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Context-Based Teaching through Education for Sustainable Development in Philippine Secondary Schools: A Meta-analysis

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Abstract

Integrating sustainability into pedagogical strategies can potentially catalyze the promotion of sustainable development knowledge and practices, thus making it an imperative trend for educational institutions. The context-based teaching through Education for Sustainable Development (ESD) was instrumental in achieving sustainability competencies and in bringing positive education outcomes in various educational milieus. Studies on its implementation in the Philippine context are still limited. This paper examines the effectiveness of Context-Based Teaching (CBT) through ESD on the science performance of secondary students in the Philippines. It reviewed pedagogical strategies applied to embed Sustainable Competencies (SCs) in the teaching-learning process. Results revealed its effectiveness and highlighted key SCs that were mostly developed and those that were least emphasized. However, the indicated variables did not influence its effectiveness. For further research, other indicators of learning that may potentially affect its successful implementation can be critically investigated.

Keywords

context-based, education for sustainable development, sustainability competency, science performance, Philippines

INTRODUCTION

Context-based teaching through ESD contributed to positive educational outcomes. Although specific contributing factors to its integration are still under investigation, teaching pedagogy is one aspect that offers a fertile research ground. The transformative power of pedagogical approaches adopted in educational settings is clear, as education is the key catalyst for reaching not only the goal of quality education (SDG 4) but also several Sustainable Development Goals (SDGs). The 17 Sustainable Development Goals (SDGs) form the core of the 2030 Agenda for Sustainable Development. This is constituting an urgent call for collective action by all developed and developing nations through a global partnership. These objectives recognize the relevance of solving poverty and other forms of deprivation through effective measures that improve health and education, reduce inequality, promote economic growth, and address climate change while protecting our oceans and forests (United Nations Statistics Division [UNSD], 2018). In spite of the growing number of educators being aware of the SDGs' impact on education, only a few apply these in their teaching-learning process due to lack of training, opportunity,

materials, time, and other factors (Leal Filho et al., 2019). Additionally, teachers expressed uncertainty about the integration of SDGs in their courses because they were not applicable or relevant to a particular subject, and the professors lacked the authority to make changes due to the restrictions in the curriculum. The lack of knowledge on the association of Science, technology, and sustainability limits the participation of several educational institutions in this global movement (Veiga Ávila et al., 2019).

CBT through ESD in the teaching-learning process exposes students to scientific ideas in settings that highlight their relevance to everyday life, which will foster SCs (Yilmaz et al., 2022). SCs respond to sustainability problems observed in different contexts by successfully facilitating teaching strategies on the cognitive, affective, and psychomotor domains (Wiek et al., 2011). Based on Wiek et al.'s (2011) framework, these competencies are Systems Thinking Competence, Futures Thinking (Anticipatory) Competence, Values Thinking (Normative) Competence, Strategic Thinking Competence, and Interpersonal (Collaborative) Comp. They are supporting the aim of the majority of the programs of educational institutions. These institutions have a role in implementing sustainable development at the local, national, and international levels (Bertschy et al., 2013 ; Mohanty, 2018). ESD incorporates the concept of sustainability during teaching and learning sessions by encouraging and preparing students to make decisions that benefit sustainability (Hoque et al.,2022 ; Trechsel et al.,2018), of which CBT is an example.

From a broad definition, CBT considers students a diverse background in applying concepts and process skills in making meaningful real-life contexts to them" (Koba et al., 2013). It resulted in positive education outcomes in teaching science (Baydere, 2021; Chen et al., 2019; Izhar et al., 2022; Okafor, 2021; Lutfianis et al., 2020). The two-eyed teaching approach, for example, was reframed to address concerns in the Science, Environment, and Health community (Zeyer, 2022). Problem-based learning (PBL) allows students to collaborate on transdisciplinary university projects to improve campus sustainability and the university community, such as student environmental behavior, building energy efficiency, waste management, and community promotion of organic foods and healthy lifestyles (Bessant et al., 2014). Service Learning (S-L) lets agricultural engineering students produce vegetables to meet the needs of a soup kitchen and distribute bags of food to those in need (Tejedor et al., 2019). In Indonesia (Baduy community), indigenous science offers a realistic context for learning that can help learners understand how environmental ethics and sociocultural life interact in some cultures, thereby promoting education for sustainable development (Zidny et al., 2021).

A strategy called 'Project Oriented Learning' (POL) aimed at fostering sustainability competencies enabled students to understand their lessons better (Leal Filho et al., 2019). Self-Experience-Based Learning (SEBL) and Self-Inquiry-Based Learning (SIBL) by Frank and Stanszus (2019) promoted the development of personal competencies for ESD. Moreover, a meta-synthesis revealed that Garden-Based Education (GBE) supported the development of the cognitive domain of learning (Paño et al., 2022). Such pedagogical innovations have explicitly and indirectly facilitated ESD concepts and principles, leading to mainstreaming Sustainable Development Goals (SDGs) or Global Goals. Aside from its wide scope in the educational curriculum, even in Science education, its integration covers different learning levels. In Early Childhood Education (ECE) in Chile, following a thorough evaluation of peer-reviewed literature on ESD for ECE, Bascope et al. (2019) proposed art-based inquiry experiences and outdoor-based and project-problem-based learning frameworks as appropriate pedagogical techniques for ESD. In secondary education, upon analyzing changes in the way one views science and technology and the development of scientific literacy through a questionnaire, embedding citizen science project in Northern Spain contributed to the attainment of SDGs through developing informed opinions based on gathered data

in the topic (Queiruga-Dios et al., 2020). At the tertiary level, the project methods in multidisciplinary and transdisciplinary teams in a university in Spain improved sustainability competencies (Fuertes-Camacho et al., 2019). Synthesis of these articles offers insight into varied pedagogical strategies that can be employed for ESD, leading to positive learning results. However, its integration into other countries still needs further research since education effects are highly context-specific (Hoffmann & Muttarak, 2017).

In the context of the Philippines, the National Environmental Awareness and Education Act of 2008, also known as Republic Act (RA) No. 9512, was created as the country prepared to respond to the worldwide appeal for Education for Sustainable Development. This law requires all "...relevant entities to integrate environmental education into public and private school curricula at all levels, including barangay daycare, preschool, non-formal, technical vocational, professional, indigenous learning, and out-of-school youth (OSY) courses" (Valencia, 2018). In this law, the integration of ESD starts with initiating changes in higher education institutions' programs, organizational structure, and cross-curricula for schools in integrating environmental education and, for some, as 'add ons' (National Service Training Program (NSTP) in tertiary level; DRR subject in Senior High School) in the school curriculum. Picardal and Sanchez (2022) highlighted the effectiveness of contextualization in maximizing learning outcomes in Science instruction. A dearth of literature on how context-based teaching is aligned with education for sustainable development and its educational outcomes at the secondary level is observed.

Overall, CBT through ESD in science education has a favorable impact on positive educational outcomes. To determine the effect of this approach on student performance, studies relevant to its application in teaching and learning must be summarized in light of its expanding popularity.

Specifically, this study aims to

1. Determine the effectiveness of CBT through ESD in the performance of students in the secondary level in Science.
2. Determine the effect of the moderators (year, school type, locale) on the effectiveness of CBT through ESD.
3. Determine the publication bias of the studies about CBT through ESD.
4. Identify CBT through ESD strategies integrated into science instruction.
5. Identify Sustainable Competencies attained by CBT through ESD.

METHODS

Research Design

This meta-analysis determined the effectiveness of context-based teaching through ESD in increasing students' academic performance.

This study adhered to the meta-analysis protocol of Borenstein et al. (2010), which includes an in-depth analysis of the quantitative data. Recent articles continue to deepen our comprehension of the scope of ESD (Acosta-Castellanos & Queiruga-Dios, 2022; Bascopé et al., 2019; Cebrián et al., 2020; Edwards et al., 2020; González-Salamanca et al., 2020). The literature on the effectiveness of teaching strategies for promoting ESD has only recently undergone a small number of reviews (Chiba et al.,2021), and none specifically in the context of the Philippines. This meta-analytic review was appropriate in synthesizing quantitative findings from different studies on students' academic achievement exposed to teaching practices that constituted CBT through ESD. Guided by the protocol of Tawfik et al. (2019), this study empirically supported published studies and coded aspects of these studies for the effect sizes to examine how the moderating effects affected the outcome.

Search and Selection Criteria

Inclusion and exclusion criteria for this meta-analysis guide the search of open-access journal articles from Scopus, Google Scholar, and CrossRef databases. This study used the software program Publish or Perish to search for lists of journal papers and assess academic citations (Harzing, 2016), along with manual searching. The search was not limited to its year of publication since there were only a few articles in the Philippines relating to the study. Boolean operators were used to filter and optimize search queries during the literature review. This enabled a systematic search for relevant publications by combining and removing keywords based on predefined criteria. These keywords were Sustainability AND Philippine Education, Policy Implementation AND Sustainable Practices AND Philippine Educational System, "Education for Sustainable Development" AND Philippines, "Sustainable Education" OR "Sustainability Education" AND "Philippine Schools," "Environmental Education" AND "Sustainable Development" AND Philippines, "Context-Based Teaching" AND "Sustainability Education" AND Philippines, "Indigenous Science" AND "Philippines," "Local Knowledge" OR "Traditional Wisdom" AND "Indigenous Practices" AND "Philippine Culture". Indigenous science was part of the keywords since it gives students authentic settings to understand scientific principles and teaches them the importance of promoting sustainability. (Zidny et al., 2021). Random and interchanging use of these keywords ensures an exhaustive literature search.

The study defined several inclusion criteria for the systematic review. These are (a) the accessibility of a research article, (b) the description of CBT through ESD either in the title or in the abstract, and (c) the inclusion of student performance as a dependent variable.; (d) respondents as strictly students in the secondary level (Grade 7-Grade 12) in the Philippines; (e) application of a casual comparative design or a mixed method where quantitative data have a distinct emphasis; (f) focus on the different disciplines under science.

The meta-analysis excluded studies with no rigorous methodology, incomplete data (reported only the final results), and quantitative data but did not refer to the effectiveness of pedagogies.

The PRISMA diagram summarizes the search strategy in Figure 1. This meta-analysis evaluated 1,257 studies on CBT through ESD generated from the literature search. Only ten articles qualified the predetermined criteria, particularly because the report lacked statistical data.

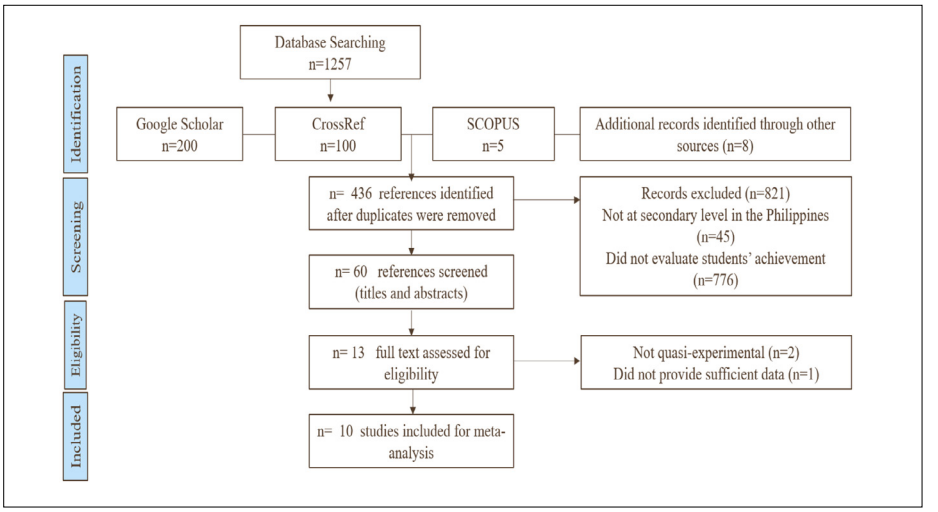


Figure 1. *Diagram of the PRISMA process for the selection of papers for meta-analysis*

Data Analysis

The effect sizes were estimated and evaluated using Hedge's g values. Hedge's g was selected over Cohen's d because it was better at determining the bias brought on by using small sample sizes. (Borenstein et al., 2010). A positive effect size in this meta-analysis indicated that the group exposed to CBT through ESD instruction performed better than the control group with the conventional approach. Cohen (1988) specifies that g values of 0.80 and above indicate significant effects; values of 0.50-0.79 have an intermediate effect; 0.20-0.47 have a small effect; 0.01-0.19 have no effect; and values below 0.0 have an unfavorable effect. These values were the basis for the magnitude of the effect size.

The statistical analysis was performed using JASP 0.16.1, and the moderator analyses looked into the possible influence of various variables (publication year, school, and locale) on the effect size of CBT through ESD. The funnel plot depicted publication bias, and the BeggMazumdar test was used to quantify it due to the smaller samples (Begg & Mazumdar, 1994; National Environmental Awareness and Education Act (2008)). The traditional fail-safe N test determined the number of studies required to negate the overall effect size reported by the current meta-analysis. All tests were at a 95% CI, and p-values less than 05 were considered significant.

RESULTS AND DISCUSSIONS

Characteristics of Included Studies

The meta-analysis had a sample size of 761 secondary students from quantitative studies in the Philippines. Table 1 summarizes these quantitative studies by year of publication, study locale and region, research design, sample size, education level, and science domain.

Table 1. *Characteristics of the included studies that employed Context-based Teaching through Education for Sustainable Development*

Authors	Year	Locale	Region	Design	Cont	Exp	Educational Level	Domain
Boracay, Herrera	2020	Public School	Luzon	Quasi	40	40	SHS	Environmental Education
Hipolito	2021	Public School	Luzon	Quasi	34	34	JHS	Environmental Education
Dalida, Malto, Lagunzad	2017	Private School	Luzon	Quasi	33	33	SHS	Environmental Education
Casumpang, Enteria	2019	Public School	Mindanao	Quasi	30	30	JHS	Environmental Education
Gabucan Sanchez	2021	Public School	Visayas	Quasi	15	15	JHS	Environmental Education
Toledo, Yangco, Espinosa	2014	Private School	Luzon	Quasi	38	40	JHS	Environmental Education
Calzada, Antonio	2023	Public School	Luzon	Quasi	40	41	JHS	Earth Science
Micayabas	2020	Public School	Mindanao	Quasi	30	30	JHS	Environmental Education
Sagcal, Valera, Maquiling	2017	Public School	Luzon	Quasi	30	30	JHS	Chemistry
Tadena, Salic-Hairulla	2019	Public School	Mindanao	Quasi	35	35	JHS	Environmental Education

This meta-analysis analyzed ten articles conducted in the last ten years (1 in 2014, 2 in 2017, 2019, 2020, and 2021, respectively, and 1 in 2023). Eight studies took place in public schools, and two were in private school settings. The context of the studies was in the Philippines (6 in Luzon, 1 in Visayas, and 3 in Mindanao). All evaluated articles employed quasi-experiments in their methodology. The sample sizes of the study's participant groups ranged from 15 to 41. Furthermore, the research covered a range of grade levels (8 in Junior High School and 2 in Senior High School) and of science domains (8 in Environmental Education, 1 in Earth Science, and 1 in Chemistry).

The National Environmental Awareness and Education Act (2008) has paved the way for the integration of ESD in Philippine Schools. Noteworthy, most published studies came only after the massive promotion of the World Economic Forum (2016). It implied that setting a targeted year for specific goals like SDGs to be attained in 2030 encouraged more integration of the concept in the teaching-learning process than merely enabling laws. However, the number of publications started decreasing after 2020. In 2022, no reported study was found.

Moreover, the integration of sustainability concepts in context was more evident in public government schools than in private schools. It reflected the enforcement of the Enhanced Basic Education Act (2013) in compliance with the Department of Education (DepEd) curriculum provision for contextualization with consideration to the needs of the national and the global community. This is the same core concept of sustainability. The predominance of studies in Luzon was consistent with the total population (57.07%) in the Philippines residing in Luzon World Economic Forum (2016). This population trend may contribute to a stronger concentration of educational institutions and research activity, making Luzon a center for academic research. Furthermore, in the science domain, CBT through ESD was commonly integrated into Environmental Education. Knowledge concerning ESD in other domains is generally rare in the literature, particularly in the Philippine context, since most of the key sustainable development issues are taught in domains where they can be related, such as Environmental Education and Earth Science.

Effect Sizes of Context-based Teaching through Education for Sustainable Development

The effect sizes of the studies that investigated Context-based Teaching through Education for Sustainable Development are presented in Table 2.

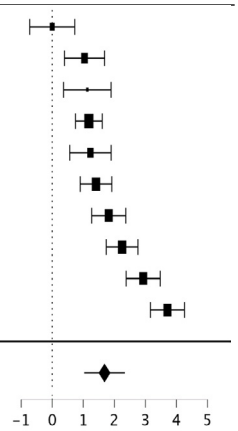
According to Table 2, all of the individual Hedge's g values fall within the 95% CI and all on the positive side of zero, suggesting significant improvements in students' science performance that happened throughout the instruction. Its effect sizes and degrees of effectiveness in these researches vary. For example, 9 out of 10 studies had an effect size (g) that ranged from 1.04 to 3.71, showing a significant effect, and only one study (Bacay & Herrera, 2020) reported otherwise (g=0.00). Using the 5Es framework, Bacay and Herrera (2020) utilized CBT through ESD, while Tadena and Salic-Hairulla (2021) employed specially-created and locally- based teachings where both studies showed a large effect size, owing to the overall effect size which was 1.68 and within the 95% confidence interval. Tadena and Salic-Hairulla (2021) study stands out for thoroughly integrating context-based teaching in the Education for Sustainable Development (ESD) framework. It has employed a comprehensive process, starting with a needs assessment and culminating in locally-grounded environmental education lessons. The study implemented a thorough evaluation both before and after lesson implementation, ensuring a careful examination of the educational intervention's effectiveness.

In contrast, the study with the lowest Hedges' g value, while offering valuable insights, was attributed to its more direct implementation strategy. Its approach exposed learners to a learning environment that encouraged engagement with various concepts and observations in real-world contexts but lacked extensive needs assessment. These variations underscored the impact of methodological differences in

context-based teaching for sustainability, with an approach reflecting a more meticulous and evaluative strategy that resulted in a higher Hedges' g value.

Table 2. *CBT through ESD studies' effect sizes and forest plot*

Authors	Hedge's g	95% CI		Forest Plot
		Lower	Upper	
Bacay	0.00	-0.73	0.73	
Hipolito	1.04	0.39	1.69	
Dalida	1.13	0.37	1.89	
Casumpang	1.18	0.75	1.61	
Gabucan	1.23	0.56	1.90	
Toledo	1.41	0.90	1.92	
Calzada	1.82	1.27	2.37	
Micayabas	2.25	1.74	2.76	
Sagcal	2.93	2.38	3.48	
Tadena	3.71	3.16	4.26	
Combined effect	1.68	1.03	2.34	



Effect Sizes of Moderators

The inclusion of student learning performance as a moderator variable in this study was typically motivated by the aim to determine whether the effect of the main independent variable, in this case, CBT through ESD, on the dependent variable (learning performance) is influenced or moderated by another variable. Being linked to the publication year, it has acknowledged the educational approaches evolving with time. Changes in educational policy, improvements in instructional strategies, and variances in the accessibility of resources can all affect the learning performance of students (Ismail & Yin, 2020; Kyriakides et al., 2017; Limniou, 2021). Learning environments such as different school types are inherently diverse in terms of public and private schools (Frenette & Chan, 2015; Hahn et al., 2014; Kunwar, 2021) and locale in terms of resources. Also, community participation opportunities and environmental concerns in urban and rural locations impact learning performance outcomes (Ahmad, 2013; Hasan & Parvez, 2019; Ramli et al., 2021). However, the data analysis found that the publication year (p=0.913, 0.472, 0.373, 0.547), school (p=0.480), and locale (p=0.94, 0.377) did not influence effect size, suggesting that these variables have no bearing to the impact of CBT through ESD to the learning performance of students.

Table 3. *Moderator analysis of studies that investigated CBT through ESD*

Moderator	B	SE	95% CI	z-value	p-value
Year (2017)	-0.280	2.548	-5.275,4.716	-0.110	0.913
Year (2019)	-3.021	4.218	-11.287,5.245	-0.716	0.472
Year (2020)	-3.210	3.603	-10.272,3.852	-0.891	0.373
Year (2021)	-2.170	3.599	-9.225,4.885	-0.603	0.547
Year (2023)	-1.390	3.595	-8.436,5.656	-0.387	0.699
School (2)	-1.800	2.550	-6.799,3.199	-0.706	0.480
Locale (2)	0.190	2.549	-4.806,5.186	0.075	0.941
Locale (3)	2.250	2.545	-2.739,7.239	0.884	0.377

Publication Bias

The funnel plot shows the probability of publication bias. An asymmetrical funnel resulted in uneven distributions around average effect sizes when subjected to Begg-Mazumdar rank correlation (Kendall's tau was -0.210 (p=0.412)) fail-safe N tests. Table 5 shows the results of the traditional fail-safe N test, where 1,291 studies about CBT through ESD were required to invalidate the overall effect size as determined by the current meta-analysis. The results of the fail-safe test were good, and Kendall's tau and visual inspection did not reveal any evidence of publishing bias. This conclusion indicates that authors typically report studies that have a favorable influence on learning and incorporate insignificant findings in their papers.

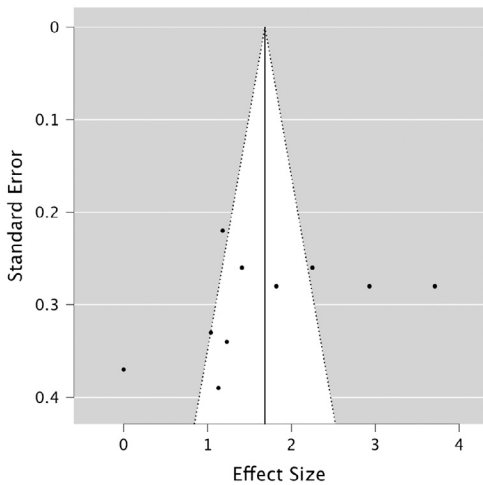


Figure 2. *Standard error funnel plot showing unbiased publication*

Table 4. *Rank correlation test for funnel plot asymmetry*

	Kendall's T	p
Rank test	-0.21	0.412

Table 5. *Robustness*

	Fail-safe N	Target Significance	Observed Significance
Rosenthal	1291.000	0.050	8.16e-79

Strategies in Context-based Teaching through Education for Sustainable Development

CBT through ESD in the teaching-learning process exposes students to scientific ideas in settings that highlight their relevance to everyday life through Sustainability Competencies (SC) (Yilmaz et al., 2022). Table 6 presents several strategies for the integration of ESD through CBT.

The strategies implemented are closely linked to the achievement of SDGs that align with numerous facets of sustainable development. Notably, the approach contributes to SDG 4 (Quality Education) by starting the learning process through real-world observations, connecting concepts to phenomena, and utilizing innovative tools such as comic strips, SIM-based education, and media cartoons. This relationship is enhanced further through problem-solving exercises that emphasize the importance of education in resolving global concerns. SDGs 12 (Responsible Consumption and Production), 13 (Climate Action), 14

(Life Below Water), and 15 (Life on Land) are directly addressed via outdoor learning activities that cover subjects such as biodiversity, global warming, waste management, and water conservation. The attention to water pollution investigations aligns with SDG 6 (Clean Water and Sanitation), highlighting the commitment to ensure access to safe drinking water. These strategies not only imply a holistic understanding of environmental issues but also nurture learners' sense of responsibility for a sustainable future.

Table 6. *Strategies in context-based teaching through Education for Sustainable Development*

Author	Year	Strategies	Explications
Bacay & Herrera	2020	Combination with other strategies	Teachers presented learners with several concepts, starting with observations from a real-world context and relating them to several phenomena. Students then presented and discussed solutions to problems based on their understanding.
Hipolito	2021	Combination with other strategies	Outdoor learning activities exposed students to real-world issues through the following topics: biodiversity, global warming, waste management, and water conservation.
Dalida et al.	2018	Use of local/community knowledge	The procedure's major issue was water contamination, an environmental hazard. Learners participated in four activities: (1) a physicochemical investigation of the site's water, (2) a survey of people's perspectives of their role in the community, (3) a clean-up drive, and (4) a presentation of the information gathered from the community.
Casumpang & Enteria	2019	Instructional Materials	Teachers used developed comic strips as instructional material for teaching specific science concepts.
Gabucan & Sanchez	2019	Instructional Materials	SIM-based instruction.
Toledo et al.	2014	Instructional Materials	Teachers introduced learners to media cartoons and comic strips from newspapers, magazines, and the internet to enhance problem-solving abilities and conceptual comprehension of environmental education issues.
Calzada & Antonio	2023	Combination with other strategies	While playing the songs, learners shared their answers and ideas with other students. They reviewed information with other students by asking and answering questions in a cordial manner.
Micayabas	2020	Combination with other strategies	Learners were taught to integrate Climate Change lessons.
Sagcal et al.	2017	Laboratory Activities	Teachers exposed learners to context-based laboratory activities.
Tadena & Salic-Hairulla	2021	Use of local/community knowledge	Learners used locally developed environmental education lessons.

From Table 6, most (40%) of the studies incorporated CBT through ESD in combination with other strategies. This includes engaging students outside the classroom (Bacay & Herrera, 2020; Hipolito, 2021; Micayabas, 2015) and instilling creativity in understanding concepts (Calzada & Antonio, 2023). Using instructional materials was second (40%) on the strategies in CBT through ESD (i.e., comic strips) (Enteria & Casumpang, 2019), Strategic Intervention Material (SIM) (Gabucan & Sanchez, 2021), and Media Cartoons (Toledo et al., 2014). The use of local/community language was also evident (30%) through local-based

lessons (Tadena & Salic-Hairulla, 2021) and the actual immersion of students in the community. Lastly, only one study employed learning through laboratory experiences (Sagcal et al., 2017).

The use of (SIM) in the teaching of environmental concepts is linked to the Department of Education (DepEd, 2005) directives, notably DepEd Memorandum No. 117 s. 2005. This memo titled "Strategic Intervention Materials (SIM) Training Workshop for Successful Learning" was a critical project launched by DepEd to address the academic issues faced by low-performing students in schools. Furthermore, Section 10.2 of the Implementing Rules and Regulations (IRR) of Republic Act (RA) 10533 (2013), which specifies the need for a contextualized and flexible curriculum, is critical in shaping the educational landscape and in promoting the integration of local and community knowledge as a strategic element in teaching. This provision emphasizes the need to customize the curriculum to each school's particular educational and social contexts. Hence, the impact of DepEd ordinances on improving the teaching-learning process, particularly CBT through ESD, is clearly evident. Conversely, the use of laboratory equipment being the least employed can be reflected in one of the factors, such as teachers not being fully equipped to use some science equipment (Hadji et al., 20205). These statements highlight the positives as well as the challenges in the integration of CBT through ESD.

Table 7. *Summary of strategies in context-based teaching through Education for Sustainable Development*

Strategy	Frequency	Percentage
Use of local/community knowledge	2	20%
Instructional Materials	3	30%
Laboratory Activities	1	10%
Combination with other strategies	4	40%

Table 8 shows the sustainable competencies attained through CBT through ESD, as shown by its indicators. Context-Based Teaching (CBT) within Education for Sustainable Development (ESD) helps in the attainment of Systems Thinking Competence by engaging students in analyzing diverse environmental issues through cause-effect structures, site immersion, and causal problem analysis. This approach encourages a contextual understanding, enabling students to identify critical factors and intervention points in complex sustainability challenges. Futures thinking competence was attained through engaging in discussions, developing viable solutions, and performing scenario construction/ analysis on sustainability problems. Students not only anticipated future visions but also enhanced their ability to address proactively and to mitigate these challenges, developing a reflective and forward-thinking mindset. The approach also contributed to the attainment of values thinking competence as students recognize and imply the importance of sustainability values, such as accountability, in addressing complex environmental challenges. It also promotes strategic thinking competence as students demonstrate resourcefulness and sustainability in their learning process by using low-cost and readily available resources for laboratory activities. This practical application extends to the development of feasible community solutions, demonstrating how CBT through ESD prepares students with strategic thinking competence that prioritizes sustainability and community relevance. Lastly, as students actively support stakeholder collaboration to attain desired sustainability results, the approach fosters interpersonal competency. This emphasis on collaboration and engagement with stakeholders not only improves interpersonal skills but also emphasizes the social dimension of sustainability. It demonstrates how CBT through ESD contributes to the holistic development of competencies required for addressing complex environmental challenges collaboratively.

Table 8. *Sustainability Competencies attained through CBT through ESD*

Author	Sustainability Competencies (SC) (Wiek et al., 2011)	Indicators of SC
Bacay & Herrera (2020)	Systems Thinking	Students analyzed waste management systems through cause-effect structures.
	Futures Thinking	Students discussed solutions that will prevent or mitigate the existing sustainability problem.
Hipolito (2021)	Values Thinking	Students implied the need for sustainability values, such as responsibility, etc., in responding to sustainability problems in biodiversity, global warming, waste management, and water conservation.
Dalida et al. (2018)	Systems, Futures, Values and Strategic Thinking Interpersonal	Students analyzed water pollution through site immersion, surveyed residents' views of their contribution to the community, and provided normative orientations to problem analysis. They then developed viable solutions tailored to the community's needs and encouraged stakeholder coordination to reach envisioned outcomes.
Casumpang & Enteria (2019)	Systems Thinking	Students analyzed waste generation and management through causal problem analysis (cause-effect structures).
	Future Thinking	Students anticipated sustainable and desirable future visions.
	Values Thinking	Students reconciled the values and principles needed to find solutions.
Gabucan & Sanchez (2021)	Systems Thinking	Students analyzed the sustainability problems related to global warming through cause-effect structures.
Toledo et al. (2014)	Systems Thinking	Students cascaded cause-effect analysis by creating rationales that will support their stand on environmental issues.
	Values Thinking	Students negotiated sustainability targets, values, goals, and principles.
	Future Thinking	Students performed scenario construction/analysis methods on how sustainability problems might occur over time.
Calzada & Antonio (2023)	Systems Thinking	Students analyzed sustainability problems such as earthquake epicenter distributions, plate movement causes, and the like.
Micayabas (2020)	System Thinking	Students analyzed concepts on Climate change and its variables.
	Futures Thinking	Students were reflective of their experiences, which resulted in a clearer vision of their desired future.
	Values Thinking	Students realized that solving sustainability problems involves understanding the norms of communities.
Sagcal et al. (2017)	Strategic Thinking	Students were able to use effectively low-cost available materials for laboratory procedures to sustain and improve their learning.
Tadena & Salic-Hairulla (2021)	Systems Thinking	Students analyzed concepts by identifying critical factors and intervention points on deforestation, improper waste disposal, the greenhouse effect, and hydroelectricity.

As shown in Table 9, all CBT strategies enabled students to examine sustainability issues at various scientific scales and domains (from local to global issues) by applying cause-effect structures and by identifying variables and indicators to understand the complex interrelationships constituting

sustainability problems and their impact. These types of activities depict that Systems Thinking Competence (STC), at its core, is an exercise of cognition. Additionally, STC encompasses the analysis of interrelations among system components and their collective impact on system outcomes, including both intended and unintended consequences, within the broader environmental context (Amissah et al., 2020). Hence, using CBT through ESD is essential in effectively addressing complex sustainability challenges, as it facilitates a comprehensive understanding of interconnected factors and enables the development of enduring solutions.

After having a clear understanding of sustainability problems, students were then able to analyze situations, trends, causes, and future scenarios they wanted to improve or solve. This conforms to the definition of Wiek et al. (2011), wherein Futures Thinking Competence (FTC) relates to the ability to evaluate, analyze, and create complete "visions" of the future with regard to sustainability issues and frameworks to resolve sustainability concerns. Moreover, Values Thinking Competence (VTC) indicates having an understanding of how fundamental ideas differ between and within cultures, which can be utilized to solve sustainability problems (Juuti et al., 2021). Even though FTC and VTC are crucial competencies in ESD, only half of the approaches attained them.

The third most acquired competency in the studies is strategic thinking competence (STC). However, only two approaches from the studies allowed students to solve problems through actions. Dalida et al. (2018), for example, allowed students to develop viable solutions to their community's water pollution, and Sagcal et al. (2017) used low-cost laboratory materials. This conforms to the definition of Wiek et al. (2011), which states that designing and implementing sustainable strategy plans may legitimately avert unfavorable outcomes to indicate strategic competency.

Lastly, the least attained competency is Interpersonal Competence (IC) which was only observed by Dalida et al. (2018) and engaged students in the community with stakeholders to understand them and develop a solution from all the inputs they obtained. Additionally, the strategy employed by Dalida et al. (2018) was the only study where all of the sustainability competencies were attained.

Overall, the data suggest that facilitating cognitive competencies through STC using CBT through ESD is more comfortable for educators than other key sustainability competencies.

Table 9. *Summary of Sustainability Competencies attained through CBT through ESD*

Sustainability Competencies (Wiek et al.,2011)	Frequency	Percentage
Systems Thinking Competence	10	100%
Futures Thinking (Anticipatory) Competence	5	50%
Values Thinking (Normative) Competence	5	50%
Strategic Thinking Competence	2	20%
Interpersonal (Collaboration) Competence	1	10%

CONCLUSION

Using CBT through ESD in the teaching-learning process effectively improved the Science performance of secondary-level students in the Philippines. The meta-analysis found that nine out of ten studies had large effect sizes and were positioned on the positive side of the forest plot, indicating that significant gains in students' science performance happened in the setting of the investigations. Moderators of its effectiveness, such as publication year, school type, and location, have no future impact on such learning. Moreover, tests for funnel plot asymmetry indicated that selected articles included studies with significant and insignificant results, making the meta-analysis unbiased.

Students' exposure to varied outdoor and creative activities, use of instructional materials such as strategic intervention materials, media cartoons, comic strips, and low-cost laboratory kits, and use of local community knowledge were the approaches used in CBT through ESD. These engaging pedagogical strategies developed the sustainability competencies. Nevertheless, despite the inclusion of systems thinking as one of the approaches highlighted along with the integration, the rest of the competencies were rarely attained.

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