

Citizen Science Integration in Biology Education : A Systematic Review

^{1,2*} Anandita Eka Setiadi, ¹ Sofia Ery Rahayu, ¹ Susriyati Mahanal

¹ Biology Education Study Program, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang, Malang, Indonesia

¹ Biology Education Study Program, Faculty of Mathematics and Natural Sciences, Universitas Muhammadiyah Pontianak, Pontianak, Indonesia

Abstract

Biology learning is closely aligned with citizen science, which actively engages students in scientific activities. However, no systematic literature review (SLR) has specifically explored how citizen science is integrated into biology education and its contributions to student learning outcomes. This study aims to analyze the integration of citizen science into biology teaching and evaluate its impact on student achievement in schools and universities. Using the PRISMA method with three stages: identification, scanning, and inclusion. The review identified 21 relevant articles.

Findings show that successful integration of citizen science in biology learning depends on the alignment of scientific and educational goals, adequate technological and resource support, effective collaboration among students, teachers, and scientists, and the design of projects that are relevant, structured, and educationally challenging. Project-based learning emerges as the most common pedagogical approach integrated with citizen science projects, particularly at secondary and higher education levels.

The review highlights that 21 types of citizen science projects have been applied in biology education, reinforcing concepts in molecular biology, genetics, biodiversity, and ecosystems. Positive contributions were observed across cognitive, psychomotor, and affective domains. Cognitive outcomes included improved conceptual understanding of biology, psychomotor outcomes included enhanced laboratory and research skills, while affective outcomes showed increased interest in science and learning motivation.

Keywords: Citizen Science, Biology Learning, Learning Achievements, School, University

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*Corresponding Author: inianandita.eka@gmail.com ^{2*}

Introduction

Biology is a natural science that studies life and the interactions of living organisms with their environment ([O'Grady et al., 2021](#)). Meanwhile, the term citizen science refers to public participation in scientific research ([Bonney et al., 2016](#); [Chowdhury et al., 2023](#)). The characteristics of biology learning emphasize direct observation, experimentation, and active student engagement in concretely understanding biological processes ([Bustami et al., 2018](#); [Hernawati et al., 2018](#)). These characteristics of biology learning are highly relevant to the citizen science approach, which involves students in scientific activities. In citizen science, students contribute to data collection, environmental observation, and monitoring of biodiversity in their surroundings ([Atias et al., 2023](#)). Student involvement in citizen science activities can foster environmental awareness and concern for broader scientific issues ([Almeida, 2023](#)).

The development of citizen science has been influenced by the growing public awareness of environmental and social issues, as well as the rapid advancement of technology. Since its introduction, citizen science has employed scientific approaches to engage the public in decision-making regarding threats to the environment ([Curtis, 2018](#)). In citizen science projects, scientists collaborate with communities to collect, share, or analyze authentic data ([Jordan et al., 2015](#)). Citizen science has expanded alongside increasing global awareness of environmental issues and the growing desire of the public to contribute to scientific efforts to monitor and address these challenges ([Butler et al., 2023](#)).

* Anandita Eka Setiadi: inianandita.eka@gmail.com

It provides opportunities for communities to participate in observing climate change and pollution ([Bowditch et al., 2022](#)) or collecting biodiversity data ([Backstrom et al., 2024](#); [Clark et al., 2023](#)). On the other hand, technological advancements have also driven the development of online platforms and applications to support public participation in science. *Online platforms and applications developed for citizen science projects include iNaturalist* <https://www.inaturalist.org/> ([Baker et al., 2023](#); [Hartmann et al., 2022](#)), Zooniverse <https://www.zooniverse.org/> (Rivera et al., 2024), dan eBird <https://ebird.org/> ([Hartmann et al., 2022](#); [Sullivan et al., 2014](#)).

Citizen science activities in education can be carried out both informally and formally. Informal citizen science in education takes place through activities outside institutions by involving the general public ([Bonney et al., 2016](#); [Roche et al., 2020](#)). In contrast, in formal education, citizen science engages university or school students in research activities. ([Hirschenhauser et al., 2023](#); [Solé et al., 2023](#)) with the aim of answering scientific questions ([Batchelder et al., 2023](#); [Bird et al., 2023](#)) and addressing issues of shared concern ([Boaventura et al., 2021](#); [Colombari & Battisti, 2023](#)), particularly in the study of environment and biodiversity.

Citizen science projects have several advantages and have been widely recommended for use in education ([Almeida, 2023](#); [Austen et al., 2024](#)). These advantages are reflected in research findings such as [Schneiderhan-Opel & Bogner \(2020\)](#), which showed that citizen science can enhance students' cognitive performance and interest in learning biology; which demonstrated that citizen science can be used as a tool to develop students' scientific knowledge and literacy; and [Elmore et al. \(2019\)](#), which indicated that citizen science can improve students' research skills. Other studies have also shown the influence of citizen science on student competencies, particularly in fostering interest and positive attitudes toward the environment ([Aivelo & Huovelin, 2020](#)), improving self-efficacy ([Smith et al., 2021](#)), and enhancing science literacy and processes ([Queiruga-Dios et al., 2020](#)).

A Systematic Literature Review (SLR) provides a comprehensive overview of a field based on previous research findings([Carrera-Rivera et al., 2022](#)). Between 2019 and 2024, eight relevant SLR articles on citizen science in education were published in Scopus. Four of them appeared between 2021 and 2024, namely [Adamou et al., \(2021\)](#), [Ponce-Martins et al., \(2022\)](#), [Hadjichambi et al., \(2023\)](#), and [Alfaro-Ponce et al., \(2024\)](#). [Adamou et al. \(2021\)](#), reviewed 31 articles published from 2000 to 2020 and found that citizen science initiatives enhanced students' knowledge of environmental systems and scientific skills. The scientific skills included thinking skills, problem-solving skills, social interaction and collaboration skills, as well as communication skills. The scientific skills referred to are thinking skills, problem-solving skills, social interaction and collaboration skills, and communication skills. [Ponce-Martins et al. \(2022\)](#) examined 28 Scopus-indexed articles published between 2000 and 2022 and concluded that citizen science projects foster complex thinking and its sub-competencies, including critical thinking, innovative-creative thinking, and scientific reasoning. [Hadjichambi et al. \(2023\)](#) reviewed 34 Scopus-indexed articles from 2000 to 2020 and found that citizen science in K-12 education positively influenced students' competencies, actions, and environmental initiatives. [Alfaro-Ponce et al. \(2024\)](#) analyzed 28 Scopus-indexed articles published between 2000 and 2022 and revealed that citizen science can serve as a valuable component of higher education curricula, offering practical methods for developing students' critical competencies. Up to 2024, no SLR article has specifically examined *citizen science* in biology education. Therefore, it remains necessary to explore the integration of *citizen science* in biology education and the extent to which *citizen science* projects in biology learning contribute to student achievement. This study aims to analyze the integration of *citizen science* in biology learning and its contribution to student achievement in schools and universities through an SLR. The objectives are addressed through two research questions (RQs) as follows:

RQ1: How is citizen science integrated into biology learning?

RQ2: What is the contribution of citizen science in biology learning to student achievement?

This study is valuable in providing a more comprehensive understanding of the contribution of citizen science to biology education. The results of this systematic review will offer useful guidance for teachers in selecting appropriate citizen science projects that align with biology learning, thereby enhancing student achievement.

Method

Research Method

This study employed a Systematic Literature Review (SLR) approach with a qualitative synthesis type to gather data on the integration of citizen science in biology learning and its contribution to student achievement. The article selection procedure followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) 2020 statement protocol through three stages: identification, screening, and inclusion (Figure 1). The PRISMA 2020 statement protocol was chosen to minimize assessment bias (Page et al., 2021).

Identification was carried out to find relevant literature. The article search was conducted through the Scopus online database (<https://www.scopus.com>), which has broad coverage and ensures high-quality articles. Articles indexed in Scopus generally come from reputable journals with a rigorous peer-review process, thus guaranteeing their validity. The keywords used in the search were: “citizen science” AND “biology” AND (learn OR teach* OR student* OR educat* OR school* OR universit*)*. These keywords were chosen to obtain specific articles aligned with the research objectives..

The screening stage was conducted to select articles based on relevant criteria. In the initial screening, a general selection of articles was carried out in the Scopus database. The inclusion and exclusion criteria for this general selection are presented in Table 1. Inclusion and exclusion criteria in an SLR must be determined before the document search to prevent bias in article selection ([Carrera-Rivera et al., 2022](#)).

The first inclusion criterion established was the year of publication, limited to articles published between 2014 and 2024. This criterion was chosen to obtain the most recent research developments over the past 10 years. The next inclusion criterion was document type, with only original research articles published in peer-reviewed international journals selected. This was intended to prevent bias and focus on empirical evidence that provides accurate data on the implementation of citizen science in biology education. To ensure that the reviewed articles were relevant to citizen science in biology learning, the selected subject areas included social sciences, biological sciences, environmental sciences, and humanities. The final general inclusion criterion was language: only articles written in English were included, as they meet international standards and are more accessible for readers.

Table 1. General Selection Criteria

No	Criteria	Inclusion	Exclusion
1	Year of publication	2014 – 2024	Before 2014, after 2024
2	Document type	Original research article	Conference paper, review, book chapter, note, editorial, book
3	Subject area	Biological science, Social sciences, Environmental science, Humanities	Biochemistry, Applied Genetics and Molecular, Applied Biology, Multidisciplinary, Medicine, Computer Science, Neuroscience, Engineering, Immunology and Microbiology, Earth and Planetary Sciences, Energy, Veterinary, Physics and Astronomy, Pharmacology, Toxicology and Pharmaceuticals, Mathematics, Health Profession, Chemistry, Chemical Engineering, Business, Management, and Accounting
4	Language	English	Non-English

The screening stage continued with specific inclusion criteria (Table 2) by reading titles, abstracts, and keywords in more detail. These specific criteria were established to ensure efficiency in identifying relevant articles that could address the research questions. At this stage, included articles had to meet several requirements: the article must focus on biology education either at schools or universities with student participants, provide a description of the integrated citizen science project, explain the related biology concepts, and describe the measured student learning outcomes. Articles that did not meet these specific criteria were excluded from further inclusion and review.

Table 2. Specific Exclusion Criteria

No	Criteria	Inclusion	Exclusion
1	Year of publication	2014 – 2024	Before 2014, after 2024
2	Document type	Original research article	Conference paper, review, book chapter, note, editorial, book
3	Subject area	Biological science, Social sciences, Environmental science, Humanities	Biochemistry, Applied Genetics and Molecular, Applied Biology, Multidisciplinary, Medicine, Computer Science, Neuroscience, Engineering, Immunology and Microbiology, Earth and Planetary Sciences, Energy, Veterinary, Physics and Astronomy, Pharmacology, Toxicology and Pharmaceuticals, Mathematics, Health Profession, Chemistry, Chemical Engineering, Business, Management, and Accounting
4	Language	English	Non-English

The screening stage continued with specific inclusion criteria (Table 3) by reading titles, abstracts, and keywords in more detail. These specific criteria were established to ensure efficiency in identifying relevant articles that could address the research questions. At this stage, included articles had to meet several requirements: the article must focus on biology education either at schools or universities with student participants, provide a description of the integrated *citizen science* project, explain the related biology concepts, and describe the measured student learning outcomes. Articles that did not meet these specific criteria were excluded from further inclusion and review.

Table 3. Specific Inclusion Criteria

No	Criteria
1	The terms “citizen science,” “biology,” and “education” or “learn” or “teach” or “student” or “school” or “university” appear in the title, abstract, or keywords.
2	The article describes research findings that integrate <i>citizen science</i> in biology learning at schools or universities.
3	The article describes a <i>citizen science</i> project integrated into biology learning.
4	The article explains the biology material or concept taught through the <i>citizen science</i> project.
5	The article focuses on student learning outcomes in biology education that integrates <i>citizen science</i> .

Figure 1 shows the selection process at the identification stage, where 143 relevant articles were found using the predefined keywords. At the initial screening stage, 11 articles published before 2014 were excluded, 42 articles that were not original research published in journals were excluded, 1 article that was not final was excluded, 1 article that was not in English was excluded, and 28 articles with unrelated subject areas were excluded. Sixty (60) articles were further analyzed based on the title, abstract, and keywords to match the specific inclusion criteria. From this screening, 21 relevant articles were selected that met the criteria. These 21 articles were further analyzed at the inclusion stage.

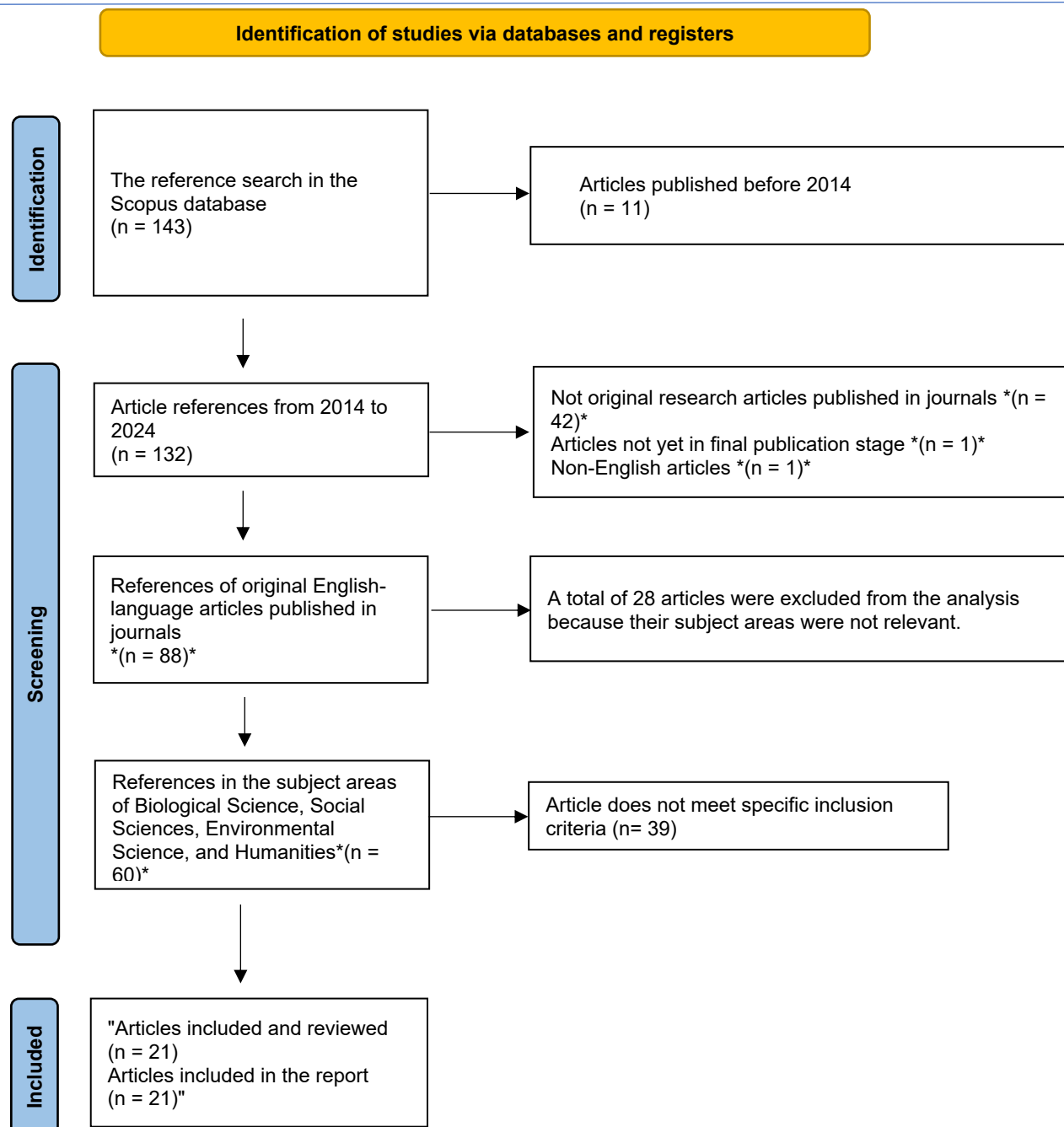


Figure 1. Article Selection Process Using the PRISMA Protocol

Research Results and Discussion

Result

Table 3 shows the list of articles reviewed at the inclusion stage. Based on geographic distribution, 1 article is the result of a collaborative study from two countries, Portugal and Spain, while the remaining 20 articles were conducted in a single country with various distributions. The articles are predominantly from the United States, with 10 articles (48%), followed by research from Australia and Germany, each with 2 articles (10%), and the remaining articles come from Austria, Belgium, Ecuador, Finland, Italy, and Spain, each with 1 article (5%).

Table 4. List of articles analyzed at the inclusion stage

No	Authors and Year	Country	Article Code
1.	Borrell et al. (2016)	Spain	CS1
2.	Grasser et al. (2016)	Austria	CS2
3.	Silva et al. (2016)	Portugal dan Spain	CS3
4.	Mitchell et al. (2017)	Australia	CS4
5.	Chiovitti et al. (2019)	Australia	CS5
6.	Eble and Pecore (2019)	America Serikat	CS6
7.	Riley et al. (2020)	America Serikat	CS7
8.	Schneiderhan-Opel and Bogner (2020)	Jerman	CS8
9.	Oliveira et al. (2021)	America Serikat	CS9
10.	Paradise and Bartkovich (2021)	America Serikat	CS10
11.	Lichti et al. (2021)	America Serikat	CS11
12.	Lobet et al. (2021)	Belgia	CS12
13.	Vance-Chalcraft et al. (2021)	America Serikat	CS13
14.	Miovi (2022)	Italia	CS14
15.	Christ et al. (2022)	Jerman	CS15
16.	Tsecouras et al. (2022)	America Serikat	CS16
17.	Cielocha J.J. (2022)	America Serikat	CS17
18.	Weisberg et al. (2023)	Kepulauan Galápagos, Ekuador	CS18
19.	Unger (2023)	America Serikat	CS19
20.	Aivelo (2023)	Finlandia	CS20
21.	Rosenthal et al. (2024)	America Serikat	CS21

Integration of Citizen Science in Biology Education

The review results in Table 4 show that citizen science in biology education can be integrated with various approaches depending on the education level of the students being taught. Project-based learning is the most commonly used approach at the secondary school (middle school to high school) and higher education levels. At these levels, citizen science can also be integrated with other approaches such as Experiential Learning, Authentic Research-Based Learning, Inquiry-Based Learning, Collaborative Learning, and STEM. At the elementary school level, the recommended approach is Community-Based Learning ([Grasser et al., 2016](#)). At the middle school level, the commonly applied approach is Contextual Learning. ([Christ et al., 2022](#)), while at the high school level, Long-term Learning ([Schneiderhan-Opel & Bogner, 2020](#)) is used. Meanwhile, the integration of citizen science with Active Learning, Data-Driven Learning, Distance Learning, and Service-Based Learning is generally applied only at the higher education level.

Table 5. Learning Approaches Used for the Integration of Citizen Science in Biology Education at Different Educational Levels

No	Learning Approach	Educational Level*	Article Code
1	Project-Based Learning	Junior High School, Senior High School, University	CS3, CS5, CS6, CS7, CS9, CS10, CS11, CS15, CS18
2	Experiential Learning	Senior High School, University	CS3, CS7, CS13, CS20
3	Authentic Research-Based Learning	University, Senior High School	CS1, CS5, CS6
4	Inquiry-Based Learning	University, Junior High School	CS4, CS9, CS13
5	Collaborative Learning	Junior High School, Senior High School, University	CS18, CS19
6	Active Learning	University	CS17
7	Community-Based Learning	Elementary School	CS2
8	Contextual Learning	Junior High School	CS15
9	Data-Driven Learning	University	CS21
10	Distance Learning	University	CS12
11	Long-term Learning	Senior High School	CS8
12	Service-Based Learning	University	CS17
13	STEM	Elementary School, Junior High School, Senior High School, University	CS14

*Note. SD: Elementary School; SMP: Junior High School; SMA: Senior High School; PT: University

Table 5 shows the types of citizen science projects integrated into teaching and their connection to the biological concepts taught. These projects are designed to achieve learning objectives, particularly related to the biological concepts being taught. The review results show that DNA Barcoding analysis-based projects are frequently used to convey concepts of genetics and molecular biology ([Borrell et al., 2016](#); [Chiovitti et al., 2019](#); [Eble & Pecore, 2019](#); [Riley et al., 2020](#); [Schneiderhan-Opel & Bogner, 2020](#)). Observation and identification projects such as BugGuide ([Paradise & Bartkovich, 2021](#)), Wild Bee Investigation ([Christ et al., 2022](#)), Zooniverse ([Cielocha, 2022](#)), Caterpillars Count ([Vance-Chalcraft et al., 2021](#)), QuoVidi ([Lobet et al., 2021](#)), and Invasive Mosquito ([Tsecouras et al., 2022](#)) focus on data collection and reinforce understanding of biodiversity and ecosystems. Other projects such as LAVA-Lobos ([Weisberg et al., 2023](#)), Snapshot Animal Behavior ([Unger, 2023](#)), and Plant Phenology ([Lichti et al., 2021](#)) are conducted to study animal behavior and species interactions. These projects strengthen ecological concepts. Programs integrating climate change, such as ClimateWatch ([Mitchell et al., 2017](#)) provide insights into the impact of environmental changes. Meanwhile, marine-based projects such as Percorsi nel Blu and Floating Forests ([Mioni, 2022](#)) dan Floating Forests ([Rosenthal et al., 2024](#)), highlight marine ecosystems and conservation efforts. This approach allows students to directly engage in real scientific research, deepening their understanding of biological concepts while also developing environmental awareness and scientific skills.

Table 6. Citizen Science Projects Integrated into Biology Education and Related Biological Concepts

No	Citizen Science Project	Related Biological Concept	Article Code
1	Food product sample analysis project for genetic laboratory practice.	Molecular Genetics and Molecular Biology	CS1
2	DNA barcoding project using reptile specimens from museum collections.	Molecular Genetics, Biodiversity, Taxonomy, Conservation Biology, and Bioinformatics Techniques.	CS5
3	"Invasive aliens" project, DNA barcoding to identify invasive lionfish (<i>Pterois volitans</i>).	Molecular Biology, Biodiversity, and Ecology	CS6
4	Sampling and DNA analysis project of <i>Delftia</i> spp., microbes capable of gold precipitation.	Environmental Microbiology, Molecular Biology, Evolution, and Genetics	CS7
5	DNA barcoding biodiversity project.	Species Identification and Biodiversity	CS8
6	Cellular Biology Research Project (Cell Spotting).	Cellular Biology and Biological Research Applications	CS3
7	Insect data collection project through BugGuide.	Species Concepts and Biodiversity	CS10
8	Wild Bee Biodiversity Investigation Project.	Ecology and Biodiversity, Insect Conservation	CS15
9	Service-learning project through Zooniverse.	Ecology and Biodiversity	CS17
10	Urban rat survey project in students' environments.	Biodiversity, Environment, and the Role of Unwanted Species (like rats) in Ecosystems	CS20
11	Budburst project for monitoring plant phenophases.	Ecology, Phenology, and Climate Change Effects	CS11
12	Participatory Ethnobiology Research Project through wild plant video creation and family interviews.	Ethnobiology and Ecosystems	CS2
13	Caterpillars Count! Project for monitoring arthropods.	Arthropod Identification, Ecology, and Scientific Methods	CS13
14	Invasive Mosquito Project for data collection on mosquito presence and development.	Mosquito Life Cycle, Biology of Mosquito-Borne Diseases, and Vector Management	CS16

No	Citizen Science Project	Related Biological Concept	Article Code
15	LAVA-Lobos project for monitoring endemic sea lion species in the Galápagos Islands.	Sea Lion Biology and Conservation	CS18
16	Snapshot project, animal behavior observation using iNaturalist app.	Ethograms and Animal Behavior Description	CS19
17	Treasure hunt project to find organisms based on specific terms and upload images on QuoVidi app.	Morphology, Ecology, and Systematics	CS12
18	Phenology observation project in the ClimateWatch program.	Phenology and Climate Change, Ecology, and Species Interaction	CS4
19	Soil quality data collection project.	Soil Ecology, Environmental Degradation, Conservation, and Sustainability	CS9
20	"Percorsi nel Blu" or "Blue School" project.	Marine Biology, Marine Ecology, Conservation, and Sustainability	CS14
21	Floating Forests project for satellite image analysis of kelp forest ecosystems.	Marine Ecology and Conservation	CS21

The Contribution of Citizen Science in Biology Education to Student Learning Achievement

Citizen science in biology education contributes significantly to student learning achievements, encompassing cognitive, psychomotor, and affective aspects. According to the review, the most noticeable improvement in the cognitive aspect is the understanding of biological concepts. In the psychomotor aspect, notable achievements include laboratory skills, conducting research, and data collection. Compared to the other two aspects, the integration of citizen science in biology education has a greater impact on the affective aspect, particularly in indicators such as interest in science and motivation to learn. Detailed student learning achievements influenced by the integration of citizen science in biology education are presented in Table 7.

Table 7. Contribution of Citizen Science in Biology Education to Student Learning Achievement

Aspect	Learning Achievement	Article Code
Cognitive	Understanding of Biological Concepts	CS2, CS3, CS6, CS8, CS13, CS15, CS16, CS18, CS19
	Understanding of Scientific Processes	CS3
	Species Literacy	CS10
	Biodiversity Literacy	CS10
	Marine Literacy	CS14
	Higher Order Thinking Skills	CS11
	Science Literacy	CS14, CS18
	Data Literacy	CS11, CS21
	Data Analysis	CS5, CS9, CS19
Psychomotor	Laboratory Technique Skills	CS1, CS5, CS7
	Research Skills	CS2, CS3, CS11
	Collaboration Skills	CS2
	Data Collection Skills	CS4, CS9, CS17
	Contribution to Scientific Data	CS5
	Identification Skills	CS10, CS13
	Scientific Writing Skills	CS11, CS17
	Observation Skills	CS12
Affective	Learning Motivation	CS1, CS3, CS5, CS12, CS18
	Participation Level	CS2

Aspect	Learning Achievement	Article Code
	Scientific Contribution	CS3, CS9, CS14
	Interest in Science	CS3, CS4, CS5, CS8, CS14, CS15
	Involvement in Research	CS3, CS4, CS13, CS16
	Perception of Citizen Science	CS4, CS21
	Perception of Science	CS6
	Perception of Environmental Change	CS21
	Environmental Awareness	CS4, CS9, CS16
	Attitude Toward Animals	CS15, CS20
	Pro-environmental Behavior	CS15
	Self-Efficacy	CS21

In the cognitive aspect, projects such as DNA barcoding for identifying invasive lionfish prey species ([Chiovitti et al., 2019](#)), DNA barcoding for biodiversity identification ([Schneiderhan-Opel & Bogner, 2020](#)), Participatory Ethnobiology ([Grasser et al., 2016](#)), LAVA-Lobos ([Weisberg et al., 2023](#)), and the Invasive Mosquito Project ([Tsecouras et al., 2022](#)) were implemented to enhance understanding of biological concepts. Meanwhile, the Cell Spotting project ([Silva et al., 2016](#)) specifically strengthens understanding of scientific processes. Additionally, species and biodiversity literacy are reinforced through the BugGuide project ([Paradise & Bartkovich, 2021](#)), which teaches practical species identification and biodiversity. Marine ecosystem-based projects like Percorsi nel Blu ([Mioni, 2022](#)), contribute to marine literacy and science literacy, broadening students' perspectives on ecology and sustainability. Higher-order thinking skills are also developed through the Budburst project ([Lichti et al., 2021](#)), which involves critical analysis of climate change data. Data literacy and data analysis skills are enriched through the Floating Forests project ([Rosenthal et al., 2024](#)) and Assessing Soil Quality project ([Oliveira et al., 2021](#)), where students learn to manage and interpret scientific data. Through participation in citizen science, students not only understand theory but also practice the scientific process and develop relevant cognitive skills for problem-solving.

In the psychomotor aspect, projects such as food sample analysis ([Borrell et al., 2016](#)), reptile DNA barcoding ([Chiovitti et al., 2019](#)), and Delftia spp. DNA analysis. ([Riley et al., 2020](#)), sharpen laboratory technique skills, while participatory ethnobiology ([Grasser et al., 2016](#)) Cell Spotting ([Silva et al., 2016](#)), dan Budburst (Lichti et al., 2021) promote independent research skills. Through Phenology in the ClimateWatch Program ([Mitchell et al., 2017](#)), Assessing Soil Quality ([Oliveira et al., 2021](#)), and the Zooniverse project ([Cielocha, 2022](#)), students learn to collect data systematically, contributing to scientific data. Species identification skills are honed in the BugGuide project (Paradise & Bartkovich, 2021) and the Caterpillars Count Project ([Vance-Chalcraft et al., 2021](#)), while the Budburst and Zooniverse projects train scientific writing skills. Additionally, the Quo Vidi project ([Lobet et al., 2021](#)) emphasizes observation skills, supporting effective and real-world relevant experiential learning.

Citizen science contributes to the achievement of the affective aspect in biology education by increasing students' interest in science ([Chiovitti et al., 2019](#); [Christ et al., 2022](#); [Mioni, 2022](#); [Mitchell et al., 2017](#); [Schneiderhan-Opel & Bogner, 2020](#); [Silva et al., 2016](#)) and motivation to learn ([Borrell et al., 2016](#); [Lobet et al., 2021](#); [Silva et al., 2016](#); [Weisberg et al., 2023](#)). Increased active participation is observed in the research by [Grasser et al., \(2016\)](#), while the increase in scientific contribution is shown in the studies ([Mioni, 2022](#); [Oliveira et al., 2021](#); [Silva et al., 2016](#)). Engagement in research is reflected in the study [Vance-Chalcraft et al., \(2021\)](#), and the rise in environmental awareness is highlighted in the research by [Mitchell et al., \(2017\)](#) and [Tsecouras et al., \(2022\)](#). Additionally, the enhancement of pro-environmental behaviour is evident in the findings of [Christ et al.,\(2022\)](#). Positive perceptions of science and environmental change are also fostered through projects such as *Invasive Aliens* ([Eble & Pecore, 2019](#)) dan floating forest ([Rosenthal et al., 2024](#)) which also build students' self-confidence in understanding global scientific issues.

Discussion

Figure 2 illustrates that the success of integrating citizen science into biology education is influenced by the alignment of scientific goals with learning objectives, the support of technology and resources, effective collaboration between students, teachers, and scientists, and the design of relevant, structured, and educationally challenging projects.

First, aligning scientific goals with learning objectives. The scientific goals in citizen science projects must align with the learning objectives and the competencies that students aim to achieve. In this regard, the citizen science project to be integrated needs to be carefully designed to align with the school curriculum, minimizing potential challenges related to learning time and student participation ([Chiovitti et al., 2019](#)). Related to this, the chosen learning approach, strategy, and methods also need to be considered to support the scientific goals and ensure the achievement of student competencies ([Solé et al., 2023](#)).

Second, the integration of citizen science in biology education depends on the support of technology and resources, particularly to assist students in performing tasks and understanding scientific material. The resources and technology provided must be designed and used to enhance students' contributions to the implementation of citizen science projects. According to [Paradise & Bartkovich](#) (2021), the support of resources and technology should provide clear information about the students' role in the scientific project and how to engage them in more complex stages. This is meant to motivate students to contribute to citizen science projects and learning.

Third, effective collaboration between students, teachers, and scientists. A key characteristic of integrating citizen science into biology education is the involvement of students in real scientific practices, such as data collection, analysis, or species identification. Integrating citizen science in biology education involves not only teachers and students or university lecturers and students, but also collaboration with professional researchers. Citizen science integration in biology education aims to answer important scientific questions, providing transformational opportunities for students, teachers, and scientists. This aligns with the opinion of [Eble & Pecore](#) (2019), who stated:

"Citizen science represents collaboration between the public and professional researchers to answer important questions in science. When integrated into a classroom setting, citizen science offers potentially transformative opportunities for both students and scientists".

Fourth, the design of relevant, structured, and educationally challenging projects. The projects to be integrated into biology education need to be considered for their relevance to the scientific goals, learning objectives, and the students' everyday life. This is to ensure that students are motivated to participate in citizen science projects and feel that the activities they engage in are meaningful and beneficial, both for learning and for the community ([Borrell et al., 2016](#)). A structured project has clear steps that are easy for students to follow, while a challenging project will encourage students to learn more deeply, develop new skills, and improve their understanding of science. Thus, relevant, structured, and challenging projects are easier to implement and integrate with teaching approaches. Additionally, such projects will motivate student involvement and contribute to achieving student competencies.

The contribution of citizen science to biology education in terms of student learning achievement has been demonstrated in several studies reviewed in this research. Among them, it provides authentic learning experiences that involve students in real research ([Eble & Pecore, 2019](#)), develops skills such as critical thinking ([Unger, 2023](#)), collaboration ([Grasser et al., 2016](#)), scientific data management, and science literacy ([Lichti et al., 2021](#)), increases environmental awareness ([Mitchell et al., 2017](#)), and boosts student motivation to learn ([Lobet et al., 2021](#)) through direct involvement with real-world issues.

Although the integration of citizen science in biology education contributes positively to student achievements, several challenges must be considered, such as the need for adequate technology infrastructure, the limited training for teachers in facilitating projects, and the risk of less valid data due

to the involvement of less skilled participants. Therefore, it is recommended to make thorough planning regarding the projects to be integrated into biology education to maximize the benefits and minimize the challenges of this integration. The development of project programs and instruments, as well as preparation for teachers and students who will be involved in the implementation of citizen science projects, should be made before integrating citizen science into biology education.

Conclusion

A review of 21 relevant articles addressing the research question of how citizen science can be integrated into biology education and its contribution to student achievement has been conducted. The results indicate that the success of integrating citizen science into biology education is influenced by the alignment of scientific goals with learning objectives, the support of technology and resources, effective collaboration between students, teachers, and scientists, and the design of relevant, structured, and educationally challenging projects. Citizen science in biology education can be integrated with various approaches depending on the educational level of the students. Project-based learning is the most frequently used approach at the secondary (middle school to high school) and higher education levels. It is known that 21 types of citizen science projects have been integrated into learning to reinforce biology concepts, particularly molecular biology, genetics, biodiversity, and ecosystems. This integration has a positive contribution to students' learning achievements in cognitive, psychomotor, and affective aspects. Understanding biological concepts is the most significantly improved achievement in the cognitive aspect. In the psychomotor aspect, notable achievements include laboratory technique skills, research skills, and data collection. In the affective aspect, student interest in science and learning motivation are indicators that have shown significant improvement.

Limitation

The article search in this SLR was limited to the Scopus database, so the number of articles found is still limited. Furthermore, the qualitative analysis conducted in this SLR does not yet precisely measure the effectiveness and direct impact of the implementation of citizen science in biology education. Therefore, future research is expected to be conducted through meta-analysis.

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