Sustainability Competencies in STEM Education at Secondary Schools: A Systematized Literature Review

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Systemized Literature Review: Integrating Sustainability Competencies into K-12 Education

Abstract

Many initiatives, such as Agenda 21, had indicated the critical role of education in the process of reaching a sustainable future, in an effort for making education an active participant towards sustainable development. This study aimed to identify key sustainability components integrated into STEM in 8th-grade curricula, we explored sustainability activities and projects aligned with the Next Generation of Science Standards (NGSS) and Standards for Technological Literacy (STL). The research question for this study focused on exploring the key components for the integration of sustainability education into Science, Mathematics, Technology, and Engineering Education in middle schools. We analyzed 73 peer-reviewed articles from 2013 to 2018, gathered through a systemized literature review, by using inductive and deductive methods. The findings from the inductive analysis revealed that projects and curricula in most of the cases used real-world issues as a critical element for the implementation of sustainability in classrooms. Our analysis also found a relationship between the content of the project and the context in which students applied their knowledge. As a result, and by using this relationship, we provide an outline that organizes the peer-reviewed articles based on the content of the project and students' context. This outline should further help educators to organize their lessons, depending on the proximity of students' contexts, and scaffold their learning to more complex contexts. On the other hand, the findings from the deductive analysis revealed some of the (NGSS) and (STL) that align with sustainability components.

Keywords: Sustainability education, K-12, Systematized literature review, STEM education

Introduction

Reports on the future economic risks, due to climate change, highlighted the importance of implementing sustainability approaches into our lifestyles [1]. The Earth Summit by the United Nations in Rio de Janeiro resulted in a non-binding action plan, known as Agenda 21. This plan acknowledges the urgency of implementing more sustainable approaches to our lifestyles, and the critical role that education has on preparing students for future challenges [2]. For instance, Agenda 21 proposed the implementation of environmental issues into existing curricula as one of the agenda objectives. However, implementing sustainability concepts into curricula is a difficult task, and educators and researchers who work towards integrating sustainability also recognized the implicit challenges. For higher education, educators and researchers' efforts have been focused on understanding what it means to integrate sustainability into their higher education curricula [3], [4]. It is imperative to mention that the complexity of integrating sustainability increases when it is necessary to encompass sustainable goals among multiple stakeholders [5]. In other words, sustainability goals could have different means and meanings for each of the stakeholders involved, making it more difficult to align the diverse and different goals from each stakeholder. In addition, the implementation of sustainability also faces another challenge in which consistency of communities' engagement in the context of higher education is in many cases lacking.

Although, higher education had multiple difficulties on implementing sustainability, there are many exemplary curricula for integrating of sustainable development as well as for integrating similar concepts, such as sustainable design [3], [4]. However, in terms of K-12 classrooms, there are no organized efforts or research that explore how sustainability should be taught in K-12 classrooms, even though higher education initiatives also advocate for implementing sustainability in early middle schools' settings [6].

In the same way, higher education, middle schools also face complexities with sustainability implementation. One of these complexities is the 'culture of consumerism' that is predominant in developed countries, such as the United States [7, p. 10]. The consumerism culture could also affect the communities' engagement with sustainability goals. As an example, Higgs and McMicmillan study [8] found that there are cultural challenges and the lack of connection between sustainability and schools' goals for success. They conducted a study in four secondary schools that implemented sustainability in their curricula. Even though some of the schools were successful in implementing sustainability, it was also hard to keep the sustainable cultures, such as recycling outside the school or establishing a connection between schools' academic goals and sustainability projects. Unfortunately, these are not the only challenge that schools have during the implementation of sustainability education to their curricula. Middle schools' curricula are already saturated with content and standards that educators need to implement. Also, educators lack of financial and logistic support to include sustainability and what they are required by their institutions, this is the main problem that our study targeted to explore.

In some cases, private schools have less burden, if the schools have resources for sustainability implementation. However, public schools have a limited budget, and they have already established schools' priorities that in some cases do not support the inclusion of new initiatives such as sustainability [5]. For these reasons it is necessary to integrate sustainability that aligns with NGSS and STL which are standards that are widely adopted among public schools. The purpose of this study is to identify the key sustainability components for integrating sustainability in STEM curricula in middle schools and explore examples of projects and curricula present in the literature aligned to Next Generation Science Standards and Standards for Technological literacy.

Literature Review

Even though the United States has initiatives in policy to address sustainability issues [9], [10], the United States is still one of the highest contributors of carbon dioxide (CO_2) because United States still highly relies on coal, natural gas, and petroleum as an energy resource [11]. Two of the main reasons for promoting sustainability education in the United States focus on the need for staying below 2 ℃ to reduce climate change [12], and the possibility for developed countries to invest in designing green technologies that can accelerate the transition to green-friendly technologies for underdeveloped countries [13].

Education for Sustainability Development

The creation of Education for Sustainability Development (EfS) was due to the global actions towards a sustainable future [14]. In the United States, the goals that EfS have been commonly shared goals with Environmental Education (EE). An example is the promotion of environmental awareness [15]. However, it is necessary to acknowledge that EfS should not be compared or understood as the same as environmental education [15]. Although there is a historical overlap between EE and Education for Sustainability Development, and this overlap could have affected the way EfS plays a role in the United States, considering that EE and EfS are not necessarily similar [16]. The frame of EfS depends not only on each country's policies, but also on the country's historical influences. For the case of the United States, the term commonly used to frame Education for Sustainable Development is "Sustainability education," and this term will be used for our study. The frame of sustainability education in the United States has been influenced not only by EE, but also by areas such as technology-society, social justice, environmental justice and environmental economy [7]

Conceptual Framework

UNESCO's eight key sustainability education competencies [17] helped our deductive data analysis. These competencies are based on De Haan's work [18] and Rieckmann literature review [19] and proposed six different sustainability education competencies:

- Critical Thinking
- Self-awareness
- Anticipatory competence
- Normative
- Collaboration
- Systems thinking

Methodology Framework

Data Sources

This study used a systematized literature review to gather lesson plans, curricula or summer camps lesson plans that integrated sustainability education in middle schools. The main reason for conducting a systematized literature review is that it allows researchers to be able to demonstrate all the technical approaches for gathering the literature, such as the entire process of the search and exclusion criteria [20]. This study followed the steps proposed by Borrego and Froyd [21] for the engineering education context.

1. Identify scope and research question and provide a conceptual framework, logical model
2. Define exclusion criteria
3. Find sources
4. Assess quality for each study
5. Synthesize.

Data Analysis

This study analyzed 73 peer-reviewed journal articles in two stages, represented in Figure 1. The first stage was an inductive analysis. This stage follows the steps suggested by Hatch [22] for conducting this type of analysis. Some of the steps proposed by Hatch included the creation of domains based on a semantic relationship between the data and the themes across domains, presented below.

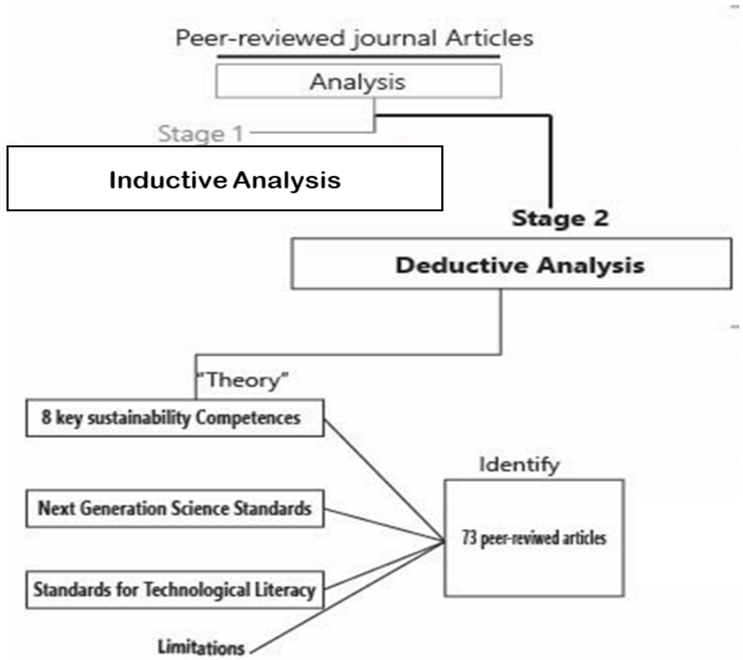

Figure 1. Stages representation for analysis

In the second stage, we conducted a deductive analysis by comparing semantic relationships among peer-reviewed journal articles and the Next Generation Science Standard (NGSS) [23], Standards for Technology Literacy (STL) [24] and the Sustainability competencies [17]. This stage allowed us to identify components that are already aligned with pre-established standards, such as Next Generation Science Standards (NGSS). Furthermore, for each lesson, we examined the learning goals, the purpose of the lesson plan, and content described in each peer-reviewed journal article. An example of this deductive scheme is presented in Table 1.

Table 1 *Example of code scheme for NGSS core ideas for middle school*

Code	NGSS excerpt	Example from peer-reviewed journal articles
E-SS	MS-ESS3: …"how their distributions are significantly changing as a result of removal by humans. Examples of uneven distributions of resources as a result of past processes include but are not limited to petroleum (locations of the burial of organic marine sediments and subsequent geologic traps)" [23]	"Many of the units draw inspiration from Earth systems and geoscience to teach sustainability concepts, especially in relation to natural cycles, resource limitations, and the effects of human– nature interactions on the environment." [25, p. 103]

We conducted a similar procedure as the one represented in Table 1 with the Standards for Technology Literacy (STL) [24]. These standards are made up of five domains: a) The nature of Technology; b) Technology and Society; c) Design; d) Abilities for a Technological World; and e) The Designed World. Each standard is listed in Table 2.

Table 2 *Code scheme for Standards for Technology Literacy (STL)*

Code	Standard
	The nature of Technology
St 1	The characteristics and scope of technology.
St 2	The core concepts of technology.
St 3	The relationship among technologies and the connections between technology and other fields.
	Technology and Society
St 4	The cultural, social, economic, and political effects of technology
St 5	The effects of technology on the environment.
St 6	The role of society in the development and use of technology.
St 7	The influence of technology on history.
	Design
St 8	The attributes of design.
St 9	Engineering design.
St 10	The role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.
	Abilities for a Technological world
St 11	Applying the design process.
St 12	Use and maintain technological products and systems.
St 13	Assess the impact of products and systems.
	The Designed World
St 14	Medical technologies.
St 15	Agricultural and related biotechnologies.
St 16	Energy and power technologies
St 17	Innovation and communication technologies
St 18	Transportation technologies
St 19	Manufacturing technologies
St 20	Construction technologies

Inclusion and Procedures for the Systematized Literature Review

We selected the peer-reviewed journals based on the scope of this study. We used the keywords ("Sustainability Education" OR "Green Technologies" OR "Ecology Education" AND "Curriculum" OR "Plan studies" AND "STEM Education" AND "K-12") in three different databases: ERIC, ProQuest Technology Collection, and Education source. The main reason for selecting these three databases was their focus on education and in STEM education journals. The inclusion criteria were the following, and all peer-reviewed needed to meet all the criteria:

1. Peer-reviewed journal articles.
2. Literature in the time range of 2013 to 2018: this range is based on one year before UNESCO launched the Global Action initiatives which the initiatives of Education for Sustainable development originated from and the year this systematized review was conducted.
3. Journal articles that have lesson plans, curricula, summer programs, or modules that focus on STEM education in middle schools.
4. Topic-focused: Literature that is focused on the integration of sustainability education and concepts in the curricula, as well as STEM education focus.
5. Literature that is designed for students or teachers.

This study used the PRISMA statement [26]. Figure 2 shows the step by step of the inclusion criteria, as well as reports the number ("n") of literature that was not included in this study.

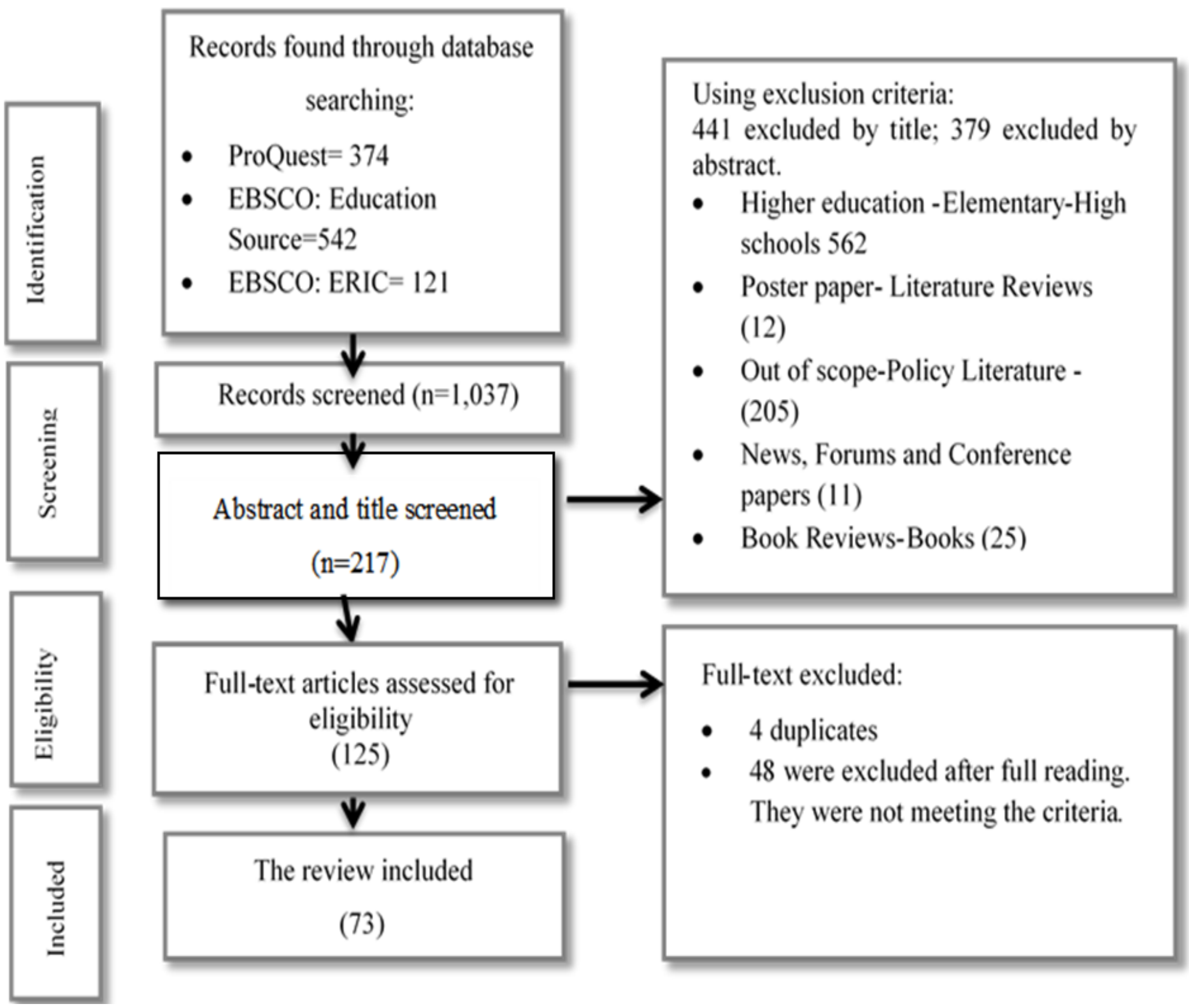

Figure 2.PRISMA flow diagram [26]

Results

Inductive Analysis Results

After reviewing the plan studies, curricula, and projects, we developed three frames of analysis that helped to identify domains and sub-domains. These domains assisted in identifying sustainability components in the plan studies, curricula, and projects. In Figure 3, we present the three frames of analysis (i.e., Attitudes, Skills, and Content-Knowledge) in step 1, and the domains and sub-domains for each one of them in step 2 and 3. In our analysis, we used the learning goals presented in each project or curricula to determine the three different frames of analysis. An example of this process is the project "Sustainability Action Project" (SAP). The major learning goals are for students to explain "how sustainability relates to their lives and their values" [27, p. 3], and "apply their understanding of sustainability by acting on an issue which they are passionate"[27, p. 3]. In this case, this learning outcome was classified in the *Attitude-Behavior* frame of analysis, due to the promotion of action and attitude change regarding sustainability issues.

Another example of the frame of analysis *Attitude-Behavior* is the study by Shuttleworth [28], in which social issues of sustainability are used to help students to make informed decisions. This analysis process was similar for all three frames of analysis. In consequence, we identify ten different domains represented in Figure 3. For instance, we found three domains for the frame of analysis *Attitude-Behavior*, named Awareness, Social Justice/Values Thinking, and Behavior Change. Consequently, we found three domains for the frame of analysis, *Skill*s that we named informed decision, Geospatial thinking and reasoning skills. Finally, we found four domains for the frame of analysis, *Content-Knowledge*, named in four different levels. These domains and some examples are represented in Table 3 for *Attitude-Behavior* and *Skills.*

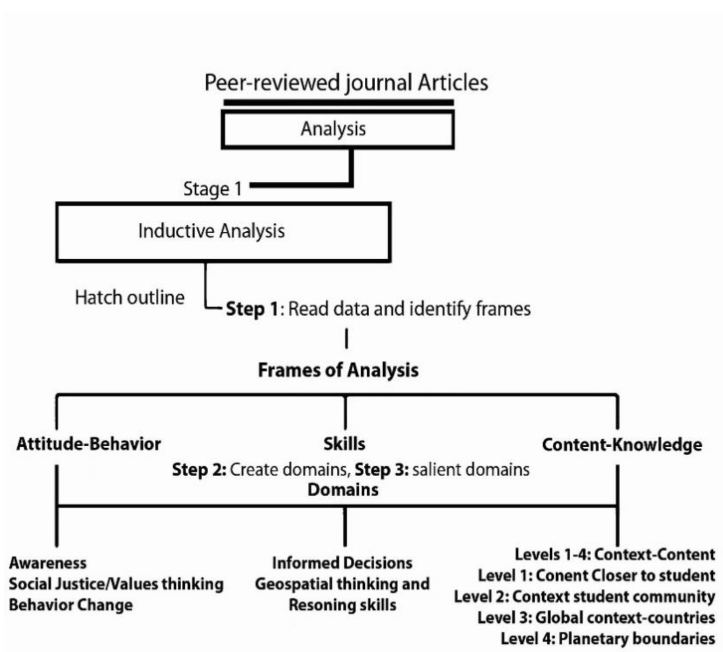

Figure 3. Domains and components found in the inductive analysis.

Table 3 *Some project examples for the subdomains for Attitude-Behavior and Skills*

Frame of Analysis	Domain	Examples
Attitude-Behavior	Awareness	Nodal points awareness of complexity [29], Eco-Factory [30], and BINKA curriculum (Mindfulness) [31]
	Social Justice/ values thinking	Sustainability Education in an Environment of Diversity (or SEEDs) module [32], value meaning making [33]
	Behavior change	Ecolife workshop [34], sustainable camp in Utah [35] and The Going Green! Middle Schoolers Out to Save the World project (MSOSW) project [32]
Skills	Geospatial thinking	Geospatial thinking and reasoning (GTR) skills using georeferenced data."[33].
	Informed-Decisions making	[34]

It is important to mention that for the *Skills* frame of analysis. We identified a few lesson plans that focused on developing a specific skill in students. However, most of the lesson plans considered skills as necessary for the learning process but not for the learning outcome. The lesson plan goals were promoting either behavior change or using sustainability content to teach a specific concept. In Table 4, we show some excerpts for the few lesson plans that focused on developing a *Skills*.

Table 4 *Domains and excerpt examples for the frame of analysis, Skills*

Domain	Excerpts
Informed-Decisions making	"The goal was to understand how students evaluated and used data to influence accounts that may impact decision-making, rather than what they thought about these particular issues." [37].
Geospatial thinking	"Work in five interrelated topic areas (energy and its everyday uses, sustainable energy sources, the United States energy production and consumption, nonrenewable resources, and energy efficiency and conservation) promoted geospatial thinking and reasoning (GTR) skills using georeferenced data."[36, p. 163].

Finally, for the frame of analysis, *Content-Knowledge*, we found that many of the lesson plans focused on developing projects that teach STEM concepts. An example of this frame of analysis was the Life-cycle analysis and inquiry-based learning project suggested by Juntunen and M. Aksela [38]. In this project, the authors promoted chemical literacy by asking students to analyze products from their daily life. Therefore, this project focused on Chemistry literacy, and it was coded in the frame of analysis, *Content-Knowledge*.

While analyzing the domains and patterns for *Content-Knowledge*, we found a relationship between the STEM concepts taught and the context used for students to apply ('transfer') their knowledge. We identified that many of the lesson plans used a specific context and a real-world issue to transfer to a concept related to sustainability or STEM related concepts. The context could be close to students, such as their houses and schools, or far, such as other countries. As a result, we classified these different proximities in relation to the student on four levels shown in Figure 4. *Level 1* represents projects that use students' homes as a context or a context that is close to them that is not necessarily their school or community. An example is the project that uses "Green Ninja Energy Tracker interface" [39], in which students record their energy consumption at home and analyze ways in which they can reduce their household consumption as a challenge for their science class. *Level 2* represents projects that use as context the school or community. Some examples are the "Wisconsin K-12 Energy Education Program (KEEP)" [40] and "Experience-based School Learning Gardens Professional Development Program Workshop" [41]. In Table 4 and Figure 4, we represent more examples for each level.

The projects and curricula integrate different concepts for each of the levels. We classified them as a subdomain represented in the divisions of each level shown in Figure 4. For example, for *Level 1* we found four subdomains representative: Health, Object-Design [42], Consumption and Manufacturing. For the case of *Level 3,* we found three subdomains that we called Industry, Resources and Sustainability Tenets.

The resources subdomain was found in two levels (Level 2 and 3). The difference between them is the type of project in the lesson plans. For instance, for the *Level 2 Context: student community schools/county state*, we found that students explored concepts such as sustainable energy supplies, water quality and purification [51] within their communities. In contrast, the resources classification for *Level 3 Global context-Countries*, students explored water and energy resources in a global perspective [28]–[54], [55], [30]. In *Level 4 Planetary boundaries,* the students explore concepts in a broader perspective, in some cases in the level of a planet [49] [50]. In Table 5, we show the different levels and sub-domains with some project examples.

Table 5. *Domains and project examples for Frame of Analysis, Content-Knowledge*

Domain	Project examples
Level 1	Consumer Behavior [43][44] Life-cycle Inquiry [45]
Level 2	Nurture Thru Nature (NtN), Health, Food [46] Evaluating Green Design [6] Permaculture (soils- food production) [47]
Level 3	Global Ed Project "GE2 is designed to cultivate a scientifically literate citizenry by grounding science education in meaningful socio-scientific" [48]
Level 4	Planetary Boundaries [49] Global Climate Change [50]

These findings provide three key components found in the literature for the integration of sustainability education into STEM education in middle schools. One is the use of real-world problems or socio-scientific issues in projects. Second, we found that projects can either focus on changing behavior or use sustainability projects to teach STEM concepts. Third, there is a relationship between content and context that the project use for their activities. This is represented in Figure 4

Figure 4. Results for the Content-Knowledge frame of analysis adapted from [56]

Deductive Analysis

The deductive analysis allowed us to identify the projects that can be aligned with Next Generation Standards, Standards for Technological Literacy, and sustainability competencies.

Next Generation Science Standards

We found that Earth Systems and Human impact were highly used in the lesson plans. This trend in most of the cases is due to the integration of aspects of sustainability already present in these core ideas of the NGSS. However, this is also due to the importance for students to not only understand concepts related to the earth systems but also how human actions impact earth systems. Physical Science was also used in the lesson plans, in specific topics such as Energy and Chemical reactions. For this case, some projects were coded as Energy, such as *Energy Sustainability and Engineering education for K-8 teachers* [57], which had concepts of conservation and energy transfer similar to the Physical Science core idea. However, it was necessary to differentiate between the two types of lesson plans. One used the concept of energy in activities that reference energy concepts such as energy conservation, and the other had energy concepts that belong to Earth systems, such as the earth process that result from energy flows. For these cases, we coded these projects in Physical science and Earth Systems. On the other hand, we did not identify activities or projects in the core ideas Natural selection, History of earth and Forces and Interactions. We present in Table 6 each core idea for the NGSS standards and the references of the coded plan studies, projects, and curricula.

Table 6 *Next Generation Science Standards code and references*

Disciplinary Core Ideas (DCIs)	Name of the code abbreviation	References
Physical Science	Structures and Properties of Matter	[25], [43]
	Chemical Reactions	[27], [38], [45]–[47], [51], [58], [59]
	Forces and Interactions	
	Energy	[36], [39], [40], [44], [48], [53], [60]–[64]
	Waves and Electromagnetism radiation	
Life-Science	Structure, Function and Information Processing	
	Matter and Energy in Organism and Ecosystems	[65], [66]
	Interdependency Relationship in Ecosystems	
	Growth, Development, and Reproductions of Organism	[34], [48], [54], [65]–[71]
	Natural Selection and Adaptations	

Table 6 Continued

Earth and Space Science	Space Systems	[25], [35], [47], [51], [53], [54], [58], [67]–[71]
	History of Earth	
	Weather and Climate	
	Human Impacts	[6], [43], [49], [62], [72]–[76], [53]
Engineering	Engineering design	[39], [57],[79], [58],[80],[81],[30], [79]

Standards for Technological Literacy results

We found that in the case of the STL some standards overlap with NGSS, such as the core ideas of Engineering design and application of science. Consequently, we found Standard 3 and Standard 11 from STL in several lesson plans. These findings can be due to the connections between technology and other fields as well as the design application in the sustainability projects.

Table 7. *Code scheme for Standards for Technology Literacy (STL)*

Code	Standard	References
St 2	The core concepts of technology.	[42]
St 3	The relationship among technologies and the connections between technology and other fields.	[43],[45],[38],[65],[63],[58],[42], [77]
St 4	The cultural, social, economic, and political effects of technology.	[33],[78]
St 5	The effects of technology on the environment.	[78], [43]
St 9	Engineering design.	[39], [57],[79]
St 11	Applying the design process.	[58],[80],[81],[30], [79]
St 13	Assess the impact of products and systems.	[37]
St 15	Agricultural and related biotechnologies.	[27],[47],[82]
St 16	Energy and power technologies	

Sustainability Competencies results

Systems thinking is the most used sustainability competencies followed by collaboration competency and problem-solving. Since we based our deductive analysis on the definitions given by UNESCO, Collaboration Competence had elements that were focused also in promoting empathic behaviors in students and teamwork. We found that none of the lesson plans had elements that exclusively focused on promoting empathy. Instead, we found that the lesson plans activities were promoting teamwork and collaboration in the projects' activities. Therefore, the references presented in Table 8 represent the use of teamwork as a collaboration competence. In addition, we present in Table 8 the results from our deductive analysis comparing the definitions of each sustainability competency by using our conceptual framework and the learning goal and activities used in each project or plan studies.

Table 8 *Results for Sustainability Competencies*

Code	Sustainability Competence	References
	Anticipatory Competence	[27], [45], [83],[58],[25]
	Collaboration Competence	[28],[45],[55],[27], [39], [49], [57],[84],[25],[37]
	Critical Thinking	[27], [29], [39], [53], [64], [67]
	Normative	[31], [70],[67],[84], [25]
	Systems Thinking	[45], [55], [63], [64], [77],[51], [52], [72], [73],[60],[83],[39], [53], [61], [67] [36], [68], [85][84][79]
	Strategic Competence	[64], [76]
	Self-Awareness	[27], [75], [83][79]
	Problem Solving	[27], [35], [79], [80], [84], [85], [43], [45], [57], [58], [60], [64], [70], [76]

We acknowledge that NGSS and STL are not implemented in many states. Our study gives an overview of components that are highly related to sustainability education.

Discussion and Implications

Our study aimed to identify the key sustainability components for integrating sustainability in STEM curricula into middle schools and to identify the projects and activities that are aligned or have elements of the Next Generation Science Standards [23] and Standards for Technological literacy [24]. The main reason for conducting our analysis is to provide a glance of how sustainability is integrated in classrooms and provide an overview and outline that could help educators to not only plan and organize their lesson plans but also to integrate standards that they are institutionally required. Since schools have already established their standards and priorities [5], we use national known standards that may align with the standards from different schools. In our analysis, we coded each project has by the articles' main goal, whether it is changing behavior or using sustainability as a vehicle for teaching a specific subject. We also coded the projects and curricula according to their alignment with standards and the sustainability competencies. If an educator wants to teach about energy resources, our coding and classification could provide a project with examples to use different contexts for students to apply (Levels in Figure 4). For example, if an educator wants to start teaching energy consumption, the educator could start from the context that it is closer to students. In this case, it could be *Level 1,* represented in Figure 4, specifically in the *Consumption* subdomain and use the "green energy tracker interface", as an example, [39] which allows students to track their energy consumption at home.

In our example, the educator can also scaffold this activity by using a different context, such as *Level 2* or *Level 3,* and use the GlobalEd 2 project [48], as an example. On the other hand, the educator can use our result tables to explore what are the standards and projects that have some elements of the Sustainability competencies. For example, in the case of the green energy tracker [39], in our analysis, it is possible to identify from Table 6 that the project integrates elements of Physical Science as a standard for Next Generation Science Standards. In addition, in this project, we could identify the application of the Standard 9 *Engineering Design* for the Standards for

Technological literacy [24], represented in Table 7. Finally, this project has also components that allow students to think critically, use systems thinking and enhance collaboration, three sustainability competencies from our conceptual framework, shown in Table 8. Our findings are only a guide of what elements were present in projects and they do not indicate that this is the only way to organize the elements found in this study.

On the other hand, in our findings, we identify some deficiencies in the UNESCO definitions [16] in some of the competencies. For example, the Collaboration competency indicates aspects of empathy toward other communities and elements that deal with conflicts in a group.

> "the abilities to learn from others; to understand and respect the needs, perspectives and actions of others (empathy); to understand, relate to and be sensitive to others (empathic leadership); to deal with conflicts in a group; and to facilitate collaborative and participatory problem solving" [16, p. 10]

In our analysis, we did not identify empathy elements in any of the projects. As a result, all the plan studies, curricula and lesson plans were coded as a Collaboration competence base in the second element of this definition, and the teamwork activities that the project implemented.

Limitations

Our study followed a systematized literature review as a method to gather peer-reviewed journal articles. Even though this method shows in detail the keywords and inclusion criteria for search replicability, this method limits the freedom to select literature that was not capture within the keywords used for this study. A more extended literature review with additional set of keywords is required to fully identify peer-reviewed articles. This will also help to corroborate the gaps found in the deductive analysis in the standards and their possible alignment with sustainability components.

References

[1] K. Gordon, "Risky business: The economic risks of climate change in the united states: A climate risk assessment for the united states," 2014.

[2] Development United Nations Conference on Environment, "Agenda 21, Rio Declaration, Forest Principles.," New York]: United Nations, United Nations, 1992.

[3] T. Waas, A. Verbruggen, and T. Wright, "University research for sustainable development: Definition and characteristics explored," *J. Clean. Prod.*, vol. 18, no. 7, pp. 629–636, 2010.

[4] R. Lozano, "Diffusion of sustainable development in universities' curricula: An empirical example from cardiff university," *J. Clean. Prod.*, vol. 18, no. 7, pp. 637–644, 2010.

[5] D. P. Chambers and C. Walker, "Sustainability as catalyst for chanfe in universities: New roles to meet new challenges," in *Challenges in higher education for sustainability*, P. Davim and W. Leal, Eds. Switzerland: Springer, 2016, pp. 1–16.

[6] M. Owald, "Sustainability interest and knowledge of future engineers: Identifying trends in secondary school students*," *Int. J. Eng. Educ.*, vol. 33, no. 1, pp. 489–503, 2017.

[7] R. McKeown and V. Nolet, "Education for sustainable development in Canada and the United States," in *Schooling for Sustainable Development in Canada and the United states.*, vol. 4, R. McKeown and V. Nolet, Eds. Dordrecht Heidelberg, New York London, 2013, pp. 237–248.

[8] A. L. Higgs and V. M. Mcmillan, "Teaching through modeling: Four schools' experiences in sustainability education," *J. Environ. Educ.*, vol. 8964, no. September, 2006.

[9] Congress, "The National Environmental Policy Act of 1969," vol. 4, 1982.

[10] President, *Executive Order 13514-Federal Leardership in Environmental, Energy, and Economic Performance*. United States: Federal Register, 2009, pp. 1–13.

[11] EIA, "U.S Energy Information Administration," *How much of U.S. carbon dioxide emissions are associated with electricity generation?*, 2017. .

[12] A. Jordan, T. I. M. Rayner, H. Schroeder, N. Adger, and K. Anderson, "Going beyond two degrees ? The risks and opportunities of alternative options," vol. 13, no. 6, pp. 751–769, 2013.

[13] Deep Decarbonization Pathways Project, "Pathways to deep decarbonization 2015 report-executive summary," 2015.

[14] UNESCO, "UN Decade of Education for Sustainable Development 2005 - 2014: The DESD at a glance," 2005.

[15] L. A. Kimaryo, "Integrating environmental education in primary school education in tanzania teachers' perceptions and teaching practices," 2011.

[16] M. Pavlova, "Environmental education and / or education for sustainable development : What role for technology education?," in *PATT 25 ; CRIPT 8 - Perspectives on Learning in Design & Technology Education. Copyright*, 2011.

[17] UNESCO, "Education for Sustainable Development Goals," UNESCO, 2017.

[18] G. d Haan, "The development of ESD-related competencies in supportive institutional frameworks," *Int. Rev. Educ.*, vol. 56, no. June 2010, pp. 315–328, 2010.

[19] M. Rieckmann, "Future-oriented higher education : Which key competencies should be fostered through university teaching and learning ? 1 Keywords," *Futures*, vol. 44, no. June 2010, pp. 127–135, 2012.

[20] M. J. Grant and A. Brooth, "A typology of reviews:An of 14 reviews types and associated methodologies," *J. Copilation--Health Inf. Libr. J.*, pp. 91–108, 2009.

[21] M. Borrego, M. J. Foster, and J. E. Froyd, "Systematic literature reviews in engineering education and other developing interdisciplinary fields," *J. Eng. Educ.*, vol. 103, no. 1, pp. 45–76, 2014.

[22] A. Hatch, *Doing qualitative research in education setting*. Albany, New: State University of New York Press, 2002.

[23] National Research Council, “Next generation science standards: For states, by states.” 2014.

[24] International Technology Education Association, *Standards for Technological Literacy: Content for the study of tecnology*. 2000.

[25] A. E. Hale, C. C. Shelton, J. Richter, and L. M. Archambault, “Integrating geoscience and sustainability: Examining socio-technological relationship within content designed to prepare teachers,” *J. Geosci. Educ. Educ.*, vol. 112, no. 65, pp. 101–112, 2017.

[26] D. Moher, A. Liberati, J. Tetzlaff, D. Altman, and P. Group, “Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement.,” *PloS Med.*, vol. 6, no. 7, 2009.

[27] C. Gleason, R. Ause, and J. Hein, “A case study in sustainability experiential education,” *J. Sustain. Educ.*, vol. 5, no. May, 2013.

[28] J. A. Y. Shuttleworth, “Teaching the Social Issues of a Sustainable Food Supply,” *Soc. Stud.*, vol. 106, pp. 159–169, 2015.

[29] H. Hasslöf, I. Lundegård, and C. Malmberg, “Students’ qualification in environmental and sustainability education — epistemic gaps or composites of critical thinking?,” *Int. J. Sci. Educ.*, vol. 38, no. 2, pp. 259–275, 2016.

[30] S. Perini, M. Margoudi, M. Fradinho, O. Marco, and M. Dipartimento, “Increasing middle school students’ awareness and interest in manufacturing through digital game-based learning (DGBL),” *Comput. Appl. Eng. Educ.*, no. January, 2017.

[31] L. Stanszus *et al.*, “Education for sustainable consumption through Mindfulness Training: Development of a consumption-specific Intervention,” *J. Tea*, vol. 19, no. 1, pp. 5–22, 2017.

[32] C. Ormond *et al.*, “Environmental education as Teacher Education: Melancholic reflections from an emerging community of practice,” *Canidian J. Environ. Educ.*, 2014.

[33] A. Manni, K. Sporre, and C. Ottander, “Emotions and values – a case study of meaning-making in ESE,” *Environ. Educ. Res.*, vol. 23, no. 4, pp. 1–14, 2017.

[34] K. Van Poeck, G. Goeminne, and J. Vandenabeele, “Revisiting the democratic paradox of environmental and sustainability education: Sustainability issues as matters of concern,” *Environ. Educ. Res.*, vol. 22, no. 6, pp. 1–21, 2016.

[35] R. Brain, S. Upton, and B. Tingey, “Extension sustainability camp: Desgin, implementation, and evaluation,” *J. Ext.*, vol. 53, no. 1, pp. 1–18, 2015.

[36] D. Bush, R. Sieber, G. Seiler, and M. Chandler, “The teaching of anthropogenic climate change and earth science via technology-enable inquiry education,” *J. Geosci. Educ.*, vol. 64, no. 3, pp. 159–174, 2016.

[37] K. Emery, D. Harlow, A. Whitmer, and S. Gaines, “Compelling evidence : An influence on middle school students’ accounts that may impact decision-making about socioscientific issues,” *Environ. Educ. Res.*, vol. 23, no. 8, pp. 1115–1129, 2017.

[38] M. Juntunen and M. Aksela, “Life-cycle analysis and inquiry-based learning in chemistry teaching,” *Sci. Educ. Int.*, vol. 24, no. 2, pp. 150–166, 2013.

[39] E. M. Walsh, D. Jenkins, and E. Cordero, “The promise of an energy tracker curriculum for promoting home-school connections and youth agency in climate action,” vol. 11, 2016.

[40] J. Lane, A. Baker, R. Franzen, S. Kerlin, and S. Schuller, “Designing resilient energy education program for a sustainable future,” *J. Sustain. Educ.*, vol. 8, no. January, 2015.

[41] J. Ray and D. Barrett, “Effect of experience-based school learning gardens professional development program workshop on teachers’ Attitudes towards Sustainability Education,” *J. Sustain. Educ.*, vol. 5, no. May, 2013.

[42] M. R. O. Beiler, “Sustainability interest and knowledge of future engineers: Identifying Trends in secondary school students*,” *Int. J. Eng. Educ.*, vol. 33, no. 1, pp. 489–503, 2017.

[43] E. Ashworth and A. Steele, “‘I’m just going to buy that!’: Confronting consumerism in teacher education,” *Discourse Commun. Sustain. Educ.*, vol. 7, no. 1, pp. 37–49, 2016.

[44] R. Christensen and G. Knezek, “Impact of middle school students energy monitoring activitie on climate change beliefs and intentions,” *Sch. Sci. Math.*, vol. 118, no. 1–2, pp. 43–52, 2018.

[45] M. Juntunen and M. Aksela, “Life-cycle thinking in inquiry-based sustainability education- effects on students’ attitude towards chemistry and environmental literacy,” *C-E-P-S J.*, vol. 3, no. 2, pp. 157–181, 2013.

[46] R. Jagannathan, M. J. Camasso, and M. Delacalle, “The effectiveness of a head-heart-hands model for natural and environmental science learning in urban schools,” *Eval. Program Plann.*, vol. 66, no. September 2017, pp. 53–62, 2018.

[47] N. Lebo and C. Eames, “Cultivating attitudes and trellising learning: a permaculture approach to science and sustainability education,” *Aust. J. Environ. Educ.*, vol. 31, no. 1, pp. 46–59, 2015.

[48] K. A. Lawless, S. W. Brown, C. Rhoads, L. Lynn, and S. D. Newton, “Promoting student’s science literacy skills through a simulation of international negotiations: The globalEd 2 project,” *Comput. Hum. Behav.*, vol. 78, no. 78, pp. 389–369, 2018.

[49] M. Fleming and R. Dawson, “Outdoor learning and sustainability education,” in *ASE’s Summer Celebration Conference*, 2013, vol. 95, no. December, pp. 27–28.

[50] K. M. Ruggiero and B. W. Golden, “Using global climate change as a platform for interpreting graphical data,” *J. Sustain. Educ.*, vol. 13, no. March, 2017.

[51] F. Affeldt, K. Weitz, A. Siol, S. Markic, and I. Eilks, “A non-formal student laboratory as a place for innovation in education for sustainability for all students,” *Educ. Sci.*, vol. 5, pp. 238–254, 2015.

[52] J. E. Dyment, A. Hill, and S. Emery, “Sustainability as a cross-curricular priority in the

australian curriculum : A Tasmanian investigation," *Environ. Educ. Res.*, vol. 21, no. 8, pp. 1105–1126, 2015.

[53] J. Schon, K. Eitel, J. Hougham, and D. Hendrickson, "Creating a research to classroom pipeline: Clossing the gap between science research and educators," *J. od Sustain. Educ.*, vol. 8, no. January, 2015.

[54] M. Hacker, D. Crismond, D. Hecht, and M. Lomask, "Engineering for all: A middle school program to introduce students to engineering as a potential social good," *Technol. Eng. Teach.*, vol. 77, no. 3, pp. 8–14, 2017.

[55] J. Hamilton and T. J. Pfaff, "Sustainability education: The what and how for mathematics," *Probl. Resour. Issues Math. Undergrad. Stud.*, vol. 24, no. 1, pp. 61–80, 2014.

[56] J. P. Quintana Cifuentes, "An environmental sustainability module that integrates science, engineering and technology education in 8th grade (Order No. 10843540)," 2018.

[57] T. Kulkarni, R. Affolter, and D. Bailey, "Energy sustainability and engineering education for K-8 teachers," *J. Sustain. Educ.*, vol. 8, no. January, 2015.

[58] F. Affeldt, S. Tolppanen, M. Aksela, and I. Eilks, "The potential of the non-formal educational sector for supporting chemistry learning and sustainability education for all students -a joint perspective from two cases in finland and germany," *Chem. Educ. Res. Pract.*, vol. 18, pp. 13–25, 2017.

[59] M. Pluth, S. Boettcher, G. Nazin, A. Greenaway, and M. Hartle, "Collaboration and near-peer mentoring as a platform for sustainable science education outreach," *J. Chem. Educ.*, vol. 92, pp. 625–630, 2015.

[60] J. Buchanan and S. Schuck, "In-school sustainability action: Climate clever energy savers," *Aust. J. Environ. Educ.*, pp. 1–8, 2018.

[61] M. Rogers, T. Pfaff, J. Hamilton, and A. Erkan, "Using sustainability themes and multidisciplinary approaches to enhance stem education education," *Int. J. Sustain. High. Educ.*, vol. 16, no. 4, pp. 523–536, 2015.

[62] B. P. Warner and M. Elser, "How do sustainable schools integrate sustainability education? An assessment of certified sustainable K-12 schools in the united states," *J. od Environ. Educ.*, vol. 46, no. 1, pp. 1–22, 2015.

[63] S. Kerlin, R. Santos, and W. Bennett, "Green schools as learning laboratories? teachers' perceptions of their first year in a new green middle school," *J. Sustain. Educ.*, vol. 8, no. January, 2015.

[64] R. J. Hougham *et al.*, "From the forest to the classroom: Energy literacy as a co-product of biofuels research," *J. Sustain. Educ.*, vol. 8, no. January, 2015.

[65] J. Ray, K. Ming, and D. Barrett, "Effect of experience-based school learning gardens professional development program workshop on teachers' attitudes towards sustainability education," *J. Sustain. Educ.*, vol. 5, no. May, 2013.

[66] S. Kelley and D. Williams, “Teacher professional learning communities for sustainability: Supporting STEM in learning gardens in low-income schools,” *J. Sustain. Educ.*, vol. 5, no. May, pp. 327–345, 2013.

[67] L. Tomas, M. Lasen, E. Field, and K. Skamp, “Promoting online students’ engagement and learning in science and sustainability preservice teacher education,” *Autralian J. Teach. Educ.*, vol. 40, no. 11, pp. 79–107, 2015.

[68] M. E. Peffer, M. L. Beckler, C. Schunn, M. Renken, and A. Revak, “Science classroom inquiry (SCI) simulations: A novel method to scaffold science learning,” *PLoS One*, vol. 10, no. 3, pp. 1–14, 2015.

[69] P. R. Sheppard, D. Hansbrough, and J. Gilbert, “Field-trip pedadogy for teaching: ‘Sense of place’ in middle school,” *Sci. Scope*, vol. 36, no. 7, pp. 49–54, 2013.

[70] T. Hodgkinson, “Translating sustainability: The design of a secondary charter school,” *Curric. Teach. Dialogue*, vol. 15, no. 1, pp. 63–82, 2013.

[71] M. Rickinson, M. Hall, and A. Reid, “Sustainable schools programmes: What influence on schools and how do we know?,” *Environ. Educ. Res.*, vol. 22, no. 3, pp. 360–389, 2016.

[72] E. Redman, “Opportunities and challenges for integrating sustainability education into K-12 schools: Case study phoenix, az,” *J. Teach. Educ. Sustain.*, vol. 15, no. 2, pp. 5–24, 2013.

[73] C. C. M. Mody and H. Choi, “Explicity linking human impact to ecological function in seconday school classrooms,” *Am. Biol. Teach.*, vol. 76, no. 8, pp. 508–515, 2014.

[74] A. Genel and M. S. Topçu, “Turkish preservice science teachers’ socioscientific issues-based teaching practices in middle school science classrooms,” *Res. Sci. Technol. Educ.*, vol. 34, no. 1, pp. 1–19, 2016.

[75] R. A. Dunkley, “Learning at eco-attractions : Exploring the bifurcation of nature and culture through experiential environmental education culture through experiential environmental education,” *J. Environ. Educ.*, vol. 47, no. 3, pp. 213–221, 2016.

[76] B. Mwendwa, “Learning for sustainable development: Integrating environmental education in the curriculum of ordinary secondary schools in Tanzania,” *J. Sustain. Educ.*, vol. 12, no. February, 2017.

[77] K. Kassam and L. M. Avery, “The Oikos of Rural Children 1 : A Lesson for the Adults in Experiential Education,” *J. Sus*, vol. 5, no. May, pp. 1–18, 2013.

[78] S. Gannon, “Saving squawk? animal and human entanglement at the edge of the lagoon the lagoon,” *Environ. Educ. Res.*, vol. 23, no. 1, pp. 1–21, 2017.

[79] M. Muurmans, P. Leahy, and L. Richards, “Communicating beach management : educators ; coastal engineers and local governments collaborating to create successful education programs . Communicating beach management : educators ; coastal engineers and local governments collaborating to create succe,” *J. Coast. Res.*, vol. 75, pp. 672–674, 2016.

[80] C. Lant, B. Pérez-Lapeña, W. Xiong, S. Kraft, R. Kowalchuk, and M. Blair, "Environmental Systems Simulations for Carbon, Energy, Nitrogen, Water, and Watersheds: Design Principles and Pilot Testing," *J. Geosci. Educ.*, vol. 64, no. 2, pp. 115–124, 2016.