differences, the environmental mind and respect for cultural diversity share values of fairness and social justice. Indeed, they participate in social activities and contribute to contemporary global issues at the local level to be responsible and responsive global citizens. The framing of citizen science and sustainable education development can be seen in Figure 2.

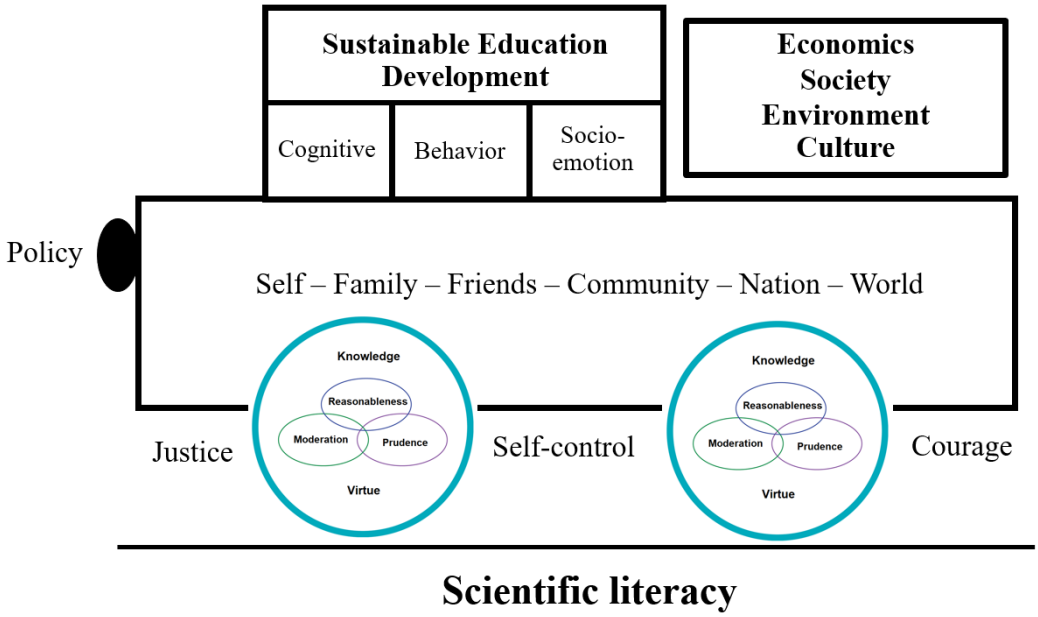

Figure 2 Framing of citizen science and sustainable education development.

Figure 2 shows that the environmental mindset and respect for cultural diversity both share the shared ideals of fairness and social justice. This is because both are essential for the creation of a world that is both sustainable and equitable. Both sides agree that it is important to learn about and appreciate the different cultures and ways of life in the world. They also agree that social and environmental problems need to be dealt with locally to have an effect on a global scale. The environmental way of thinking places a lot of emphasis on protecting the natural world and reducing the damage that humans do to their surroundings. This point of view recognizes that environmental problems, such as climate change, pollution, and the destruction of habitats, are global issues that require both individual and group action. We can help protect the natural world and ensure that future generations will be able to live on a healthy planet if we support activities that are good for the environment and take steps to reduce our impact on the environment.

On the other hand, having respect for cultural variety places an emphasis on the significance of understanding and appreciating the distinctive cultural customs and behaviors that are practiced by many groups located all over the world. This viewpoint acknowledges the value of cultural variety as an intrinsic component of the human experience and the notion that every culture has something unique to offer the larger global community. We can contribute to making the world a more peaceful and fairer place where everyone has the chance to prosper if we educate people about other cultures and show respect for those cultures.

Respect for cultural variety and the environment both emphasize the significance of social justice and fairness. Citizens are aware that problems affecting society and the environment are intertwined and that tackling one of these problems necessitates addressing the other. We can assist in promoting sustainable practices and conserving the natural environment while also promoting social well-being and human dignity if we work together to build a society that is more just and equitable. Citizen science may increase the capacity of local communities while also providing educational opportunities and encouraging sustainable development.

In addition, citizen science helps promote sustainable development. Anyone can increase their understanding of scientific methodology and add to the body of scientific knowledge by participating in citizen science programs. The participation of local communities in environmental monitoring and research is one of the primary ways in which citizen science has the potential to contribute significantly to the cause of sustainable development. Citizen science entails the participation of people who are not trained as scientists in the process of data collection and analysis. This method has the potential to provide significant information on environmental concerns and to improve sustainable development methods. Participation in citizen science can also provide educational opportunities and contribute to local community capacity building. Respect for different cultures and a concern for the environment are both based on the ideas of fairness and social justice, which are needed to make a world that is both sustainable and fair. Each of us can become responsible global citizens who work to make the world a better place for everyone if we take part in social activities and help solve problems on a local level that affect the world as a whole.

Serious environmental issues are being caused all over the world as a result of human population increase, the rapid consumption of the earth's natural resources, and the destruction and contamination of tens of thousands of ecosystems. Environmental education is the most important answer to these problems because it tries to teach people information, attitudes, behaviors, and skills that are related to the relationship between humans and nature and environmental issues.

Environmental education is the most important response. An individual's ecological literacy may be improved through environmental education by informing and improving knowledge about research, analysis, and problem solving for sustainability. This, in turn, leads to positive behavioral change and growth.

Therefore, environmental education and local knowledge should be emphasized since everyone knows that environmental problems will continue to worsen. This means that people need to learn about the environment so they can be effective in the long run. This is because everyone knows that environmental problems will keep getting worse, and it is important to teach people about the environment. To guarantee the existence of a sustainable environment, education must be taken into consideration throughout the entirety of the educational process. Learners should be focused on establishing a balance between the economy, society, environment, and culture. In addition, curriculum and pedagogical approaches should include instruction on how to prevent difficulties and encourage environmentally responsible actions.

UNESCO (2015) provides global citizenship education based on the three domains of learning, which consist of cognitive, socioemotional and behavioral domains. *The cognitive* domain referred to knowledge, understanding, applying information to deal with others, and thinking skills to better understand the world. *The socioemotional* domain refers to attitudes, values, perspectives, and social skills that enable learners to develop their affective, psychosocial, and physical abilities to live together with others respectfully and peacefully. *The behavioral* domain refers to manipulating, investigating, conducting applications and engaging in exposure to surroundings. These are interconnected to key learning outcomes that can be employed for local and self-development in concrete performances.

Table 1 Framing of citizen science and sustainable education development.

Cognitive	Socioemotional	Behavioral
• Learners develop information and insight in order to connect local, national, and global challenges • Learners obtain critical thinking and analysis abilities based on scientific concepts and a holistic approach	• Learners demonstrate a sense of connection to a shared humanity through sharing values, obligations, and scientific endeavors • At each level, learners build empathy, solidarity, and respect for individual differences and cultural variety • Learners are eager to share their innovative ideas and creative thinking in order to maintain a healthy local, national, and global environment	• Learners act effectively and responsibly at local, national, and global levels for a more peaceful and sustainable development through community-based learning, service learning, and engagement in environmental preservation • Learners increase their motivation to learn and their willingness to participate in community development and cross-cultural understandings

The comprehensive approach to educational sustainability may be carried out across three dimensions: cognitive skills can be taught through formal, informal, and nonformal education settings. Learners are able to access and question knowledge from a wide variety of types and techniques of learning sources, which is especially true in this age of information technology and increased communication. Despite the fact that the epidemic is currently targeting our social activities, there appears to be less connection between socioemotional skills among learners and others. It is the kind of influence that leads to genuine conduct, such as participation in local development, environmental campaigning, science education in public schools, and green democracy. Although scientific information should be shared globally, sustainable educational development guides learners to prepare themselves to deal with variations and diversity. This is done with an eye toward achieving pattern solidarity.

Science education, on the other hand, can bring diversity and uniqueness to practical learning. The core teaching and learning practices in the current era of equality need retraining in a respectful, inclusive, and interactive classroom and school ethos, as well as culturally responsive, independent, and interactive instructional practices that align with sustainable education. Teachers should use globally oriented learning resources and cross-cultural understandings to provide learners with opportunities in a variety of contexts that balance environmental protection and science and technology development (Figure 3).

On a local, national, and international level, it is important to show how education helps achieve human rights, peace, and responsible citizenship and contributes to sustainable development and education. The information in this kind of education needs to be up-to-date, and it needs to focus on both the cognitive and noncognitive parts of learning. We can give people the knowledge, skills, values, and attitudes they need to live useful lives, make good decisions, and help deal with and solve global crises both locally and globally. As stated in the description of SDG Target 4.7,

"By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and nonviolence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development".

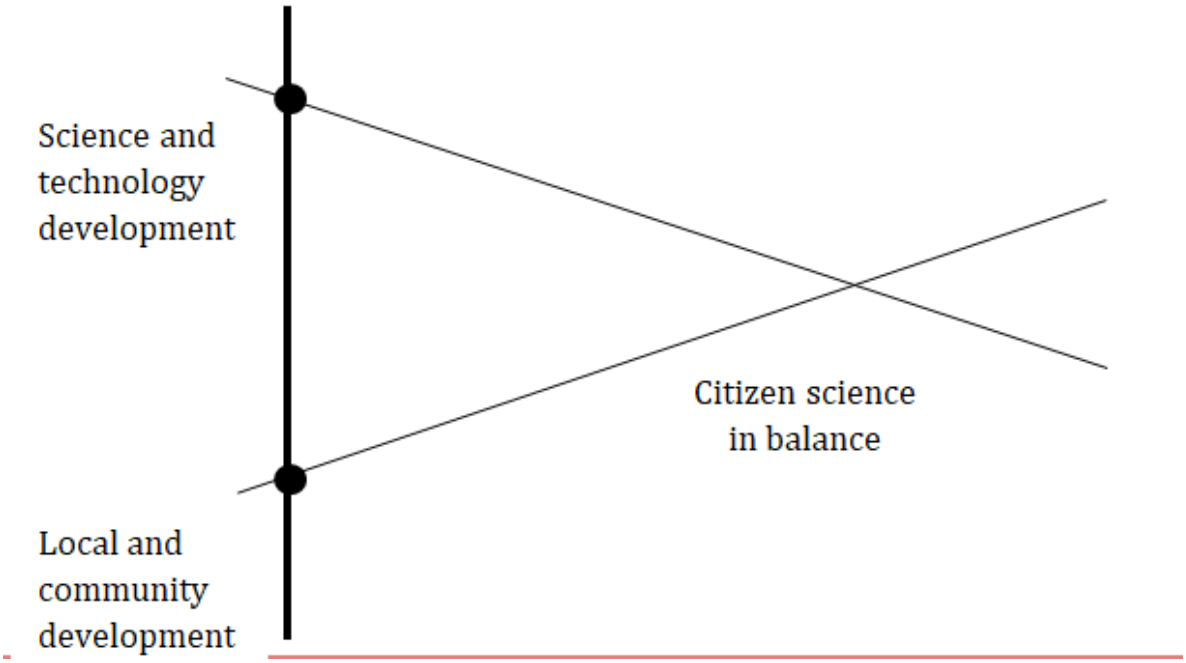

Figure 3 Balancing of citizen science.

In the new field of scientific communication, there is a push to use the Internet to manage information from many different sources. To ensure that people can use digital technology in a way that is good for society, education should include a framework that helps people develop critical thinking, a sense of right and wrong, and a conscience. Additionally, for sustainable development to work in the modern world, it needs good citizen scientists who know a lot about science and can serve as a base for moving forward with sustainable development. A scientifically accurate explanation of a phenomenon, the evaluation and design of scientific investigation, the scientifically accurate interpretation of data and evidence, and a grasp of environmental concerns are the four components that make up scientific literacy. Table 2 displays the indications that citizen science could wish to have scientific literacy for local, national, and global development. These indicators are important for understanding the role that citizen science plays in these areas.

Table 2 Balancing of citizen science.

Rated Aspect	Indicator
Explain the phenomenon scientifically	Recognizing questions that could be investigated scientifically in the present scenario. Identifying keywords and gathering information. Identifying keywords in scientific investigation.
Evaluate and design scientific inquiry	In the provided scenarios, science knowledge is applied. Describing the phenomenon and predict changes. Introduction and selection of acceptable descriptions, explanations, and predictions.
Interpret data and evidence scientifically	Using scientific results as evidence to support a conclusion. Using words, diagrams, or other visual representations to express evidence and judgments. Being able to explain the relationship between evidence and conclusions or decisions in a straightforward and logical manner.
Understanding of environmental issues	Recognize the environmental concerns raised in the essay.

Literacy in the natural and social sciences is a necessary component of sustainable education. The term scientific literacy refers to the knowledge, abilities, and attitudes that enable individuals to understand and apply scientific information to make informed decisions about their lives and the world around them. In the framework of education for sustainable development, scientific literacy is of utmost importance because it enables individuals to comprehend the scientific principles that underlie environmental challenges and to devise solutions that are both scientifically sound and environmentally responsible. Individuals are able to become more educated and involved citizens who are able to contribute to the development of sustainable practices if scientific literacy is promoted within the context of sustainable education. Literacy in science may also assist individuals in making educated decisions about their lives and the world around them, especially those pertaining to matters of sustainability and environmental protection. In the end, scientific literacy is an essential

component of sustainable education and is needed for the construction of a future that is both sustainable and equitable for all people.

The cultivation of scientific literacy paves the way for the field of research known as citizen science, which places a primary emphasis on citizenship education. By applying scientific literacy, learners ought to have the ability to acquire scientific thinking, an awareness of local and global governance systems, human rights and social duties, and how national and local processes are interrelated. By applying scientific literacy, learners ought to be capable of recognizing not only differences but also numerous identities, such as natural resources, local culture, languages, gender, and common humanity. Learners will not only have a scientific grasp of the phenomenon but also have the capacity to cultivate the skills essential to succeeding in an environment that is growing increasingly diversified. While doing research, it is vital to analyze and incorporate several components of citizenship, including decision-making, the use of information technology, critical thinking, and the acceptance of personal and community responsibility. Facts and evidence need to be understood in a scientific manner while still keeping values such as care and concern for other people and the environment, respect for diversity, and the pursuit of goals related to fairness and social justice. Learners will have a better chance of being aware of environmental concerns if they stay current with current events.

4. Discussion and Final Considerations

Science is universal knowledge dealing with local knowledge on the part of social science enterprises. The impact of science and sustainable development is called for collaboration, and sustainable education is a bridge to citizen science within the scope of awareness, protection, informing, sustainability and sensitivity (Durmuş and Kınacı, 2021). The three domains of learning, which consisted of cognitive, socioemotional and behavioral domains, were embedded in the curriculum and pedagogies. A holistic approach is needed to conjugate knowledge, appreciation, awareness, and affective attributes to help learners achieve universal science and local science (UNESCO, 2015). Burgees et al. (2018) found that citizen science is actively responsible in citizenship education and sustainable development. Holistic and system thinking, life-long learning, learning how to learn, scientific reasoning, engagement in group collaboration, and action in key learning sustainability can prepare citizens (Frisk and Larson, 2011; Redman, 2013; Ferreira et al., 2021).

Citizen science is driven by scientific literacy, which is the basis of learning, and citizens are curious or concerned community members. The wheel of sustainable development can explain in terms of sufficiency sustainability, consisting of knowledge and virtues as the main structure. The three pillars of sufficiency are reasonableness, moderation, and prudence. The relationship between local and global contexts concerns participation at all levels by starting from the self until the world in action. Learners should develop attitudes of care and empathy for others more than those social media movements. They can share knowledge, understanding, attitudes, feelings, and campaigns to respect multiculturalism and environmental diversity (Fraisl et al., 2020).

Sustainable education development should prepare learners to be global citizens in an increasingly globalized world (Vongsatan et al., 2020). The curriculum and instructional practices should aim to promote the characteristics of local-global citizens. Learners will have improved knowledge and virtues to live with others, public environmental awareness, respect for differences and diversity. The action in which we do and act on the environment and others is interconnected to environmental degradation and social changes (Ekantini and Wilujeng, 2018; Whiting et al., 2018). The deep mind in consciousness and awareness are now distinguishing between virtues and values. Sustainable development goals (SDGs) are key changes to engage in sustainable development, especially sustainable education development by citizen science, as well as holistic views proposed. Sustainable Development Goal (SDG) 4.7 focuses on the importance of learners acquiring the knowledge and skills they need to promote sustainable development and needs to be considered to be incubated to all people and continuously operationalized (Mitchell et al., 2020).

Sustainable education is a significant approach to instructing and learning that places an emphasis on the long-term viability of the planet's ecosystems, the wellbeing of its people, and the health of the economy. The goal of this approach to education is to equip students with the information, skills, and values that will allow them to construct a future that is both sustainable for themselves and for future generations (Topothai, et al., 2019; Waleewong and Yueayai, 2022). Educators can help learners understand the interconnectedness of environmental, social, and economic issues and encourage them to become active and engaged citizens committed to creating a more sustainable world by integrating sustainable education into the curriculum and the culture of the school. This can be accomplished by helping students understand the interconnectedness of the issues and by incorporating sustainable education into the culture of the education institutions (Crocco and Pitiyanuwat, 2022). The study can continue to highlight the necessity of providing teaching practitioners with hands-on learning-to-teach opportunities with new technology as a tool to complete sustainable education (Lee and Hwang, 2022; Usman et al., 2023).

Sustainable development emphasizes education that is good for the environment, society, and economy. This makes sustainable education an important part of this movement. Recent examples show how Thailand's move toward more environmentally friendly ways of teaching has had an effect. Chuenchoksan and Phongam (2020) carried out another study to assess the effectiveness of the Eco-Schools Program in promoting sustainability. They discovered that participating schools

had decreased their consumption of waste and water and improved their environmental management practices. Moreover, Kiatkawsin and Siripun (2021) performed a study to see how well the Green School Project promoted environmental literacy. They found that students in schools that took part in the project had much better environmental knowledge and attitudes than students in schools that did not take part.

In this article, it is possible to explain how economics and sustainable development goals can be used by citizen science and sustainable education development to make all parts of life sustainable. To achieve sustainable development, the Sustainable Development Goals (SDGs) provide that people need to learn how to be good global citizens. King Bhumibol Adulyadej made it possible for Thais and citizens around the globe to deal with life's challenges and contribute to such efforts. There are problems with the economy, society, and the environment. Additionally, the King wanted Thai schools to include lessons about how to live in a way that is good for the environment. He thought that schools should teach students about how important it is to take care of cultural heritage, build communities, and protect the natural environment. An educational philosophy was based on the sufficiency economy, which stresses the importance of moderation, self-sufficiency, and resilience. We cannot think of it as a reductionist way to solve problems; instead, we should look at a holistic approach from a political, moral, economic, and environmental point of view (Oxley and Morris, 2013; Goren and Yemini, 2017). Learners gain knowledge, skills, and attitudes that help them understand, respect, and appreciate the complexities of differences in individuals and groups (Perry and Southwell, 2011; Hovland, 2014).

The goal of education should be to help learners develop the body of knowledge that is needed for conceptual skills and to emphasize the psychomotor domain so that learners can practice practical processes. Our sustainable education development needs to create the value of sustainable development, teach with integration so that every body of knowledge fits together, share ideas to protect the environment, and give students positive attitudes. Through civic education, people may be better able to understand science, do citizen science, make decisions based on sustainability, and live in harmony.

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Ethical considerations

Not applicable.

Conflict of Interest

The authors declare no conflicts of interest.

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