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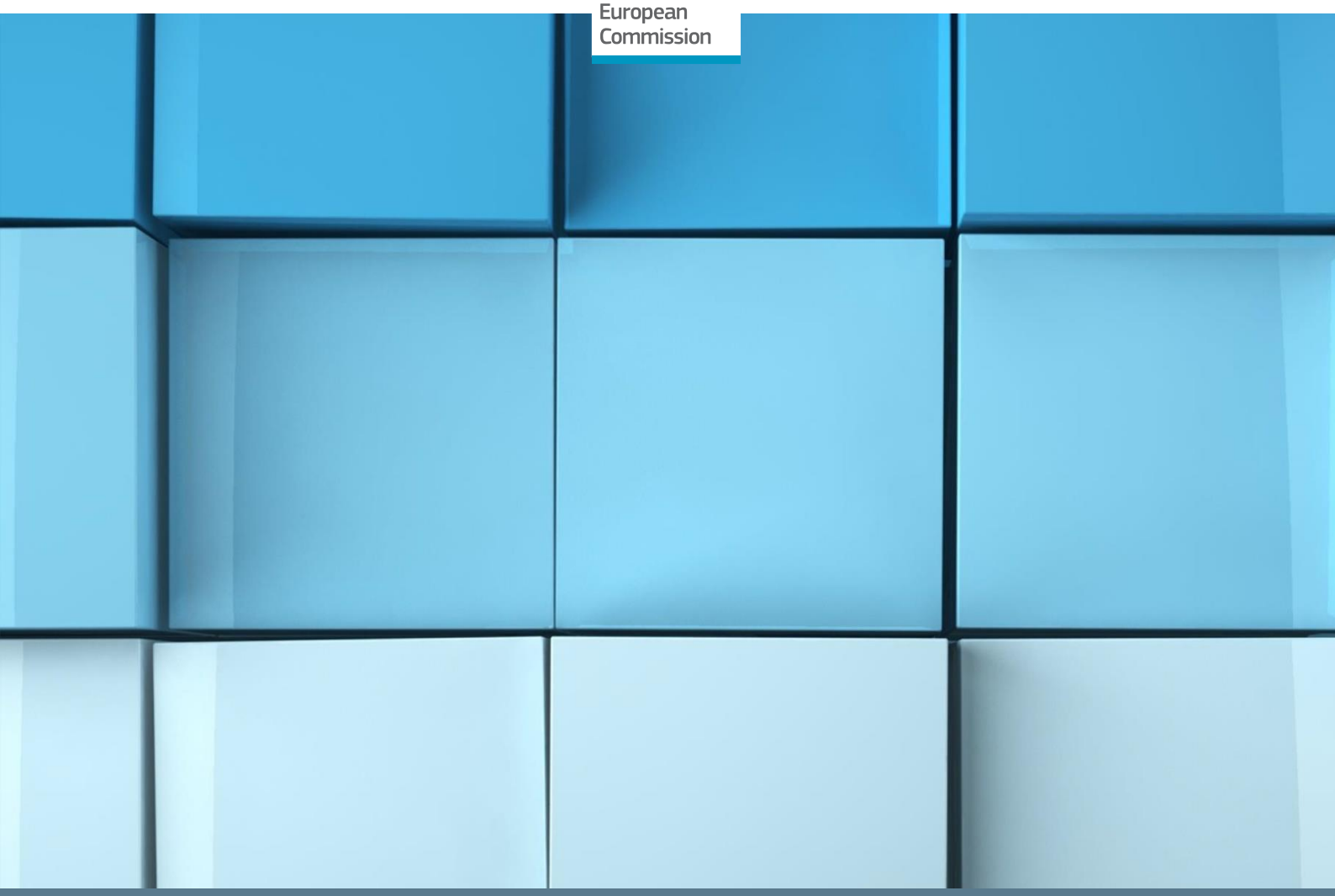

Enhancing education through learning for sustainability: an explorative review of broader benefits

Analytical report

NESET

Education and Training

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ABOUT NESET

NESET is an advisory network of experts working on the social dimension of education and training. The European Commission's Directorate-General for Education and Culture initiated the establishment of the network as the successor to NESET II (2015-2018), NESSE (2007-2010) and NESET (2011-2014). The Public Policy and Management Institute (PPMI) is responsible for the administration of the NESET network. For any enquiries please contact us at: info-neset@ppmi.lt.

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Enhancing education through learning for sustainability: an explorative review of broader benefits

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Executive summary

Aims

Learning for sustainability (LfS) encompasses holistic, interdisciplinary experiences that equip learners with essential sustainability competences (European Commission, 2024). The 2018 Council Recommendation on key competences for lifelong learning emphasises improving, among others, basic skills (such as literacy and numeracy), competences in STEM, and digital competences, while fostering citizenship and appreciating cultural diversity. This study aims to explore how LfS contributes to those broader learning outcomes, particularly in (pre-)primary and secondary education.

Methodology

A literature review was conducted to provide timely evidence for policymaking. The primary databases used were ERIC, the Web of Science and Scopus, with a focus on peer-reviewed studies published between 2015 and 2024 focusing on (pre-)primary and secondary education. Documents were screened in multiple stages, and snowballing techniques were used to complement the selection. No distinctions were made between urban or rural schools, or between public and private institutions. Details regarding the methodology used, including search terms and selection criteria, can be found in Appendix to this report.

Results

The present report reveals some broader learning benefits of LfS. These can be classified into basic skills, transversal skills, psychological benefits, and institutional benefits. Many studies have reported these benefits within the context of outdoor, nature-based learning for sustainability settings.

Impact of LfS on basic skills

Although the number of studies identified is relatively small, LfS appears to enhance basic academic skills by integrating real-world sustainability contexts into education. For example, cross-curricular approaches can enhance basic skills such as numeracy, while experiential learning can boost typical STEM skills. Moreover, nature-based learning can improve students' connection to their environment, fostering academic success. An inclusive approach to LfS can also support the participation of minority groups and students with special needs, offering broad educational and developmental benefits.

Impact of LfS on transversal skills

Learning for sustainability can affect the development of transversal skills that are essential for navigating today's complex world. For instance, it can foster higher-order thinking skills, thereby equipping students for a complex and uncertain future. In addition, LfS can also promote citizenship by encouraging civic engagement and social responsibility. This, in turn, enhances students' understanding of local and global challenges. Furthermore, while research into LfS and employability is still emerging, it shows promising results in developing entrepreneurial skills, especially through hands-on, cross-curricular projects. In addition, LfS can also enhance adaptability and resilience.

Psychological benefits of LfS

Learning for sustainability can provide psychological benefits for students, particularly through nature-based experiences. Exposure to natural environments enhances physical and emotional well-being, fostering healthier development. Nature-based LfS is linked to increased motivation, improved behaviour, and better academic performance. This is due to the fact that students are exposed to calm, engaging learning environments that promote attention and self-discipline. In addition, outdoor activities improve physical health, reduce stress, and enhance self-esteem, leading to greater overall well-being. For younger students, exposure to nature supports holistic child development, encouraging socio-emotional growth and the development of interpersonal skills and a deeper connection to the environment.

Institutional benefits of LfS

Learning for sustainability can positively transform school culture by fostering collaboration among students, teachers and the community – particularly in urban settings, where diversity and socio-emotional needs are critical for educational equity. Through a whole-school approach, sustainability is integrated into all aspects of school operations, thereby promoting a more inclusive and participatory learning environment. Furthermore, teachers' competence in LfS is essential to this success, whereby proximity to green spaces enhances teachers' attitudes towards LfS.

Recommendations

Policy recommendations

Learning for sustainability should be prioritised as a vital component of quality education, potentially enhancing students' basic and transversal skills while promoting psychological well-being. Schools should be encouraged to adopt a whole-school approach to integrating LfS into curricula and teaching, fostering collaboration among primary and secondary school students, teachers and the community. This requires increased support and investment to overcome implementation challenges:

- Professional development: invest in teacher training to equip teachers with the competences needed for the effective integration of LfS.
- Cross-curricular programmes: promote cross-curricular instruction or projects to enhance LfS practice, while simultaneously improving basic skills such as numeracy.
- Nature-based and outdoor learning: integrate nature-based learning to foster environmental literacy and support health and well-being, especially for disadvantaged students.
- Experiential learning: emphasise experiential and place-based education through community partnerships to address real-life challenges.

Recommendations for future research

So far, the impact of LfS on broader learning outcomes remains underexplored. In particular, research on the impact of LfS on numeracy and mathematical proficiency is very scarce. Moreover, most of the research found is of a rather explorative character, which makes it difficult to derive strong conclusions about LfS as a means to guarantee quality education. To strengthen the case for LfS, researchers are encouraged to replicate previous studies in order to validate earlier, positive findings, and to prioritise longitudinal research to capture the long-term impacts of LfS:

- Inclusivity in research: future studies should include low-income groups and minorities to ensure equal opportunities in sustainability initiatives.
- Assessment tools: tailored assessment tools should be developed to evaluate student progress within LfS, focusing on long-term outcomes.
- Literacy and numeracy outcomes: refined methods should be used to better evaluate the impact of LfS on literacy and numeracy, and reliable progress indicators should be investigated.
- Well-being and employability: further research is needed on the impacts of LfS on well-being in secondary education and on employability, along with support for teachers across different contexts.

Introduction

"It is vital now to conceive education in a more encompassing fashion. Education throughout life is based on four pillars: learning to know, learning to do, learning to live together, and learning to be" (Delors, 1996, p.37).

Learning for sustainability in the context of competence-based education

With the Decade of Education for Sustainable Development (DESD) from 2005 until 2014, the United Nations launched a global movement to reorient education towards sustainable development. This resulted in the inclusion of education for sustainable development (ESD) as an integral part of SDG 4 (Quality education), highlighting its role in supporting the achievement of the Sustainable Development Goals (SDGs) by 2030. These goals should go hand in hand to achieve peace and prosperity for people and the planet through a global partnership (United Nations, n.d.). Within SDG 4, ESD is explicitly incorporated into target 4.7 to ensure that all learners acquire the necessary competences to foster sustainability. To scale up ESD, UNESCO developed a Global Action Programme as an official follow-up to the DESD (UNESCO, 2016). With the Berlin Declaration on ESD (UNESCO, 2022), UNESCO invited its member states to once more commit to the integration of ESD into all levels of education and to monitor progress in implementing this. Over the past 20 years, therefore, ESD has gained increasing attention from policymakers, scholars and educators.

In papers and policy documents, various terms are used to describe the implementation of ESD. Frequently used terms are environmental education (EE), environmental and sustainability education (ESE), education for sustainability (EfS), climate change education (CCE), and green education. These different terms share the same purpose, but each has a specific accent. For instance, ESD goes beyond the ecological focus of environmental education by also integrating the social, economic and cultural dimensions of sustainable development into the curriculum (Laine, 2016; UNESCO, 2022). In this report, we use the term "learning for sustainability" (LfS), which is the terminology used in official EU documents.

The European Commission defines LfS as:

> *"Holistic and interdisciplinary learning experiences that enable learners to embody sustainability values, vision and mindset, as well as to understand and critically analyse complex economic, environmental, and social systems, to live and work sustainably, contribute to the green transition and to actively participate in restoring and maintaining ecosystems and taking individual and collective action for a sustainable future for all."* (European Commission, 2024, p.19).

The aim of LfS is also reflected in the 2018 Council Recommandation on key competences for lifelong learning. The accompanying Reference Framework contains eight key competences needed for personal fulfilment, a healthy and sustainable lifestyle, employability, active citizenship and social inclusion. Among other aspects, it emphasises the improvement of basic skills and investment in language education. It also encourages the acquisition of STEM competences, which include support for sustainability. The Recommendation and its associated Reference Framework also aim to motivate students, especially girls, to pursue careers in STEM fields. In addition, the Recommendation focuses on enhancing digital and entrepreneurial skills and promoting diverse learning approaches.

It also mentions a bidirectional relationship between LfS and citizenship competence. An understanding of sustainability and an awareness of sustainable systems are assumed to be important bases for the ability to act as responsible citizens and to fully participate in social and civic life. Citizenship competence, in turn, is intended to stimulate effective engagement with the development of a sustainable society. Moreover, awareness of challenges to sustainable development is also mentioned as a precondition for entrepreneurship competence. The key competences for lifelong learning therefore respond to the need for sustainable growth. The Recommendation states that Member States should mainstream the SDGs into education.

Impact of learning for sustainability

Learning for sustainability aims to empower students with sustainability competences that encompass knowledge, skills, values and attitudes toward sustainable development (Bianchi et al., 2022; Boeve-de Pauw et al.; 2015; UNESCO, 2017). These competences enable individuals to think critically, plan effectively, and act to support sustainable living, ensuring that human activities stay within planetary boundaries (Bianchi et al., 2022; UNESCO, 2017). In its GreenComp Framework, the European Commission has put forward four areas of sustainability competences: (1) embodying sustainability values, (2) embracing complexity in sustainability, (3) envisioning sustainable futures, and (4) acting for sustainability. These are to be considered an interlinked and holistic set of competences, providing students with multiple perspectives on sustainability issues (Bianchi et al., 2022). LfS not only enhances students' sustainability literacy, equipping them with the capacity to make informed decisions, but it also offers the potential to foster their action competence toward sustainability (Boeve-de Pauw et al., 2015; Sass et al., 2023).

To increase the effectiveness of LfS, it is crucial not to treat sustainability as a separate or standalone subject, as this approach can hinder students' understanding of the interconnectedness of the environmental, social, cultural, and economic dimensions of LfS. Instead, LfS requires a cross- and transcurricular approach due to its inherent complexity, whereby an integrated and comprehensive curriculum is essential (Klausen & Mård, 2023; Öllerer, 2015; UNESCO, 2017; Wals & Benavot, 2017). This shift involves moving away from traditional teaching methods and adopting an emancipatory pedagogy that emphasises collaborative, action-oriented, participatory and transformative learning. In LfS, hands-on learning involving real problems and cases plays a crucial role. Students interact directly with their environment and apply sustainability principles to solve problems, and their emotional and personal connections to place and nature are central (UNESCO, 2017; Wals & Benavot, 2017).

Research into the effect of LfS on sustainability competences has usually been cross-sectional (i.e. at a moment in time), whereas a longitudinal approach (i.e. over time) would be more appropriate (Boeve-de Pauw et al., 2015). Nevertheless, it is important to emphasise the significance of contextual factors, which can influence the effectiveness of LfS (Boeve-de Pauw & Van Petegem, 2013). Hence, it is essential to consider differences between regions and the socio-economic and cultural contexts of students by adopting transformative and culturally responsive teaching methods. However, teachers are often unfamiliar with transformative teaching methods. Hence, they do not know how to trigger experiences for their students that result in "a deep, structural shift in the basic premises of thought, feelings and actions" (O'Sullivan et al., 2002, p.11). Grand sustainability challenges are so utterly complex that they require an approach that takes into account different cultural and socio-economic backgrounds to come up with a solution that is supported by many (Zenasni et al., n.d.).

Problem statement

Thus far, research on LfS has predominantly concentrated on its conceptualisation, the identification and definition of sustainability competences, and didactic approaches, particularly within higher education curricula (see authors such as Bianchi, 2020; Lambrechts et al., 2018; Sterling, 2001; Wals & Benavot, 2017). In addition, much of the research has concentrated on the impact of LfS on students' sustainability competences and on the development by teachers of competences for delivering LfS (see Boeve-de Pauw et al., 2015; Corres et al., 2020).

Limited research (e.g. Christie & Higgins, 2020) has investigated the broader learning outcomes of LfS – that is, beyond the achievement of sustainability competences. Learning outcomes describe what a learner is expected to know, understand and be able to do upon completing a learning experience (Bianchi et al., 2022). Demonstrating that LfS has a broader impact on education could support its implementation for improved learning outcomes. For instance, if it can be demonstrated that LfS has a positive impact on numeracy and literacy, one could argue that LfS might have the potential to contribute to reversing the decades-long decline in EU-average achievement rates in reading, maths and sciences, as reported in the latest survey results from PISA (the Programme for International Student Assessment) (OECD, 2023). In times of increasing polarisation and declining democratic values, another example of a broader impact of interest is the contribution LfS can make to global citizenship. Earlier research (specific to Scotland) on the broader educational outcomes of LfS by the University of Edinburgh (Christie & Higgins, 2020), explored its impact on the personal development of learners; young people's understanding of citizenship; academic attainment; skills for life and work beyond formal education; closing the poverty-related attainment gap and reducing inequity within education; and overall educational settings. This report aims to explore, through a literature review, the full potential of LfS to contribute to such broader learning outcomes.

Objective and scope of this study

This literature review examines academic evidence demonstrating the outcomes of LfS, shifting the focus from the direct achievement of sustainability competences to broader learning outcomes, particularly within (pre-)primary and secondary education. The review focuses on (pre-)primary and secondary education because these levels of education are usually part of compulsory education, which lays the foundation for the aforementioned basic skills. By addressing the research gap in this area, the review aims to assess how LfS improves the overall quality of learning, specifically examining broader learning outcomes such as literacy, motivation to learn, academic achievement, well-being, etc. The objectives of this report are twofold. First, the authors wish to identify the full spectrum of the broader learning outcomes of LfS that have been investigated to date. Second, the authors aim to highlight the robustness of those broader learning outcomes. To achieve this, the authors have formulated one main research question:

> To what extent does learning for sustainability contribute to broader learning outcomes – i.e., beyond the realisation of sustainability competences – within primary and secondary education?

The remainder of this report consists of four main sections. The next section, on research methodology, outlines the approach used to gather, screen and analyse data relevant to this report. The results section then presents the findings of the research, with a focus on the pedagogical and psychological learning benefits of LfS, taking a closer look at effective teaching methods that align with the principles of LfS. This is followed by the recommendations section, which offers actionable suggestions for policymakers and researchers. The final section of the report details its conclusions.

Research methodology

The data sources used to carry out the search for this review were electronic databases. ERIC was the principal resource, primarily due to its focus on educational literature. In addition, the databases Web of Science and Scopus were used. The search focused on documents in the three languages mastered by the first author – namely English, Dutch and French – with a primary emphasis on (pre-)primary and secondary education.

Several search strings were developed to query the aforementioned databases. More specifically, the search strategy was structured into two phases, ensuring the inclusion of peer-reviewed publications, published between 2015 and 2024. In the first phase, different search strings were used to include specific types of learning outcomes. For instance, the set of specific search strings included one referring to the impact of LfS on numeracy and literacy. Based on the broader learning benefits identified during an initial exploration of the literature, other impact domains for which specific search strings were developed included STEM skills, transversal skills, well-being and health, employability skills, and motivation. To ensure other impacts of LfS were not overlooked, a general search string was added into the second phase of the search strategy. The exact search strings used by the research team can be found in Appendix A (Table 3).

During the first round of screening, documents were screened on the basis of their titles, abstracts and keywords. The second round focused on the conclusions section of the articles that remained. A third and final round of screening was then based on an in-depth analysis of the full text (see Figure 3). Inclusion and exclusion criteria were defined to support the screening process. The criteria defined related to the benefits and impacts considered; the form, types and level of education; and the interpretation of sustainability adopted. A detailed list of the inclusion and exclusion criteria is presented in Appendix A (Table 4). The selection was further complemented through the use of snowballing techniques and by incorporating additional documents, such as reports and recommendations, which were already available to the research team prior to the start of the review process.

The search was limited to pre-primary, primary and secondary education. Furthermore, no distinction was made between (sub)urban or rural schools, nor between public or private schools. Moreover, this report uses the term "students" to refer to children or pupils. "Pre-primary students" in this context refers to children in kindergarten. A more comprehensive overview of the methodological approach can be found in Appendix A.

Results

Based on the themes that emerged during the search, the research team has divided the results section into the following parts: (1) an overview of the context of the studies considered, (2) the impact of LfS on basic skills, (3) the impact of LfS on transversal skills, (4) the psychological benefits of LfS, and (5) the institutional benefits of LfS.

Many of the studies on the benefits and impact of LfS on quality education have been conducted within the context of action-oriented (experiential or enquiry-based) outdoor LfS. As a result, research into the benefits and impact of nature-based outdoor LfS is likely to be more frequent, compared with other types of LfS. Such learning can take place in various settings, including outdoor classrooms, projects, experiential activities or school gardens, in which students apply theoretical knowledge in practical contexts.

An important requirement for experiential teaching methods is a certain degree of teacher regulation – in particular, ensuring the necessary knowledge base through explanation and instruction (Han et al., 2022; Teegelbeckers et al., 2023). Herein, it is the combination of different methods and didactics that should be prioritised.

Contexts of the studies considered

Appendix B contains a table of the studies reviewed, organised by year. The present report analysed 71 documents (of which 55 were effect studies). For each study, the table indicates the year of publication, study type, continental region, educational level, age group, gender, and aspects relating to socio-economic status (SES). Blank fields indicate that no information on the corresponding areas was provided in the study. Very few studies explicitly considered aspects relating to gender or SES. This section provides further details on the numbers of studies in relation to specific aspects of contextual information.

When we examine the studies that resulted from our initial search string for the period 2015-2024 on the basis of **publication date**, the largest group (8 out of 22) are concentrated in 2021/22.

Table 1 represents the effect studies analysed (a total of 55), which include various **study** and research methods. The "article" category encompasses all documents that do not specify a particular research method. The "other" category comprises conceptual frameworks, recommendations, reports and working documents.

Table 1: Number of studies based on type of study

Type of study	**Number**
Article	5
Book(let)	3
Case study research	5
Mixed-methods research	7
Other	7
Project	2
Qualitative research	9
Quantitative research	5
(Systematic) review	12

In terms of the **number of studies per continental region**, 13 out of the 55 documents reviewed originated from Europe, with the UK being the European country that featured most frequently. Another 13 studies came from North America, including 11 from the United States and two from Canada. An additional 16 documents did not specify their regional context.

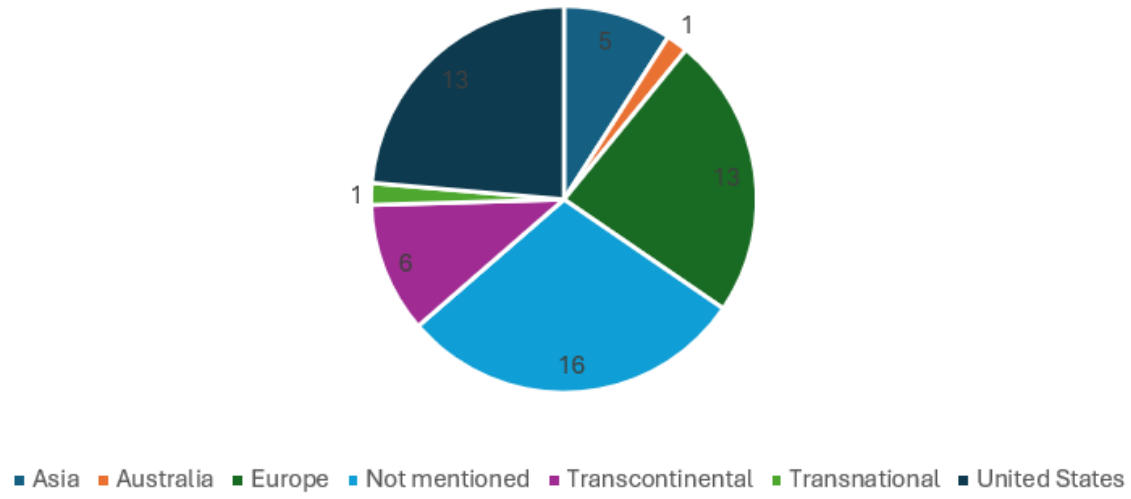

Figure 1: Number of studies based on continental region.

In terms of **educational level**, most of the studies focused on secondary education, while those related to higher education were mainly concerned with the theoretical foundations of LfS. The term "none" refers to documents in which no information on the educational level was provided.

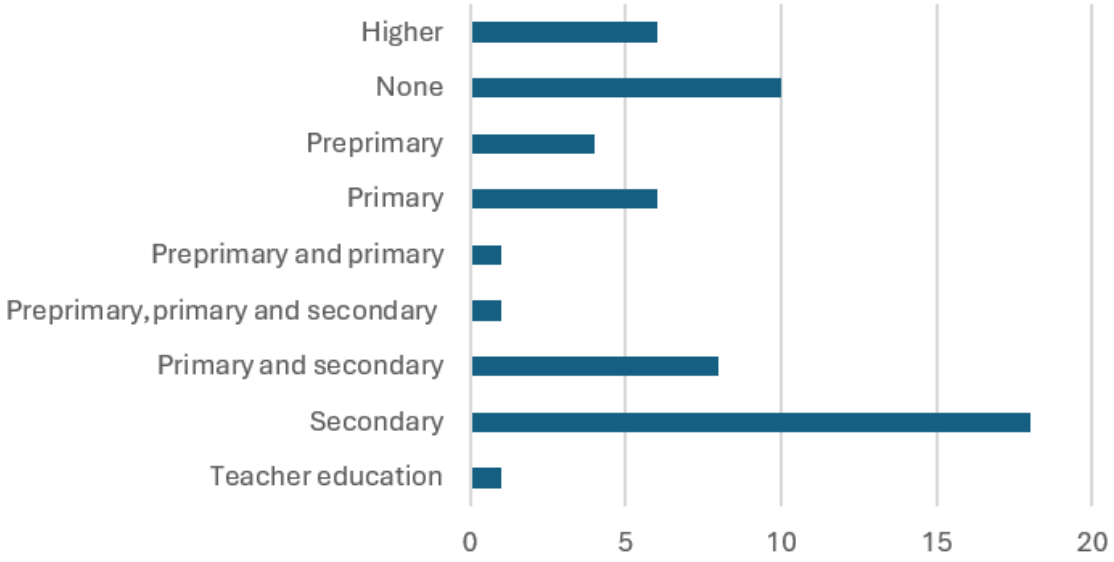

Figure 2: Number of studies based on educational level.

Most studies (29 out of 55) do not specify a specific **age group**, while five studies refer to a broad age range (e.g. childhood or adolescence, spanning 2 to 19 years). The age categories covered in most of the other studies (17 out of 55) fall between 10 and 18 years. Four studies focused specifically on the age range 4-9 years.

Impact of LfS on basic skills

This section discusses the learning benefits of LfS on basic skills, such as reading and writing (literacy), numeracy and science skills. The section on science skills focuses primarily on STEM, but overlaps partially with *higher-order thinking skills* in the section on transversal skills. Conversely, certain *higher-order thinking skills* can also be considered STEM skills.

Literacy

One narrative case study (see box of illustrative examples below) by Eick (2012) demonstrated that integrating scientific concepts, such as plant studies by means of outdoor classrooms enhances the **reading skills** of primary school students aged 8-9 from diverse demographic backgrounds. This approach creates a meaningful context for reading and writing about science from experience. The method provides a real-world context for children's learning, making the material more engaging and relevant. By connecting academic subjects to nature-based experiences, students are more likely to develop a deeper understanding and retain the information better (Eick, 2012).

The research by van Haren and Kiddy (2018) states that the participatory aspect of LfS helped (pre-)primary school students in Australia, aged 4-6, to expand their understanding of the subject while enhancing their **writing skills.** The diverse activities proposed (such as community clean-up activities) created rich environments for language and literacy development. For instance, the students involved ranged from those who were just learning the alphabet and its sounds, to those who were able to write independently using their knowledge of phonics, as demonstrated in their simple accounts of visits to a pond.

Examples of the use of LfS teaching methods to enhance literacy skills

Lundahl (2022) explored how nature-based settings influenced adolescents' writing experiences during a summer camp, noting explicitly that the integration of a rich, meaningful context is seen as an added value. Secondary school students participated in multi-day **backpacking journeys** in the Sierra Nevada mountains, living and learning amid forests, mountain peaks and rivers while alternating between base camp and wilderness environments. The students interacted across various differences in identity, including race and ethnicity, socio-economic status and sexual orientation. An important consideration in relation to this study is the unique nature of its specific context, which may differ from typical school settings.

The academic curriculum included English grammar and acquisition; independent and collaborative reading to encourage leisure reading and enhance fluency and comprehension; narrative and persuasive writing; and a spoken word performance featuring metaphor poems. The study indicates that integrating nature into writing instruction can enhance both the social and the cognitive dimensions (such as direct attention) of adolescents' writing experiences.

A case study by Eick (2012) investigated how a rural teacher utilised an **outdoor classroom and nature study** to enhance science and language literacy learning for primary school students. The student population included 16 students aged 8 to 9 years (third grade) from diverse demographic backgrounds.

Data triangulation from the researcher's field notes, the teacher lesson plans and teacher interviews shows how the teacher integrated nature study with the state science and language arts curriculum, using outdoor experiences to connect classroom lessons to real-world scientific concepts. The study explored how these outdoor lessons, which

included topics such as plant studies, habitat protection and creating a butterfly garden, aligned with the science and literacy curriculum.

The study also analysed the impact the teacher's nature-study approach to literacy learning had on state test results for Adequate Yearly Progress (a measure of school performance) in reading and grammar. The literacy component involved students reading and writing about their outdoor experiences through, for example, poetry. The teacher indicated that the outdoor learning activities had motivated the lowest-performing children both to write a longer text and to write more coherently than they had previously. The results indicated that students using this approach achieved high reading scores in comparison to other third-grade classrooms , with 12 of the 16 students exceeding academic content standards in reading and grammar by the end of the school year. The pass rate in reading among the students who participated in these activities and who were on free or reduced lunches (a measure of poverty) were higher than the school system's entire third grade. However, it is unclear whether the other classes had a comparable student population.

The potential for integrating literacy education with sustainability concepts is also outlined by Guardino et al. (2019). In their mixed-methods study, the authors explore the implementation of literacy activities, specifically focusing on writing and reading about their experiences during **outdoor nature-based education**. The case study involved 37 pre-primary students in the US, including five with special needs (e.g. autism). It aimed to examine their perceptions of teaching and learning during literacy activities and breaks, comparing experiences in both traditional indoor classrooms and outdoor environments. Throughout the study, students were encouraged to engage with texts that addressed environmental topics.

Numeracy

The relationship between LfS and numeracy remains underexplored. However, LfS holds the potential to improve students' numeracy skills by fostering adaptability and problem-solving abilities (see below). Integrating mathematical concepts with real-world challenges, such as those related to sustainable development, can make mathematics more engaging and relevant, thereby deepening students' understanding. In primary education, empirical studies indicate that **interdisciplinary curricula**, which combine mathematics with other subjects, can enhance mathematical outcomes in the context of LfS (Christie & Higgins, 2020; Oldakowski & Johnson, 2017).

Examples of the use of LfS teaching methods to enhance mathematical skills

A quantitative study by Oldakowski and Johnson (2017) involved a total of 120 students aged 10-11 in three US primary schools – one public and two private. The students explored climate change and sea level rise while deepening their understanding of geography, mathematics and science. The implementation of this **interdisciplinary curriculum** led to short-term improvements in learning outcomes across all three subjects, thus including mathematics. Notably, this approach yielded equally significant academic gains for both girls and boys. Furthermore, the school with the most diverse student population – both academically and socio-economically – showed improvements on a par with (and at times exceeding) those of the two private schools involved. As far as we know, this is one of the first quantitative studies of its kind.

Science skills

Science education delivered through experiential learning methods in the early years of schooling is a strong catalyst for **scientific literacy** (Ferreira et al., 2015). In their study, Ferreira et al. (2015) investigated a pedagogical interventional school visit focusing on the properties of air, involving 12 Portuguese primary school students aged 5 to 8 years. The goal of the research was to assess how engaging in hands-on experimental activities, in which students take a proactive rather than a passive role, fosters **science learning** and enhances interdisciplinary skills. The students demonstrated both a conceptual and a procedural understanding of the issues, problems and questions presented.

Science subjects should provide a real-world context that prepares students for current and future challenges, while cultivating transversal skills (Levrini et al., 2021). Looking more closely at STEM fields (science, technology, engineering and mathematics), it is supposed that teachers who acquire LfS competences can support their **students' experiences and STEM skills**. This includes improvements in motivation, analytical thinking, creativity, self-esteem and problem-solving skills (Çevik et al., 2024). In addition, improvements in students' STEM skills are also associated with the benefits of effective teacher instruction and the collaborative practices of secondary school teachers (Han et al., 2022).

LfS approaches to STEM education can significantly enhance student learning and outcomes in these fields. For instance, Purwanto et al. (2022) incorporated simple socio-scientific issues such as rainwater pollution into the chemistry classroom in secondary education (see box of illustrative examples below). Students analysed articles relating to rainwater pollution and collected rainwater samples, which sparked their curiosity and enthusiasm. This approach helped to clarify the chemical concepts underlying a social issue, promoting scientific critical thinking among the students. Following this analysis, a debate was held on the social issues using the evidence available. This activity enabled students to engage in discussions and develop **argumentation skills and meta-reflection,** ultimately increasing their involvement in addressing social issues.

Türe et al. (2020) also examined the impact of teaching socio-scientific issues to secondary school students aged 13-14 (see box below). The authors found that this encouraged students to engage in critical thinking, problem-solving, discussion and decision-making, and boosted **motivation toward science learning**. The above methods illustrate how integrating real-world problems into secondary school STEM education can enhance student engagement and critical thinking (Han et al., 2022).

In addition to enhancing **science literacy**, critical thinking, problem-solving and collaboration skills, the study by Abdurrahman et al. (2023) found that secondary school students aged 16-17 who engaged in LfS within STEM education developed superior systems-thinking skills and creativity in comparison to peers who followed traditional approaches (see box below). This positively influences students' **dispositions towards STEM**, and thereby their interest in a future career in a STEM field.

The experiential learning aspect of LfS can thus contribute to fostering more **positive attitudes** towards STEM and improving content knowledge. A quantitative study by Knezek and Christensen (2020) examined the extent to which hands-on projects, such as assessing the energy consumption of electronic devices in students' homes and communities, can positively impact knowledge of STEM content and dispositions towards STEM among US secondary school students aged 11-14. The study found that this experiential approach often led to more significant improvements in positive dispositions towards STEM, particularly among girls. Moreover, nature-based and/or place-based LfS initiatives can further enhance these STEM skills. For more details, see the box of illustrative examples below (Takkouch, 2022).

For secondary school students, nature-based learning experiences promote a connection to and love for nature, as well as a respectful attitude that can lead to students showing increased responsibility towards living things as they learn to tackle problems through **scientific literacy and enquiry** (Çalışkan et al., 2021; Takkouch, 2022; Walker et al., 2017).

Among primary school students, outdoor nature-based LfS (e.g. nature play), fosters curiosity towards the natural world, a sense of belonging to the place itself, and **naturalistic intelligence** (Jacobi-Vessels, 2013). The concept of naturalistic intelligence has been defined by Gardner (1999, as cited in Jacobi-Vessels, 2013) and encompasses the ability to recognise animals and plants, and an understanding of one's connection to other living beings.

In addition, LfS is expected to enhance the participation of minority groups in STEM fields. This is supported by findings from a case study by Oyana et al. (2015) conducted during a summer camp at a US university, in which 13 girls and seven boys aged 16-17 participated. Over the course of the programme, students gained a deeper understanding of various STEM fields, with LfS strategies proving effective in fostering engagement among underrepresented groups. By making STEM education **more accessible** and meaningful – in particular, to minority students – the study highlights the value of place-based education, enquiry-driven learning, LfS, and civic engagement. The study demonstrated that these educational approaches helped to reshape students' **perceptions of STEM**. This led to increased participation and interest in pursuing STEM careers, ultimately promoting greater diversity in these fields. Furthermore, the cross-curricular nature of LfS appears to be effective in engaging those students who are underrepresented in STEM disciplines and careers (Oldakowski & Johnson, 2017).

Examples of the use of LfS teaching methods to enhance STEM skills

In their research study, Tucker-Raymond et al. (2019) demonstrate how **creative and interactive teaching methods** can improve secondary school students' understanding of climate issues. The study explored the role of critique in the process of designing computer games that focused on climate change and climate systems. The research was conducted in two US secondary school science classrooms, and involved 22 students aged 13 to 14. The participatory practice of critique fostered spontaneous feedback as students interacted with one another, actively observing each other's work while questioning, arguing and reflecting on climate-related topics throughout the game creation process. This allowed them to explore different perspectives and cultivate critical thinking skills. However, the data reveal that during the sessions, students tended to focus more on the gameplay aspects of the design rather than the science aspect. Despite this, they still engaged with multiple aspects of computational thinking. By incorporating **game design** into the secondary education curriculum, the intervention offers a practical approach to LfS, in which students apply their knowledge through hands-on projects. This can improve creativity and collaborative sense-making, as students work together to devise effective solutions within the game. These activities can promote a classroom environment that promotes persistence, interest and deeper learning. Nevertheless, it can be challenging to create opportunities for students to critique one another's work in schools. To address this, ongoing construction projects (i.e. the construction of artifacts), spread throughout the year, can give students repeated practice in providing feedback, refining their designs, and applying lessons learned from one project to improve their work in future projects (Tucker-Raymond et al., 2019).

The use of **design-based learning** (i.e. the design and creation of a project) within LfS STEM education has also been studied by Abdurrahman et al. (2023). In this study, the authors found that secondary school students who engaged in design-based learning developed superior systems-thinking skills compared with those who followed traditional STEM approaches. A total of 67 Indonesian students aged between 16 and 17 years were tasked with exploring the principles and applications of renewable energy by designing and constructing a simple vacuum cleaner. This hands-on project allowed students to delve more deeply into knowledge about and the context of renewable energy. It is important here that the activities involved are designed in such a way as to enhance students' enthusiasm and curiosity toward STEM learning. Moreover, the deeper understanding of component interactions gained by students as a consequence of the design-based approach is likely to have resulted in enhanced systems-thinking skills. This approach not only promoted STEM literacy but also stimulated confidence, creativity and problem-solving skills. However, when interpreting the findings of this study, it is important to consider the small sample size.

Çiçek Şentürk and Selvi (2023) examined the effectiveness of **argumentation-supported educational comics** as a teaching tool for LfS within science lessons. Their study involved 290 Turkish primary school students aged 10 to 11. Once the primary school students had read the comics, discussions were facilitated on the topic of the environment, allowing the students to develop their skills in self-expression, argumentation and questioning. The data reveal that this approach captured students' interest, significantly boosted their motivation to learn, and moderately affected their environmental academic achievement. The study highlights that the use of educational comics facilitates a unique learning environment in which students can critically examine their existing knowledge and explore new information relating to sustainability issues.

Purwanto et al. (2022) highlight the critical role of teachers in facilitating discussions and debates by offering both stimulation and encouragement, particularly for students who may be shy or reluctant to participate. They also stress the importance of closely monitoring debate sessions. However, the authors point out that implementing these strategies can be time-intensive for teachers. The study sought to integrate LfS into STEM through **problem-based learning**. Its goal was to enhance students' understanding of chemical concepts while raising awareness of the actions needed to address environmental issues in Indonesia. This initiative arose from the authors' observation that students critical thinking skills were limited, as they had been taught scientific concepts without understanding their meaning or real-life application, which leads to a loss of motivation. In the study, this understanding was achieved through group discussions and debates on social-scientific issues involving 36 secondary school students aged 16 to 17 years. It appears that LfS problem-based learning approaches can enhance secondary school students' learning outcomes, including critical thinking skills, argumentation skills, problem-solving skills, curiosity, motivation, engagement and a positive disposition towards STEM (Knezek & Christensen, 2020; Purwanto et al., 2022; Rizki & Suprapto, 2024).

Türe et al. (2020) also examined the impact of teaching socio-scientific issues in Turkish secondary schools. In this study, the authors did not employ the problem-based learning method; instead, they utilised a **case-oriented station technique**, and assessed the effect this had on fostering students' motivation to learn science. The mixed-methods study involved 38 boys and 33 girls aged 13 to 14 years, with students rotating through various stations to explore a socio-scientific issue. The research found that this approach could enhance both academic achievement and motivation towards science learning. By engaging with socio-scientific issues (e.g. environmental protection) within this structure, students were able to make meaningful connections between scientific concepts and societal challenges. The study also demonstrated that this approach could be especially effective in promoting both cognitive outcomes (e.g. researching) and affective learning outcomes (e.g. fun). In addition to improving academic performance, the case-oriented station technique helped students to develop the critical skills necessary for tackling complex socio-scientific problems. Specifically, it encouraged students to engage in problem-solving, discussion and decision-making activities, all of which are crucial for understanding and addressing the multifaceted nature of socio-scientific issues.

An alternative teaching method that may also be able to offer advantages is highlighted by Liang (2021). The author developed a **collaborative gaming approach** that connected a secondary school in Taiwan with a science museum to enhance students' competences in addressing environmental challenges. The intervention was designed to create a cross-field learning activity between these institutions. This game-based collaboration allowed 55 students aged between 13-14 years to engage actively with environmental issues through interactive learning experiences. The study revealed that this approach could be effective in supporting competence-based education by helping students to develop the critical skills needed to tackle complex sustainability challenges. In addition, this game-based collaboration proved to be highly beneficial in fostering collaborative learning among students and a deeper understanding of environmental issues. Students were encouraged to navigate environmental scenarios and devise solutions through gaming. This collaborative aspect contributed to improved learning outcomes for the students, particularly in areas such as scientific competence, problem-solving and critical thinking. The results suggest that it is essential to provide clear guidance to students in order to foster effective collaboration. Furthermore, promoting equal participation among all students is crucial to ensuring the success of collaborative activities. This method supports the construction of knowledge by encouraging active participation and deeper engagement with the subject matter. However, the study

highlights the need for effective methods to assess individual student learning outcomes. This underlines the importance of developing tailored assessment tools to ensure a more comprehensive understanding of each student's growth within a collaborative learning approach.

Impact of LfS on transversal skills

This section of the report explores the impact of LfS on transversal skills, including higher-order thinking skills, citizenship, entrepreneurship and adaptability.

Higher-order thinking skills

De Corte (2019) highlights the increasing need to reform education to equip future generations for a "learning society" and a competitive, technology-driven world by fostering essential higher-order thinking skills such as critical thinking and problem-solving skills. Offering students different perspectives and insights into uncertainties fosters a deeper understanding of the **complex** nature of sustainability (Hacking et al., 2010; Hicks, 2012; Walker et al., 2017).

The impact of LfS on school attainment emphasises its role in cultivating lifelong skills. Although research into its influence on life and work skills is still emerging, LfS is expected to extend beyond traditional education. The studies researched in the present report frequently emphasise outdoor nature-based LfS education, which fosters the **higher-order thinking skills** of students (particularly those in primary school). These include decision-making, creativity, critical thinking and problem-solving skills (Christie & Higgins, 2020; Hicks, 2012; Jacobi-Vessels, 2013; Kuo et al., 2019).

An example of the use of an LfS teaching method to nurture creativity

Akman et al. (2022) propose the use of art education to foster environmental literacy in secondary school students. This should not only deepen their awareness of ecological issues, but also contribute to the development of creativity. A central focus in the use of **arts-based methods** is aesthetic learning, where the "method of art" is seen as a tool not only to deepen understanding within the arts, but also to enhance learning across the entire curriculum, which can provide added value in addressing sustainability topics (Klausen & Mård, 2023).

The activities included in the research by Akman et al. (2020) involved the transformation of art materials collected from nature, such as mud, stones and pine cones, using traditional handicraft techniques. Such creative activities can allow students to acquire individual skills and cultivate essential social competences, such as building self-confidence. They also provide opportunities for students to express their environmental understanding artistically. This quantitative study, conducted in Turkey, involved a sample of 53 girls and 71 boys aged 12 to 14 years. The data suggest that after the study's activities, students' environmental behaviours and perceptions varied on the basis of their socio-economic status, with those from higher-income backgrounds exhibiting stronger environmental behaviours and perceptions compared with those from lower-income backgrounds. In addition, the results reveal that the environmental behaviour scale scores of participants were significantly higher for girls than for boys.

Citizenship

LfS pedagogies can empower students to explore their self-identity, understand their interconnectedness with the global environment, and recognise their roles within society. The transdisciplinary nature of LfS encourages primary and secondary school students to understand interdependencies and develop connections with their surroundings, such as through **active engagement** with local community issues, which results in improved social skills. These approaches not only enhance interpersonal communication but also promote ethical reflection by addressing significant societal impacts (Breunig et al., 2015; Christie and Higgins, 2020; Öllerer, 2015).

Participation in school-community activities through LfS encourages primary and secondary school students to engage actively in civic life (Hicks, 2012). It also raises students' awareness of their communities and provides learning benefits such as a **deeper understanding of local challenges**, greater insight into democratic processes, and respect for others. Moreover, opportunities to discuss and participate in community development support the growth of confidence and active citizenship (European Commission, 2022a; Hacking et al., 2010; Ofsted, 2010).

By integrating such activities, LfS enriches students' learning experiences and encourages them to reflect on their connections to the broader interdependencies of life. This allows students to explore various perspectives and understand issues such as **fairness, justice and equity**, while also cultivating empathy, promoting positive attitudes toward cultural and social diversity, and contributing to a sense of place through real-world contexts (Christie & Higgins, 2020; Dyson & Gallanaugh, 2008; Hacking et al., 2010).

To help schools to integrate cross-curricular topics such as civic responsibility into their instruction, Walker et al. (2017) identified best practices for effective LfS instruction that can be adapted for traditional secondary education. The authors analysed interactions among 215 students at a recognised residential camp. Given the interdisciplinary nature of LfS and the time constraints involved in formal education, the research proposes that embedded and implicit instruction methods can be the most promising for developing sustainability practices among future citizens.

Examples of the use of LfS projects to promote community engagement

In their study, van Haren and Kiddy (2018) examine the application of learning principles for sustainability through community engagement and experiential learning. This project aimed to foster a connection between 1,400 Australian pre-primary and primary students, aged 4 to 6, and their local environment, emphasising the concept of "giving" as a catalyst for both personal growth and community transformation. Through collaborative projects centring on acts of giving, such as community clean-up initiatives, (pre-)primary students can develop a greater sense of connection to their environment and are inspired to take action to support it, while cultivating critical thinking and problem-solving skills. By engaging in these authentic experiences, students can directly appreciate their relevance to their communities and lives. This learning experience has positively impacted students' well-being, fostering increased empathy, as observed by their teachers. Following the project, the school integrated acts of giving into school culture, with students participating in annual "giving" projects. In addition, connections between the schools have been strengthened through assemblies involving secondary school students.

The case study by Takkouch (2022) also highlights the benefits of teamwork in a school garden project in Canada that expanded to engage the local community. Twenty-three secondary school students aged 16-18 expressed a sense of belonging as they worked alongside community volunteers in the garden and donated the crops they harvested, fostering a deeper connection with the community.

Entrepreneurial skills

Amid global challenges such as social inequality and youth unemployment, entrepreneurship models have the potential to drive sustainable socio-economic growth. Achieving this, however, requires education that adopts effective methods, tools and goals while reaching all segments of society. Despite this, a noticeable gap remains with regard to research into LfS that specifically focuses on developing employability and/or entrepreneurial competences.

The studies reviewed frequently emphasise teamwork or nature play in primary school settings, thereby fostering students' **collaboration, negotiation, communication and leadership skills** (Hacking et al., 2010; Hicks, 2012; Jacobi-Vessels, 2013; Kuo et al., 2019; Thomas and Thomson, 2004).

One of the initial studies to analyse the relationship between entrepreneurship and LfS was conducted by Rashid (2019). This research emphasises the critical role of entrepreneurship education in promoting sustainable development, especially in fragile contexts. It also illustrates the potential of educational technology in enhancing the accessibility and effectiveness of education.

To implement this integration in practice, it has been shown that incorporating cross-curricular programmes is once again beneficial. For instance, Hermann and Bossle (2020) conceptualised a framework aimed at making LfS more entrepreneurially oriented, particularly in higher education. This interdisciplinary approach implicitly addresses complex community issues by fostering solutions related to sustainability challenges.

In addition, to foster employability skills it is essential to provide students with experiences and environments in which they can actively apply their knowledge. The case study by Zinkunegi-Goitia and Rekalde-Rodríguez (2022), carried out within higher education, examines how **employability** competences can be cultivated within a framework of LfS, through a hands-on project. This initiative allowed students to engage with real-world sustainability challenges concerning ocean education. Interestingly, the study found that factors such as gender did not influence students' perceptions of the concept of employability. Projects of this nature could probably enhance employability competences among secondary education students by offering practical experience, encouraging **collaboration**, and developing the skills necessary to address sustainability issues. As a first step in exploring this complex topic, the study highlights the need for further research, to determine which employability competences should be prioritised and how these can best be developed within LfS (Zinkunegi-Goitia & Rekalde-Rodríguez, 2022).

Adaptability and resilience

Adaptability involves the ability to remain flexible and adjust to changing situations in response to the complexities of today's world (Bianchi et al., 2022). Learning for sustainability provides an opportunity to develop essential skills that enable individuals to navigate an increasingly unpredictable and rapidly changing world (Christie & Higgins, 2020). LfS also helps students to manage **uncertainty** about the future and the complexity of wicked sustainability problems (Bianchi et al., 2022).

Psychological benefits of LfS

In the European Commission's report "Pathways to School Success", student well-being is described as a state of mental and physical health, resilience, strength and fitness that allows students to thrive both academically and personally. The report underlines that the school environment plays a crucial role in determining the mental health of children and adolescents, and that well-being and health are vital to improving academic success (European Commission, 2022b).

Taking this into account, this section of the report explores the specific impact of nature-based LfS on motivation, child development and well-being. Child development refers to children's cognitive, social and physical development.

Contact with nature not only supports a child's well-being, but is also essential for their healthy development. Exposure to natural environments also plays a vital role in fostering physical and emotional well-being in children (Guardino et al., 2019; Largo-Wight et al., 2018; Thomas & Thomson, 2004).

Motivation and academic achievement

In addition to fostering lifelong learning skills, LfS can encourage primary and secondary school students to question their knowledge and seek new information. This has been positively linked to **academic achievement** (Çakirlar-Altuntaşet al., 2023; Christie & Higgins, 2020; Çiçek Şentürk & Selvi, 2023; Kuo et al., 2019; Rizki & Suprapto, 2024; Türe et al., 2020).

Research shows that LfS enhances the relevance of and engagement in learning by connecting academic content with primary and secondary school students' lives and communities. As a result, students become **more motivated and interested,** and exhibit better behaviour, improved attendance and increased concentration (Hacking et al., 2010; Kuo et al., 2019).

This is particularly true for nature-based experiences. In addition to fostering environmental literacy and responsible lifestyles, these can play an important role in enhancing students' academic success. Such experiences appear to provide a calm, quiet and safe learning environment for both (pre-)primary and secondary school students, which improves attention, encourages self-discipline, and fosters the development of perseverance and **self-confidence** (Hacking et al., 2010; Kuo et al., 2019; Malone, 2008).

The context of outdoor LfS is also seen as relevant in helping (pre-)primary school students to develop **self-regulatory skills**, and preparing them to tackle real-life challenges. Cultivating self-regulation in (pre-)primary and secondary school students is recognised as a crucial educational goal, given the positive correlation between self-regulation and student learning outcomes (Bilton, 2010; De Corte, 2019).

Physical and mental well-being and health benefits

Some research underlines the profound connection between exposure to nature and students' overall well-being and health (Largo-Wight et al., 2018; Malone, 2008; Thomas & Thomson, 2004; Wolsink, 2016). Largo-Wight et al. (2018) investigated the effects of contact with nature on a sample of 37 pre-primary school students aged between 5 and 6 years old. Improvements were observed in behaviour, attention and well-being compared with an indoor classroom setting. The findings suggest that outdoor classrooms are a promising approach for increasing contact with nature, promoting child health and well-being, and meeting academic requirements.

Nature-based LfS offers a promising approach to creating a healthier school environment by promoting a wide range of benefits to physical well-being. These include increased physical activity, reduced obesity and the encouragement of **healthier lifestyles** (Jacobi-Vessels, 2013; Kuo et al., 2019; Malone, 2008).

Beyond physical health, nature-based LfS also improves the quality of the school environment, creating a setting that nurtures self-esteem and pleasure, reduces stress, and promotes emotional well-being. Students experience heightened enjoyment, better social interactions and enhanced **overall well-being**, with positive effects that extend into their academic and personal lives. On the basis of the present report, we can conclude that this is especially true for (pre-)primary students (Christie & Higgins, 2020; Guardino et al., 2019; Hacking et al., 2010; Kuo et al., 2019; Largo-Wight et al., 2018; Malone, 2008). The study by Guardino et al. (2019) indicates that outdoor experiences may also benefit students with special needs.

Furthermore, the study by Guardino et al. (2019) found that outdoor classrooms enhanced students' well-being and engagement, with natural settings benefitting both teachers and students. Students with disabilities showed fewer distractions and positive behaviour, thereby supporting inclusivity. However, the small sample size of this study limits the extent to which these findings can be generalised.

Child development

By offering opportunities for outdoor LfS, teachers empower students to enhance their contact with nature, inviting curiosity and exploration. This healthy exposure to the natural world has been shown to promote holistic child development, supporting not only **physical growth** but also **socio-emotional growth.** Based on the present research, we conclude that this is particularly true for pre-primary students. (Guardino et al., 2019; Jacobi-Vessels, 2013; Largo-Wight, et al. 2018)

As pre-primary school students engage with their outdoor natural environment, they can develop a profound **sense of peace** and freedom, allowing them to connect more deeply with themselves and with the world around them. This immersion in nature can foster a respectful attitude as students interact with peers and the environment (Jacobi-Vessels, 2013).

Institutional benefits of LfS

School culture

Research shows that schools that incorporate LfS may witness a **positive transformation in school culture**, marked by increased collaboration between students, teachers and the broader community. This shift promotes more holistic, participatory and pluralistic learning approaches, creating a supportive and inclusive learning environment that serves as a role model for students (Didham & Ofei-Manu, 2015; Ichinose, 2017; UNESCO, 2017).

Particularly for urban schools in a diverse context, achieving educational equity involves transforming school cultures to recognise and embrace diversity, creating a safe, trusting and caring environment that addresses socio-emotional needs and fosters **inclusivity** and a sense of belonging. Giving equal opportunities to students from minority backgrounds ensures their active participation in sustainability discussions. This approach helps to cultivate learning environments that respect and value the unique backgrounds of every student (Zenasni et al., 2024).

The whole-school or **whole-institution approach** is a vital strategy for promoting LfS and meeting sustainability challenges, as it integrates sustainability into education by reconsidering schools' operations, pedagogy and community relationships. In doing so, this approach positions the entire educational institution as a living example for students. Furthermore, sustainable educational environments provide opportunities for both students and teachers to practice sustainability in everyday activities. Consequently, these settings foster skills development, cultivate competences and support value-based learning in an integrated and meaningful way (UNESCO, 2017; Wals & Benavot, 2017). Research on the impact of such approaches on LfS shows that they promote an inclusive school ethos and a healthy school environment, which improve the health of students and the quality of their learning (Hacking et al., 2010).

LfS fosters **transformative learning** approaches and systemic change, enabling students and schools to undergo meaningful changes in perspectives, values and practices. This constructive and participatory approach fosters a shift from traditional teaching towards dynamic learning. It can empower students to question their core assumptions, as well as encouraging active participation and emphasising learner-centred education while being sensitive to various cultural contexts (Bianchi, 2020; Sterling, 2001; UNESCO, 2017). This holistic approach is particularly relevant in an era in which adaptability and the capacity to navigate ambiguity and uncertainty are critical.

Nevertheless, implementing a **whole-school approach** to LfS presents numerous challenges for schools. These challenges can include the limited strategic capacity of school management, which is often constrained by tight budgets and high levels of teacher turnover. In addition, schools may face difficulties due to curriculum restrictions that limit flexibility, as well as issues with maintaining and sustaining long-term projects, and barriers linked to the poverty of students (Zenasni et al. n.d.). In tackling this, a key obstacle is the lack of funding for LfS, as well as a lack of institutional support and training, which are often the result of insufficient prioritisation at governmental level (European Commission, 2022a).

Teacher competences in LfS

Cloud (2014) emphasises that LfS fosters teaching approaches that support whole systems thinking, positively impacting **teacher attitudes**. Wolsink (2016) conducted an empirical study involving all secondary schools in Amsterdam to examine the value of urban green spaces for LfS fieldwork. The study found that the proximity of green spaces significantly enhances LfS by positively influencing teachers' attitudes. In addition to this, to be effective, outdoor LfS needs to be organised carefully (Dillon et al., 2006).

Furthermore, to promote transformational perspectives **teachers** must develop **competences** such as connections with the community, community participation, learning to live together, and critical thinking (Corres et al., 2020). A key aspect here is the teacher's readiness to engage in transformative learning. This involves recognising the essential role emotions play in the learning process, and creating a safe environment in which students can develop their ability to navigate emotions and explore alternative perspectives, feelings and actions. It also includes teachers engaging in reflection on personal teaching beliefs and methods, and being able to guide students through their periods of transformation (Förster et al., 2019).

Recommendations

Policy recommendations

LfS should be recognised as a crucial aspect of quality education, as it appears to offer potential benefits beyond its direct impact in terms of the achievement of sustainability competences. As the present report shows, LfS provides opportunities to enhance students' basic skills (such as numeracy, literacy and STEM skills), their transversal skills (such as higher-order thinking, citizenship, employability and entrepreneurial skills), and their psychological well-being (which includes motivation, physical and mental well-being, and child development).

Schools should be encouraged and advised to integrate and embrace LfS into their teaching or projects in an interdisciplinary way, through a whole-school approach. Research shows that schools incorporating LfS may witness a positive transformation in school culture, marked by increased collaboration between students, teachers and the broader community. However, implementing a whole-school approach to LfS presents numerous challenges for schools. This highlights the need for stronger support and investment in LfS to ensure its long-term success.

This includes increased investment in the professional development of teachers, ensuring they acquire the competences necessary to effectively incorporate LfS into their lessons and to promote sustainability throughout the entire school environment. In addition, when implementing LfS, it is essential to consider the differences between various spatial contexts and the socio-economic and cultural backgrounds of students (Zenasni et al., n.d.).

Among other factors, LfS activities depend on the proximity of public green spaces to schools. Such proximity enables nature-based experiences to be incorporated within LfS, which the present report strongly recommends. These experiences foster environmental literacy, a connection to nature and responsible lifestyles, and have a positive effect on motivation, health, child development and well-being. Furthermore, they are recognised as beneficial in achieving a range of broader learning outcomes, and play a significant role in enhancing students' academic success.

In the context of the gap in mathematics performance across the OECD countries, whereby socio-economically advantaged students tend to outperform their less advantaged peers (OECD, 2023), LfS encourages inclusive education that benefits all students. By equipping students with sustainability competences through (among other approaches) nature-based learning, LfS can enhance academic achievement through increased motivation to learn science. As such, it might ensure a more inclusive educational environment.

Moreover, nature-based experiences can create a positive social environment by promoting a sense of peace, freedom and belonging while cultivating care and respect for others. Such an environment nurtures students' holistic development, enhancing both their academic and social skills.

In addition to nature-based LfS, it is also important to view LfS within its broader approach, which takes into account economic, social and cultural dimensions. Furthermore, greater emphasis should be placed on experiential learning through place-based education, including partnerships with local communities, which also bring psychological and pedagogical benefits for students. Furthermore, pedagogical

approaches to sustainability that focus on addressing complex, real-life problems are recommended in order to close achievement gaps.

Recommendations for future research

Very few articles have been identified that address gender differences, cultural differences or differences in students' socio-economic status. It is important to ensure that students in disadvantaged areas enjoy equal opportunities to participate in sustainable initiatives. Nevertheless, no research was found on LfS that targets conflict-affected individuals or migrants.

Another critical area for future research is the development of assessment tools tailored towards gaining a deeper understanding of each student's development within LfS. While studies emphasise the importance of tracking lifelong skills and individual competences, effective methods to monitor such progress remain underexplored. Longitudinal research is particularly crucial in this, as the improved learning outcomes observed in this review were primarily short-term, whereas sustainability requires a long-term perspective.

A further challenge lies in the complexity of evaluating literacy and numeracy outcomes within LfS. This underlines the need for more refined tools and methods, as well as the development of reliable indicators to measure progress toward these goals.

Moreover, the impact of LfS in terms of learning benefits such as numeracy and employability remains underexplored, while its effect on well-being has primarily been measured at the primary education level. Further research is therefore recommended in these areas. In addition, providing concrete support to teachers within LfS, taking particular account of the varying contexts in which they work, is another aspect that requires more attention.

Limitations

The present report is subject to several limitations, primarily due to the relatively limited coverage of this topic in academic literature. As a consequence, a significant portion of its analysis relies on works that examine the effects of outdoor or nature-based LfS on students.

Another notable limitation is an emphasis on the short-term effects of LfS, primarily due to the scarcity of studies which explore its long-term impacts. The limited number of available sources that address this complex topic further complicates the ability of this report to make generalised conclusions. This reflects the genuine scarcity of studies relevant to the research topic and highlights a gap in the literature that could be addressed by future research.

The present report emphasises the additional learning benefits of LfS. While this approach highlights the potential advantages of LfS, it may unintentionally create an overly positive impression by not addressing the challenges or limitations associated with its implementation.

Conclusions

The present report looks specifically at the broader learning benefits LfS offers for education, which directly and indirectly promote students' academic success and well-being. While evidence on its direct impact on numeracy is limited, LfS can improve these skills by connecting learning to real-world issues, fostering engagement, and making subjects such as mathematics more relevant. In addition, interdisciplinary LfS approaches, while less frequently studied, appear promising in simultaneously improving numeracy and reading skills, as well as providing other learning benefits.

In addition to potentially enhancing numeracy and literacy, nature-based LfS appears to be highly effective in supporting a wide range of psychological benefits. Research has demonstrated that LfS can positively impact students' academic achievement and motivation. In relation to the role of LfS in developing STEM skills, the present findings underline the importance of real-world problem-solving in fostering student engagement and critical thinking. LfS initiatives encourage students to investigate socio-scientific issues, promoting scientific enquiry and collaboration while increasing their motivation towards STEM subjects. Furthermore, LfS offers the potential to enhance inclusivity in STEM education, making it more accessible to minority groups and fostering diversity among students.

The present report emphasises that LfS not only develops essential academic skills but can also cultivate transversal and lifelong learning skills such as higher-order skills, citizenship, entrepreneurial skills and adaptability. These skills are crucial for navigating the complexities of today's world and preparing students for future challenges. Furthermore, effective LfS pedagogies empower students to explore their identities and recognise their interconnectedness with their communities and the global environment, thereby promoting active citizenship.

The psychological and physical well-being benefits of nature-based LfS are profound. The present report highlights the connection between the quality of the environment and children's overall well-being and development, underlining the importance of creating healthier school environments. Through enhanced contact with nature, students experience a range of benefits, including increased physical activity, reduced stress, improved self-esteem, and enhanced overall well-being.

Overall, the insights in the present report underline the growing importance of LfS in shaping the future of education by integrating real-world contexts, fostering interdisciplinary learning and supporting student well-being. This approach not only supports academic achievement but also equips learners with essential lifelong skills to navigate the complexities of a rapidly evolving world. The path forward lies in further research and the broader implementation of LfS, ensuring that its benefits reach all students and contribute to a more sustainable, equitable future.

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Appendices

Appendix A: Research methodology

Search strings

Based on the objective and scope of the report, several search strings were developed to search relevant databases for educational research. Each search string consisted of four dimensions that were connected using the Boolean operator AND. These four dimensions are represented by the columns in Table 2. For each dimension, a list of potential search terms was compiled on the basis of an exploratory search of the literature with reference to the broader benefits of LfS beyond sustainability competences. These were connected using the Boolean operator OR. Truncation symbols and wildcards (*, # and ?) were used for completeness.

Table 2: Search terms

Types of benefit	Benefits	Learning	Sustainability
pedagogic*	benefit*	learn*	sustainab*
soci*	outcome	teach*	environment*
psychologic*	impact*	educat*	green
indirect	effect		climate
transversal	skill*		
basic	competenc*		
soft			
metacogniti*			
emotion*			
non-cognitive			
well#being			
health			
stem skills			
numer*			
literacy			
reading			
math*			
engagement			
motivation			
attainment			
self#regulati*			
concentration			
employability			
problem?solving			
critical thinking			
digital			
entrepreneur*			

The search strategy was structured into two phases. In the first phase, targeted searches were conducted to ensure the inclusion of references specifically related to certain learning outcomes. These outcomes covered a wide range of areas, including numeracy and literacy, critical thinking and problem-solving skills, STEM competences, engagement and motivation, self-regulation and concentration, as well as well-being and health.

This focused approach aimed to capture studies directly addressing these key areas. Following this, a broader search string was employed to identify broader learning outcomes that we might have overlooked in the exploratory literature search. Table 3 presents the Boolean searches used, which were constructed by combining the aforementioned search terms, to maximise the identification of relevant literature across both phases.

Table 3: Search strings

The **specific search strings**
(benefit* OR outcome* OR effect* OR impact) AND (learn* OR teach* OR educat*) AND (sustainab* OR environment* OR green OR climate) AND (well#being OR health)
(benefit* OR outcome* OR effect* OR impact) AND (learn* OR teach* OR educat*) AND (sustainab* OR environment* OR green OR climate) AND ((problem?solving OR (critical AND thinking) OR digital OR entrepreneur* OR employability)) AND (skill* OR competenc*)
(benefit* OR outcome* OR effect* OR impact) AND (learn* OR teach* OR educat*) AND (sustainab* OR environment* OR green OR climate) AND (stem skills)
(benefit* OR outcome* OR effect* OR impact) AND (learn* OR teach* OR educat*) AND (sustainab* OR environment* OR green OR climate) AND (numer* OR literacy OR reading OR math*)
(benefit* OR outcome* OR effect* OR impact) AND (learn* OR teach* OR educat*) AND (sustainab* OR environment* OR green OR climate) AND (engagement OR motivation)
(benefit* OR outcome* OR effect* OR impact) AND (learn* OR teach* OR educat*) AND (sustainab* OR environment* OR green OR climate) AND (attainment OR self#regulati* OR concentration)

The **general search string**
(pedagogic* OR soci* OR psychologic* OR indirect OR transversal OR basic OR soft OR metacogniti* OR emotion* OR non-cognitive) AND (benefit* OR outcome OR impact* OR effect OR skill* OR competenc*) AND (learn* OR teach* OR educat*) AND (sustainab* OR environment* OR green OR climate)

ERIC was searched via the research platform EBSCOhost. EBSCOhost's advanced search feature was used to perform targeted keyword searches within the fields 'Title', 'Abstract' and 'Subject'. Only the first 50 results within the Web of Science and Scopus databases were screened for relevant studies.

Screening process

First, the authors screened the documents by focusing on titles, abstracts and keywords. Next, the remaining documents underwent a second round of screening, this time with a focus on their conclusions. Subsequently, the full texts of the final set were studied (see Figure 3). To ensure the comprehensiveness and depth of the literature review, the selection was further complemented by employing snowballing techniques and incorporating additional documents that were already available to the research team prior to the start of the review process.

This strategy ensured that the search encompassed peer-reviewed publications, published between 2015 and 2024. This date range was not applied to the additional documents. The search included English, Dutch and French documents, focusing mainly on primary and secondary education.

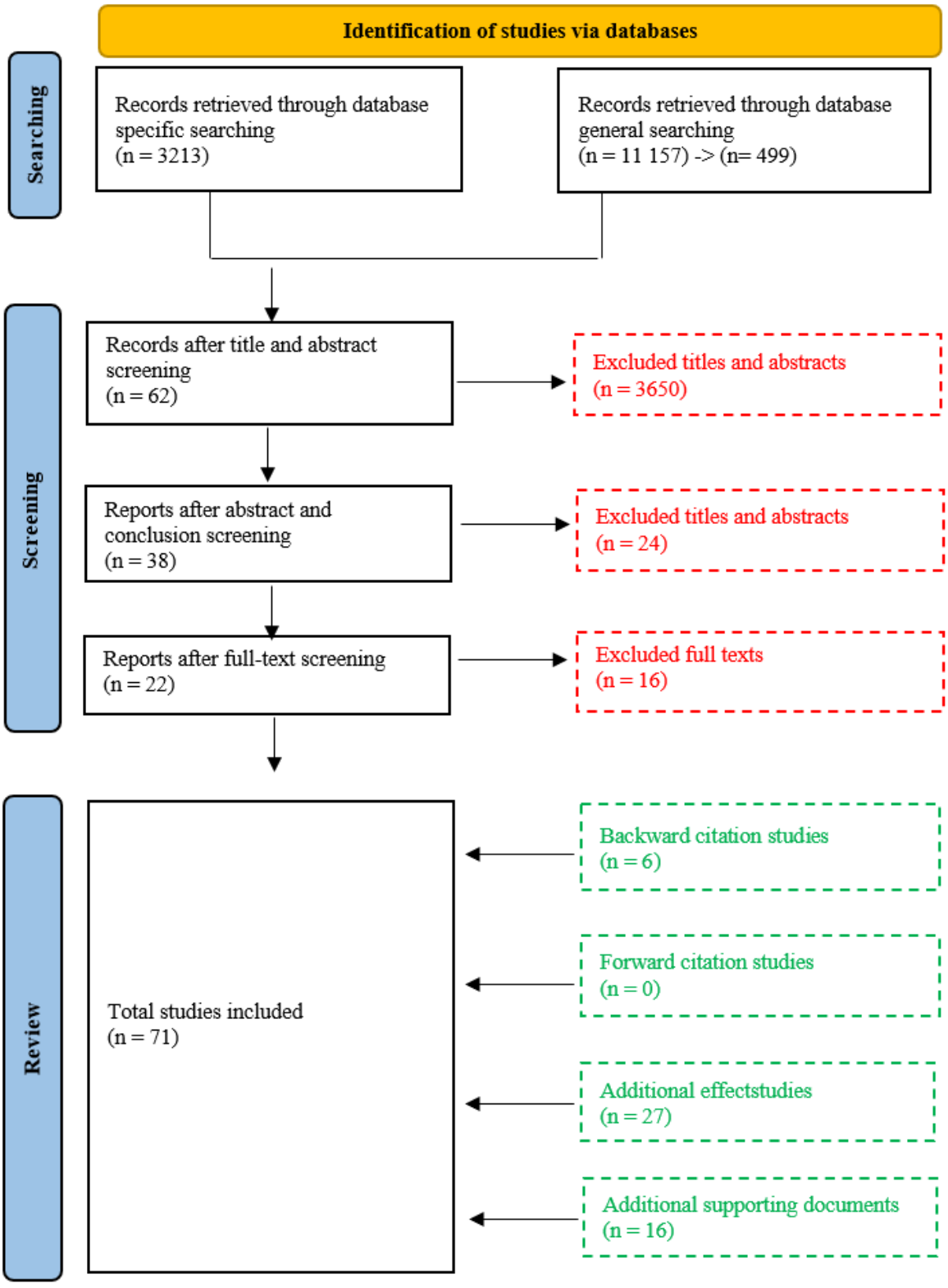

Figure 3: Scoping review search strategy.

Table 4 presents the inclusion criteria and the corresponding exclusion criteria that were used in the two phases of the screening process.

Table 4: Selection criteria

Criterion	**Included**	**Excluded**
Benefits and impact considered	Wider pedagogical and socio-psychological benefits of LfS, e.g. in terms of numeracy, literacy*, and well-being. **Literacy in the meaning of the ability to read and write.*	Environmental and sustainability outcomes not consistent with sustainability competences, such as climate justice, environmental concerns, eco-anxiety. Environmental and sustainability outcomes of LfS, e.g. in terms of sustainability competences* acquired by students. **Literacy in the meaning of environmental literacy, i.e. the understanding of environmental issues, is considered a sustainability competence, and hence excluded from the review.*
Types of education	Types of education that have an obvious link with LfS*, e.g. - Nature-based outdoor education - Ocean education - Climate education - Energy education **STEM education and place-based education are only included when they can be situated within the context of sustainability*	Types of education that have a weak or no link with LfS*, e.g. - Health education - Physical education - Drug education **STEM education and place-based education are excluded when their context is not situated within sustainability.*
Meaning of sustainable/ sustainability	Sustainable and/or sustainability in the usual meaning of the environmental, social and ecological dimensions associated with concepts such as the SDGs or LfS	Sustainable and/or sustainability only in the meaning of being maintained over time.
Type of learning	Formal learning	Non-formal learning Informal learning
Level of education	Secondary education Primary education Pre-primary education	Higher education

Next, the literature was screened on the basis of the benefits and impacts considered. Articles were included whenever they discussed one or more broader benefits of LfS beyond the acquisition of sustainability competences. This included literacy as an impact of LfS in the meaning of the ability to read and write. Documents were excluded when they only discussed the direct learning outcomes of LfS in terms of sustainability competences. The specific search string that included literacy as a search term also yielded articles that dealt with literacy in the meaning of a student's understanding of something. This resulted, for instance, in articles about the impact of LfS on environmental literacy or thus a student's understanding of environmental issues. We considered the latter to be an example of sustainability competences, and hence excluded articles that only dealt with the impact of LfS on environmental literacy.

The literature encompasses many types of education, such as nature-based education, outdoor education, place-based education and STEM education. Whenever the type of education was framed within the context of sustainability, it was included in the analysis; otherwise, it was excluded. In addition, any document retrieved in which "sustainable" or "sustainability" referred solely to maintaining something over time, rather than to its typical association with concepts such as the SDGs or LfS, was also excluded from further consideration.

Furthermore, the search was limited to formal education. Other forms of education, such as informal and non-formal education, were excluded. Lastly, the search was limited to pre-primary, primary and secondary education. All articles focusing exclusively on higher education were excluded. No distinction was made between (sub)urban or rural schools, nor between public or private schools.

Analysis

A more in-depth analysis was conducted utilising Zotero as the reference management program to enhance the rigour of the literature review. This choice of software was intentional, allowing the research team to systematically organise and manage the data collected. By leveraging Zotero's capabilities, the team ensured consistency across the key dimensions of the dataset, facilitating a more coherent synthesis of the literature. For each learning benefit, level of education or teaching method, the documents were categorised and analysed comparatively to identify similarities and differences. This approach enabled the team to draw connections and insights, enriching the analysis and findings. Appendix B presents the list of studies considered. It also provides contextual information about the studies, demonstrating the robustness of the key findings as well as the scope and scale of the impact of this report.

Appendix B: List of studies considered

Table 5: List of documents analysed

Author(s)	Year of publication	Type of study	Region	Education level	Age group	Size of student population	Gender	Sample diversity
Sterling	2001	Article		Higher				
Thomas & Thomson	2004	Project	UK	Primary school	10-11y			
Dillon et al.	2006	Article		Primary and secondary school				
Dyson & Gallannaugh	2008	Review	UK (London)	Primary and secondary				
Malone	2008	Review	UK	(Pre)primary and secondary				
Bilton	2010	Book		(Pre)primary school	2-8y			
Hacking et al.	2010	Booklet		Primary and secondary				
Ofsted	2010	Report	UK (Manchester)	Primary and secondary	5-19y			
Eick	2012	Case study research	USA	Primary	8-9y	16 students (rural)		Ethnically diverse population
Hicks	2012	Book	Scotland	Primary and secondary				

Jacobi-Vessels	2013	Review study	USA	Pre-primary				
Cloud	2014	Editorial Introduction from the Guest Editor						
Breunig et al.	2015	Case study research	Canada (Ontario)	Secondary	15-17y	45 students		
Didham & Ofei-Manu	2015	Review study						
Ferreira et al.	2015	Qualitative action research	Portugal	Primary	5-8y	12 students		Heterogeneous population
Oyana et al.	2015	Review and case study research	USA	Secondary	16-17y	20 students (mostly urban)	M: 7, F: 13	Ethnically diverse population
Öllerer	2015	Review study	Romania (Bucharest)		Childhood			
Wolsink	2016	Case study research	Netherlands (Amsterdam)	Secondary	12-18y	42 teachers (urban)		
Ichinose	2017	Qualitative research	Japan	Primary and secondary				
Oldakowski & Johnson	2017	Quantitative	USA (Florida)	Primary	10-11y	120 students	M: 63, F: 57	Diverse student population
UNESCO	2017	Learning objectives						
Walker et al.	2017	Case study research	USA	Secondary	17-18y	215 students		
Wals & Benavot	2017	Article		Primary and secondary				
van Haren & Kiddy	2018	Project	Australia	Pre-primary	4-6 y	1,400 students		
Largo-Wight et al.	2018	Qualitative research study	USA (Southeast)	Pre-primary	5-6y	37 students (5 with special needs)	M: 20, F: 17	Majority ethnically homogeneous populations

De Corte	2019	Article		Primary and secondary				
Förster et al.	2019	Article		Higher				
Guardino et al.	2019	Mixed-method research study	USA (Southeast)	Pre-primary	5-6y	37 students (5 with special needs)		
Kuo et al.	2019	Review study		Primary				
Rashid	2019	(Systematic) review study						
Tucker-Raymond et al.	2019	Qualitative research	USA (Northeast)	Secondary	13-14y	22 students (urban)		Socio-economically heterogeneous population
Bianchi	2020	(Systematic) review		Higher				
Christie & Higgins	2020	Review study						
Corres et al.	2020	(Systematic) review	Europe	Teachers				
Hermann & Bossle	2020	Conceptual framework		Higher				
Knezek & Christensen	2020	Quantitative research	USA	Secondary	11-12y			
Türe et al.	2020	Mixed-method research study	Turkey (Eastern Anatolia Region)	Secondary	13-14y	71 students	M: 38, F: 33	
Çalışkan et al.	2021	Mixed-method research study	Turkey	Secondary	11-13y	18 students	M: 11, F: 7	Low-SES backgrounds
Levrini et al.	2021	Qualitative research study	Finland, Iceland, and Italy	Secondary	16-19y	24 students	M: 11, F: 13	Diverse cultural backgrounds
Liang et al.	2021	Qualitative research study	Taiwan	Secondary	13-14y	55 students	M:32, F: 23	

Akman et al. (2022)	2022	Quantitative research study	Turkey (Isparta)	Secondary	12-14y	124 students	M: 71, F: 53	Diverse backgrounds based on income level and educational level
Bianchi et al.	2022	Framework	Europe	Higher				
European Commission	2022	Working document	Luxembourg					
European Commission	2022	Working document	Luxembourg					
Han et al.	2022	Case study research	USA	Secondary		3 teachers		
Lundahl	2022	Qualitative study	USA (Sierra Nevada mountains)	Secondary	Adolescents			
Purwanto et al.	2022	Qualitative study	Indonesia (Jakarta)	Secondary	16-17y	36 students	M: 14, F: 22	
Takkouch	2022	Mixed-method research study	Canada	Secondary	16-18y	23 students (urban)	M: 7, F: 16	
Zinkunegi-Goitia & Rekalde-Rodríguez (2022)	2022	Qualitative study	France	Higher				
Abdurrahman et al.	2023	Quantitative research	Indonesia	Secondary	16-17y	67 students		
Çakirlar-Altuntaş et al.	2023	Mixed-method research study	Turkey (Thrace)	Secondary		32 students	M: 16, F: 16	
Çiçek Şentürk & Selvi	2023	Mixed-method research study	Turkey southeast	Primary	10-11y	290 students		
Teegelbeckers, et al.	2023	Systematic Review						

Çevik et al.	2024	Mixed-method research study	Turkey (Anatolia)	Primary		23 teachers		
Rizki & Suprapto	2024	Quantitative study	Indonesia	Secondary	15-16y	74 students		

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