Content

Layman's Summary

As a Biology teacher in secondary school, I experience students' attitude towards nature on firsthand. When the students are shown different kinds of clothing brands, they recognize them immediately. But when I show them different kind of leaves from around, students struggle to name the tree they belong to. Students do not seem to find it interesting enough. It shows that many students have little knowledge of, and affinity with ecology.

Why would this be important?

Ecology is the study of relationships between living creatures – microbes, bacteria, fungi, plants and animals – and their environment. Ecosystems, living creatures in a certain environment, provide us with services that make life on earth possible. Think of providing resources such as water and food. Therefore, healthy ecosystems are responsible for the water we drink and the food we eat, the air we breathe and the places we visit to live a healthy life. When we are unaware of the relationships in an ecosystem, and the benefits they give, we act and make decisions that are harmful to them. That is the reason why it is important that we increase the knowledge on ecology.

Teachers play an important role in increasing ecological understanding, since they influence our future generations. However, today's courses still lack content to accomplish that. The aim of this review was therefore to present an overview of teaching strategies that improve ecological understanding in students. This overview can serve as a recommendation, or source of inspiration for teachers all over the world.

I selected relevant articles on teaching methods that improve ecological knowledge and analyzed them. The most mentioned strategy is going out there, use nature as a teacher instead of only learning from a textbook. It is also possible to increase ecological understanding by bringing nature closer to schools. Think of creating school gardens, or planting greenery inside and around the schools. These methods make connections between human and nature stronger, which eventually leads to a better understanding of nature. Strategies that use new technologies, like gaming, were also successful in improving knowledge of ecology. These methods have the power to entertain a student, and make it possible to visit a place that is too far, expensive or difficult to visit in real-life. Finally, many articles presented creative, new ways of teaching about ecology. Music, poetry and photography can bring across the message of nature. This makes it possible to teach ecology to a wide range of students.

When more strategies like these are used while teaching about nature, it results in knowledge, empathy and action that is needed to make our living on earth sustainable.

Raising "Earth Smart" Students: An Overview of Educational Approaches Increasing Ecologic Literacy in Students

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Abstract Today we are facing a great amount of sustainability challenges that are related to the global decrease of ecological knowledge, termed ecological literacy. The problems associated with the lack of knowledge can only be overcome by way of involving our future generations. New educational approaches are necessary to create communities that are in sync with the processes of nature for sustainable living. Therefore, the aim of this literature review was to present the state-of-the-art on stimulating ecoliteracy in schools. Relevant articles were systematically selected and analyzed, leaving 18 articles that proved several methods to be successful in increasing ecological literacy. They were summarized and presented in this report, providing current insights in stimulating ecological literacy in schools. This review first presents how natural and designed environments can increase ecological literacy by evoking engagement and motivation in students and teachers. Outdoor activities, like fieldtrips, were mostly represented in the analyzed literature. Limitations to visit real-life natural environments were mainly overcome by new technology strategies, proven effective through their immersive character. Lastly, other out-of-the-box strategies on increasing ecological literacy were described. They offer effective learning experiences that differ from traditional learning experiences. All strategies serve as inspiration for educators to broaden the horizon of environmental pedagogies and to increase ecological literacy in students: an important aspect of creating a sustainable society.

Keywords: ecological literacy, ecoliteracy, environmental education, place-based learning, serious games, mobile learning, multiliteracy.

I. Introduction

Climate change is one of the greatest and imminent challenges our earth is facing. According to the sixth assessment report of the Intergovernmental Panel on Climate Change (2022), atmospheric greenhouse gas levels have reached a historic high, largely due to human activities. This has caused our climate system to warm, having all sorts of adverse effects on the environment. Human-induced climate change causes serious adverse impacts on ecosystems, as well as the services they provide. If nothing changes, we will see more damages and losses to nature and humanity. Meanwhile, our population continues to grow, meaning we consume more finite resources every day (IPCC, 2022; World Bank Data, 2022).

Although it is clear that our behavior is causing environmental hazards to humanity, and that we need to change to create a sustainable world, we still take harmful decisions. How come we act in ways that worsen the environmental hazards we are challenging? Yes, our growing population and unsustainable use of resources are main aspects of the problem we need to solve, but in this review I focus on a more inconspicuous concern: the universal downturn of ecological knowledge. We lack understanding of, and affinity with the natural systems that we benefit from, disabling us to recognize basic ecological relations, leading to poor decision-making that endangers environments and the services they carry. Hence, the importance to improve ecological literacy (Middendorf, 2013).

Unfortunately, as stated by David Orr (1992), educational institutions are failing to improve this lack of ecological understanding. This problem is as accurate today as it was years ago. It is safe to say that we have generations of ecological illiterates. Today's courses are still lacking content that will increase ecological literacy. This urges new educational approaches, not based on the individual disciplines and sectors, but that consider the relations between them. Previous research describes strategies to enlarge the horizon of environmental pedagogies. Most articles point out that to further engage students, we have to think of learning and teaching strategies that are problem-based, action-oriented and involve collaboration. Easily said, the articles describe strategies that are relatable, interpretable and entertaining to students (Orr, 1992; Capra, 2007).

The aim of this review is therefore to describe the strategies in these articles and present the state-of-the- art: depicting current insights on stimulating ecoliteracy in schools.

As a high school Biology teacher, I feel I carry a great responsibility, considering education is the most influential tool to address the loss of ecoliteracy (Orr, 1992; Bell, 2012). Analysis of the literature will aid my own contribution in this matter and can be used as inspiration and recommendation for others. Increasing ecological knowledge and skill set seems like a simple step, but in the end it will contribute to the ability of decision making that sustains our life and environment on earth (Orr, 1992; Capra 2007).

Preview

Based on the aim of this study, key concepts were defined. Relevant articles were systematically selected[1] by using Web of Science (WOS) and Google Scholar. A broad search for ecological literacy and its synonyms in WOS defined 462.163 articles. Narrowing down by discarding some synonyms - now only searching for ecoliteracy and ecological literacy - resulted in 882 articles. Articles published longer than 4 years ago were removed from the list, since I wanted to analyze articles describing the latest insights on increasing ecological literacy. This left 464 articles. 85 articles met the search criteria after specifying that ecological literacy was to be searched as a whole instead of separate words. Finally, 'education' was added to the search query, resulting in 52 articles. The titles and abstract were scanned, whereafter literature that did not meet the objective of this review was removed from the list. 15 articles met all the criteria.

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[1] *An extensively detailed description of the methodology can be found in Appendix I – Methodology. This includes motivation for choices made regarding to databases and search strategy, the process of defining key concepts, and a list of final articles.*

These 15 articles could be divided into three different categories: increasing ecoliteracy though reconnecting with nature, through new technologies and by artistic or multiliteracy approaches. However, the number of articles was not distributed evenly across the themes. Therefore, articles from the overrepresented theme were scanned again. The most outdated and lowest in relevance were removed from the list. To find more articles regarding to the underrepresented themes, I searched for methods on increasing ecological literacy through technologies, and by multiliteracy approaches in Google Scholar. The most relevant and recent articles were added to the list. Now I was left with 18 articles, more evenly distributed across the different categories. They were read entirely and analyzed for methods that increase ecological literacy.

The next sections of this review list the strategies that were found, and reasons why they are so effective. Later on in, I deliberate which strategies I suggest to be used to broaden the horizon of ecological pedagogies. This can serve as inspiration or recommendation for educators all over the world.

Scope

Improving ecoliteracy can be challenged in all age groups. One is never too old to learn. However, human behavior is guided by beliefs, perspectives, attitudes and opportunities one has in life. These assets begin to develop from an early age, and susceptibility to change of behavior is stronger in younger age groups (Wellman & Gelman, 1992; Gopnik, Griffiths & Lucas, 2015). Therefore, articles targeting school students were selected and analyzed.

II. Background information

This section provides some essential background information on the origination and definition of the term ecological literacy.

David W. Orr, one of the leading voices of the environmental movement, argued in Ecological Literacy: Education and the Transition to a Postmodern World (1992) that most educational approaches fail to cover the interconnectedness between nature and humanity. Physicist Fritjof Capra and others later drew heavily on Orr's work, and further shaped the notion of ecoliteracy at the hand of the framework of systems thinking. Described in the Web of Life (Capra, 1996), living systems are non-linear and integrated in a network of relationships. To grasp the principles of ecology, one must think in terms of connectedness. Sustainable living is therefore a property of entire ecosystems, instead of single organisms or species. When systems thinking is applied the relationship between all inhabitant of earth and earth itself, core principles arise that describe the patterns of ways in which nature sustains life (Capra 2007; McBride, Brewer, Berkowitz & Borrie, 2013).

Shapers of ecoliteracy, including Orr and Capra, have informed the curricula of schools over the years. Additionally, Capra co-founded the Centre of Ecological Literacy (www.ecoliteracy.org) in Berkely (CA) in 1995, addressing education where students understand and experience how ecosystems sustain life.

III. Results

The 18 articles that have been analyzed can be classified in three categories: methods to increase ecological literacy of students through place-based strategies, technological approaches, and multiliteracy practices. The results section takes you through each category, providing a wide range of ways to increase ecoliteracy.

Place-based strategies to improve ecological literacy

Various articles point out that a sense of place is necessary to understand the principles of Biology. These studies stress the need for (1) children to sense they are being a part of something, and (2) a place-based educational approach that is based on increasing children's knowledge of ecology.

A. Outdoor activities

Häggström and Schmidt (2020) think outside the classroom, and view nature as a coteacher. A place can serve as the words we read in a book. Spatial and visual embodied 'words of the place' tells something to students, and means something to them. Students can also interact with the non-human world, in other ways then in a traditional classroom setting. Their study explores ways in which nature can teach students. The aim of the research was to find the possible connection between environment and ecological literacy, by observing 43 students and two teachers during fieldtrips in a forest. The students were asked to pick a tree and take a selfie with it, followed by presenting about the tree. They found that the forest engendered new ideas and expanded views. Novel and re-actualized knowledge about the plants was produced by the students in their reporter role. When conversing about their fieldtrip, they talk with as much enthusiasm as when they talk about the swimming pool, the pizzeria or the church. The activity sparked a meaning-making process through interaction with the forest and the children shaped and expressed their content knowledge about trees. This research clearly shows the value of place-based learning, where the forest became a learning space more activating than a classroom. It contributes to student agency, human-nonhuman interaction, outside-of-the-box thinking, and evokes emotion and interest.

Persson and Caiman (2022) found similar results in their study of ecological fieldwork in a nature guide course with students ages 17-18. The students were to develop their knowledge and understanding of ecosystems during several excursions. In one of them, they experienced the courtship rituals of the black grouse and the ecology of a marsh. They were first introduced with lessons about the ecology of the marsh around a campfire. At sunrise, they observed the courting of the grouse. This combination of teaching and real-life examples, seeing the lesson you just had happening right in front of you, results in interest and emotion becoming entangled with ecological facts.

Reconnecting with nature can not only increase ecoliteracy directly through students, but also impact teachers in such a way it increases the ecological literacy in the students they educate later on. Teachers that participated in an Adventure Learning workshop, were shown to undergo positive change in their attitude towards, and knowledge of nature. In one of the workshops about water quantity, teachers rafted down the local river, visited relevant sites and met stakeholders to talk about their perspectives on water resources. Later, all teachers reported that they had incorporated the experience in their education practices as a result of the workshop. They became aware of the importance of engaging students in local ecology projects, which can eventually lead to increased ecological literacy of students (Olsen, Miller, Eitel & Cohn, 2020).

All abovementioned studies show that places elsewhere than classrooms, can be important for new ways to increase ecoliteracy. Different places allow for other actions, thoughts, synergy, reflections and emotions, and thereby bring opportunities for agency and participation. When emotion and interest is triggered, it stimulates the meaning-making process that improves ecological literacy.

B. School Gardens

Numerous articles explored the potential of gardening for enhancing ecological literacy of students.

Wells, Hatley and Walsh (2021) investigated the effect of planting native species on improving botanical literacy in science students aged 18-27. Participating in hands-on activity of planting a pollinator garden on the campus of the University of North Carolina, resulted in engagement in, and valuation of the pollinator terrain. Orr (1992) has stated that these developments can improve ecological literacy. The activity of planting, combined with lessons on their ecological importance, caused a shift in attitudes among the students. Students considered the plants more important than before and indicated to be interested to continue planting in the future. Lastly, they were more familiar with the global decline of pollinators and felt more connected to nature. Two leading principles of ecological literacy.

A kitchen garden program proved to be successful in developing and increasing ecological literacy of children aged 9-11, by connecting them with nature. Recurrent visits to the garden raised a sense of ownership and familiarity. This affection aided the developments of perceptive observations on changes in the garden, empathy with nature and interest in the natural environment. The project consisted of students gardening, cooking and exploring in the kitchen garden, supervised by classroom teachers. The children gained significant plant knowledge, being able to name them, describe their uses and how they are related with their environment. This study illustrates that the multiple immersive activities used in this project, engage children with each other's perspectives and environmental concerns: increasingly moving towards ecoliteracy (Wallace, 2019).

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Another garden, but less familiar with the public, was investigated by Hammersten, Askerlund, Almers, Avery and Samuelsson (2018). They analyzed the development of ecoliteracy in a forest garden in Sweden. A forest garden is a food production and agroforestry system based on forest ecosystems. It is low maintenance and has a longer harvest season, enabling students to use them for a longer period of time. Through stimulation of innovative thinking, discussions, joy of exploration and play, children were found to have increased biological knowledge and ecological understanding. Activities included building a butterfly bed and insect hotel and creating a dry grassland to invite pollinators. Lunch was provided out of the forest garden itself and children were

given the opportunity to choose between recess or teacher-led activities like composting or observing bugs in the forest garden. The majority of children participated in the educational activities. Few students will choose learning out of a book above free time. This study showing change of this attitude towards learning, confirms the motivational aspect of school gardens. As proved by the other studies, this garden too, provides context and reason.

Abovementioned studies show that activities in gardens allow students to have hands-on experience. This provides motivation and context for learning, other than solely theoretical approaches do. We have seen three different uses of school gardening, providing different benefits to ecoliteracy in a wide range of age groups.

C. Bringing the green closer to home

We have seen strategies that connect humans to their surroundings to increase ecoliteracy. Another way for students to detect these relations is through their school building. Zangori and Cole (2019), assessed the contribution of green buildings to ecological literacy in the classroom. Two groups of students were placed in a green and non-green classroom over a period of an academic year. A green classroom is characterized by features such as native plants, biobased floor tiles, light colored (sun reflecting) roofs and pavement, recycling stations and solar panels. Student interviews, drawings and writings of the two groups showed different descriptions of the human-ecosystem connection. Students in formal classrooms typically hold the idea of humans using ecosystems solely for their own use, but do not acknowledge the deeper relation, while students in green classrooms had a better understanding of the connection between human and ecosystems. And to be ecoliterate, one must understand this connectivity fully. Combined with curriculum and engagement by teachers to further support their ideas, green features in school buildings could be used to demonstrate the links between humans and their environment.

An older study from 2012 showed the preferences of students for natural environments. Children were asked to take photographs of preferred scenes in a park and were later interviewed to explain themselves. The study suggests that students prefer natural environments over man-build landscapes. Elements as flowing water and trees scored high in the preference ranking. These findings can be helpful in designing green buildings and schoolyards. Increased attachment to nature sparks emotion and motivation, which enhances learning, which finally increases ecological literacy. Understanding the preferences of students therefore improves environmental education programs (Mahidin & Maulan, 2012).

Digital strategies to improve ecological literacy

The previous section describes the benefits of first-hand, outdoor experiences on learning about the environment. This section depicts another set of strategies found in literature. They could be used as an addition or alternative to previously mentioned methods - when going outside is too costly, time consuming or difficult. These innovative strategies are strongly connected with a modern and growing media driven audience.

A. Mobile learning

Phoebes, Rutledge and Sadler (2018) describe a way in which outdoor activities can be enhanced by technology. The authors created an interactive online botanical garden guide for the garden on a university campus. Visitors could access biological metadata by scanning tags on trees with their mobile equipment, engage in self-guided tours and receive information about the ecology of the individual species. This is an example of an easily accessible strategy that can be endorsed in current teaching strategies. It makes use of already existing local spaces, generally available tools (smart devices) and already researched data (plant databases). It still requires students to go out there, and reconnect with nature, but simple technological additions provide opportunities for enhancing ecological knowledge.

B. Game-based learning

Serious games are not solely for the purpose of entertainment but are designed to also improve knowledge or teaching new skills by means of gameplay. Madani, Pierce and Mirchi (2017) found that game-based learning improves soft skills like creative problem solving, teamwork and critical thinking, along with increasing memory, recognition and cognitive skills. They can therefore be a powerful tool to increase ecological literacy of students that live in the modern, digital world (Madani, Pierce & Mirchi, 2017; Fjællingsdal & Klöckner 2017).

A virtual environment with a narrative, quests and relatable characters are elements that draw an audience of players. Game developers have created serious games that incorporate the flow concept: the absolute immersion of a player in the gaming environment. Additionally, the information embedded in narratives is specifically designed to improve solving complex problems. By enabling communication via multiplayer games, forums, chats, digital worlds and video calling, players can experience cooperation. The avatar of a player must be designed to have positive environmental values, morals and beliefs. Even when the actual player differs in these views, forms of roleplay with such avatars have shown to influence real-life attitudes. By using graphics, realistic simulations, and interactive spaces, children are given the opportunity to experiment and see the immediate results of their actions. This gives the actor an increased sense of autonomy, and active participation in the environment. All these game elements contribute to a better learning process, resulting in an increased ecological literacy (Madani, Pierce & Mirchi, 2017; Fjællingsdal & Klöckner 2017).

Fjællingsdal & Klöckner (2017) found 25 environmental serious games that met the criteria previously described. Themes are not mutually exclusive and range from climate change to water regulation, ecosystem interactions, and many more. SeAdventure is an example of a serious game that was proven to be effective in enhancing ocean literacy. The knowledge gained by children was actually caused by them using the new technologies (Veronica & Calvano, 2020). Games like these could be readily used in teaching programs.
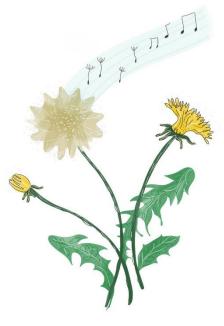
Analyzed literature has shown what qualities of serious games improve learning experiences and ecological literacy. The authors of these articles therefore advocate the use of serious gaming in teaching settings.

C. Different dimensions

Multiple articles point out how important it is for students to be able to immerse themselves into the environment during a learning process. Virtual Reality (VR) is frequently named in ecoliteracy literature. Ritter, Stone and Chambers (2019) developed the Virtual Reality Ecoliteracy Curriculum (VREC). This curriculum consists of environmental classes in an interactive virtual space. Virtual reality is a highly immersive technology that creates a simulated environment. Its effect was tested on middle school students that used it during their classes for a year. The results were overwhelmingly positive. It shows that learning in immersive virtual environments increases ecological literacy among students. When used in combination with the previously described technologies, VR can increase engagement and motivation. Two aspects very important in acquiring knowledge.

Multiliteracy strategies to improve ecological literacy

I found many articles that present multidisciplinary and creative possibilities in increasing ecological literacy. I realize there are more strategies, beyond the Biology classroom, that I gave a place in this section. Nevertheless, they are still applicable for a Biology teacher. Some articles are published years ago, but still describe the current insights on increasing ecoliteracy. When that was the case, I combined it with a similar article published more recently.

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A. Music

Several articles present their theories on the application of music in environmental teaching. Jorritsma (2021) found that music can be helpful in emphasizing the importance of place. This allows people to link their views on local music with environments. Through this connection of local places, music can play a role in improving ecological literacy. Additionally, organizing musical events such as soundwalks can work as attractors to get students outside and experience different places they normally would not visit. Combined with ecology courses, it can contribute to cultivating our emotional and imaginative responses to nature. Jorritsma states that the connections made through music are consistent with the principles of the Center for Ecoliteracy such as: "making the invisible visible", "embracing sustainability as a community practice".

Surprisingly, green themed hip-hop was found to be helpful as well (Cermak, 2012). A misconception around hip-hop is that it is always glorifying things as violence and drugs. However, this type of music can be used to stimulate learning in environmental education through its very empowering character. A study of 200 creative pieces collected over four years have convinced Cermak that green hip-hop lyrics improve ecological literacy. Rappers are often extremely passionate about the local place they live in, and the problems that occur in these places. Allowing them to write lyrics in their "slang" could reach an audience bigger than you can imagine. Because of this creative expression, many of Cermak's students became outspoken environmentalists.

B. Writing

Balgopal and Wallace (2009) tested whether ecoliteracy can be improved through writing activities. Students wrote three guided essays, which made use of their cognitive and behavioral domains. The students first read recent news articles concerning ecology. The essays, based on these articles, were examined and showed that the majority of students improved their ecoliteracy. The authors conclude that writing can be a successful instrument for improving ecological literacy of students. Writing forces students to be reflective and self-critical. Producing their own initial conceptions, thoughts and views can help students to gain knowledge and connect scientific ideas. The authors encourage all educators to incorporate more writing in their curricula.

Gilbert (2021) found that many poems address the connection between human and nature. Creative writing and reading can produce new modes of contemplating about the environment. Poetry writing, termed free writing, about the environment, enables a writer "to start creating an

ecological picture of their mind and world". It increases ecoliteracy by embracing many different conversations and views on ecology. The process of writing in a creative manner about the environment helps people to better explain and develop their knowledge. Regarding schools mostly use strictly guided writing assignments, it can be an addition to give students more freedom in writing: an aspect necessary for increasing ecological literacy through writing.

C. Images

Conservation photography is a relevant pedagogical enterprise. Farnsworth (2011) investigates the potential of photographs in environmental education. Photographs help to quantify impacts, image non-linear relationships in ecology, convey worldview and incorporate action. A picture can broaden the audience, engage multiple sectors of society, and enhance accessibility. A good photograph empowers the message that is depicted in a scene. It can address the pristine of nature and capture its complexity and totality. A picture made by an ecoliterate photographer communicates an ecological message. The author hopes these findings encourage teachers to incorporate photography projects and discussions around photos in their educational approaches.

IV. Discussion

Conclusions The results broadly summarize what existing literature found on educational approaches that increase ecological literacy. They sum up fun, adventurous, modern, creative and out-of-the box ideas that could enlarge the horizon of environmental pedagogies. It represents the state-of-the art: current insights in stimulating ecoliteracy in schools.

Reconnecting with nature, going out there, was represented the most in literature. This demonstrates how powerful this measure is. Considering the large amount of evidence there is on improving ecoliteracy though place-based learning, I suggest that wherever possible: bring the students out in nature. Plan fieldtrips that teach students the lessons that you initially wanted to teach out of a traditional book. The studies prove how much more effective this is.

However, as a teacher I understand there are often limits in time, program and budget. Fieldtrips and excursions are sometimes difficult to plan into the schedule. Studies presenting strategies on bringing nature closer to teaching institutes, present opportunities where connections with nature can be established without traveling too far. Think of school gardens, insect hotels, forest gardens, pollinator gardens, but also green buildings and classrooms. Additionally, creating opportunities where students can connect to nature in their free time or lunch breaks will continue increasing learning experience of the student, while saving a teacher's time.

While many articles stress to improve the connection with nature, articles on new technologies suggested that sitting behind a screen could increase ecological literacy as well. Although seemingly contradictive to the nature-based strategies, new technologies hold great opportunities through their alignment with interests of many students born in the digital age. Technologies also enable student to experience an environment, without actually being there. This overcomes spatial, time and in certain cases monetary boundaries. Technologies enables students to experience all sorts of environments all over the world. You could experience the ecosystem on an island far away, interacting with endemic species you will rarely or never see in real-life.

Disciplines not primarily related to Biology are also proven useful in increasing ecoliteracy. When comparing to traditional teaching approaches, these different and creative strategies result in other learning experiences than we are used to see. This means that increasing ecoliteracy does not necessarily rest solely on the shoulders of a Biology teacher. Increasing students' affinity towards, and knowledge of ecology could be "outsourced" to music teachers, language teachers, art teachers or physical education teachers. Of course, these creative approaches could be used by a Biology teacher, but this shows how educational horizons can be broadened and how we can think outside boxes (or certain classrooms). This complies to Capra's idea of cultivating competencies of mind, hands, and heart. Creativity such as music and art are powerful tools in evoking these competencies.

In my opinion, one must examine the area of a school, and determine what strategies fit the place and students best. It would be ideal to use a combination of the different methods in one educational setting, because this takes the needs of a wider range of students into account and thus increases the ecological literacy in many students.

Limitations and future research lines However, one can argue that there is no perfect recommendation, since ecological literacy is highly correlated with variables as gender, age, employment status, place of birth and lifestyles. In addition, most of the studies were small scale and documented ecoliteracy in geographically isolated areas, making it more difficult to be used in other environments. For this reason, methods for increasing ecoliteracy should be designed, finetuned or adapted to different public and environments. There is no recipe for the perfect approach. The findings in articles and the summary in this review should serve as sources of inspiration, encouraging creative-, out-of-the-box- and systems thinking. For instance, hip hop as a method of education is possibly more effective in urban areas then in rural areas. Rural areas might hold more potential for organizing educational fieldtrips, while urban areas could make more use of technologies to bring nature closer. Different circumstances sometimes ask for different approaches. This is the reason why I tried to describe strategies that are very different in method and cover multiple disciplines. They are applicable in a wide range of situations.

In the future, efforts could be made to focus on this adaptation to different areas. I found very few articles that examine successful strategies on enhancing ecoliteracy in more generic areas such as forests, dunes, or meadows in general. This is a potential focus for future research. The same goes for comparing the effectiveness of different strategies on increasing ecoliteracy. future studies could focus on creating an instrument that could be used consistently to measure ecoliteracy. Future studies should also examine a larger number of articles. During the process of this review, it was not possible to take more articles into account due to limited time. Additionally, this review showed that improvements of ecoliteracy can be found in unexpected places. Creatives thinking and more research is required to cover all disciplines holding potential. Many more fields of studies can be explored on potential of increasing the ecoliteracy of students. Lastly, the world is ever changing, and people are too. Fifty years ago, new technologies to increase ecoliteracy were nowhere in sight. Research on needs and interest of students should be constantly updated to redefine the state-of-the-art.

Final remarks Overall, the strategies described were proven successful in increasing ecological knowledge. This might seem like a small step towards a sustainable world. However, improved understanding of natural systems leads to decision-making and action that sustains environments and their services. I believe the methods described in this review followed the approach stated in Capra's phrase that describes the mission of the Centre of Ecology "Education for Sustainable Patterns of Living is intended to facilitate understanding of nature's principles, while fostering a deep respect for living nature through an experiential, participatory, and multidisciplinary approach." I hope educators from around the world can draw inspiration from the wide variety of methods on increasing ecoliteracy out there. I certainly have.

Reflection

A lot of the findings in the articles correspond to what I observe in my everyday working life. For instance, last year I undertook a series of dune excursions. Together with students aged 12-15, we cycled to the coastal area. We picked a sunny day in the weekend. I prepared a class about the local ecology and made a route that led us along vegetation I talked about. In this way, examples in the course could be experienced first-hand, right in front of them. I made sure I more or less knew which animals, plants and fungi lived in the area, and what their relationship with each other was. In this way, I could tell a story about their ecology when one of them surprised us on our route. We installed mini clip-on microscopes on our cellphones and looked at some plants up close. They could take pictures and short videos through the microscopes. During the break, which was free time, all kids went exploring with their microscope-phones. Afterwards, some of the student send me their microscope videos of which they were so proud. We spend some time walking on the beach and got ice cream afterwards. The students noted it felt like a fun weekend day, instead of a classroom course. They were overwhelmingly interested and asked me all the question that popped up in their head. They also came up with quite some ecological examples themselves and shared them with the group. Children that did not know each other before started bonding. Later, some of the children signed up for caring and maintaining our schoolyard garden (voluntary), and visit it every week up to this day. I did not really think about it at the moment, but now I have done this literature research, I see the value of those days. The fieldtrip supports the findings in this review, showing what impact outdoor experiences can have on engagement with nature.

It made me realize that there are so many opportunities, probably right in front of me, without me knowing of it. Therefore, I looked at the school I work at, and explored in what ways I could apply the methods described in this review. Sometimes you have to step out of your routine to search for new ways. I think that is something not often done by many teachers. They are busy and efficient, and easily slip into manners they are comfortable with. I hope more research on ecoliteracy, along with the existing knowledge, will make us think outside the box more often.

The school has a garden with insect hotels. Engage students by letting them plant and tidy up the garden + take classes outside when sunny.

We have a technical studio with green screen, video equipment, editing tools and VR glasses. Incorporate the glasses in one of the lessons and use a readily available serious game.

Our school is known as an artistic/theatre school. Numerous of musical project are organized. Make a music project about environment.

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Appendix I – Extensive methodology

Database

Based on the objective - describing the state-of-the-art of improving ecological literacy in schools - Google Scholar and the Web of Science (WOS) have been utilized in finding relevant and useful articles. I have chosen broad, multidisciplinary databases, since the objective covers multiple disciplines such as science and education. Also, I wanted to think outside the box and not only include the field of ecology and education, but also explore possible strategies that cover other fields of interest, such as art or technology.

Key concepts

First, I defined the key concepts and identified their synonyms and similar words using an online thesaurus. They are listed in the table below.

Increasing	Ecological literacy	Students	Teachers	Education	Popular Science
Improving Improvement Enhancing	Ecoliteracy Environmental literacy Ecological knowledge Environmental knowledge Ecosmart Ecosystem Services knowledge	Graduates Scholars	Educators	Teaching Learning Schooling Pedagogy	Teaching strategies Popular education Multiliteracy

Search strategy

To acquire articles that describe strategies to improve ecological literacy, I started off with WOS. Google Scholar gave too many results while using the same search terms, operators and data ranges. Relevant articles were initially selected by means of a systematic search strategy described in LibGuide and below.

First, I searched for ecological literacy and its mostly used synonyms. This broad exploration resulted in 462.163 articles. Thereafter, I discarded the term *environmental education,* considering the term was too broadly used in articles. This narrowing down left me with 882 articles. Since I am trying to define the state-of-the-art, the latest insights in educational methods to increase the ecological literacy, I chose to search for articles published in the last 4 years. Still 464 articles met these criteria. Since I wanted *ecological* and *literacy* explicitly used together, an operator ("") was used, leaving 85 articles. Finally, I added the search term *education* to the query, since the aim was to improve educational approaches. This resulted in 52 articles. The titles and abstracts were downloaded and scanned to identify articles of interest. Many merely described the theory of ecoliteracy, instead of exploring new strategies to improve it. Additionally, some articles were too small scaled, had limited citations or did not meet the objectives of this review. These articles were discarded, resulting in 15 articles left. They were fully read to explore the latest insights in stimulating ecological literacy.

Search terms, operators and data ranges are depicted below.

```
((ALL=(ecological  literacy))  OR  ALL=(ecoliteracy))  OR  ALL=(environmental
education) → 462.163

(ALL=(ecological literacy)) OR ALL=(ecoliteracy) → 882

(ALL=(ecological literacy)) OR ALL= (ecoliteracy) and 2022 or 2021 or 2020
or 2019 (Publication Years) → 464

(ALL=("ecological literacy")) OR ALL= (ecoliteracy) and 2022 or 2021 or 2020
or 2019 (Publication Years) → 85

((ALL=("ecological literacy")) OR ALL= (ecoliteracy)) AND ALL=(education) and
2022 or 2021 or 2020 or 2019 (Publication Years) → 52
```

Categories

I noticed that the strategies on increasing ecological literacy in the final articles were clustered in three certain themes: reconnection with nature, technology and artistic methods. Hence, the primary search strategy identified articles that present the main strategies for enhancing ecoliteracy. However, not all groups were evenly represented (8/3/4 articles, respectively). I therefore continued to search for more articles of the underrepresented categories (technologies and artistic methods), and discarded some of the overrepresented articles with the earliest dates of publication. At this moment, I changed from a systemic, to a snowball search strategy. Google Scholar was used to find more relevant articles on the underrepresented categories. Resulting in a better distribution of number of articles for each theme.

- Increasing ecoliteracy with new technologies
- Increasing ecoliteracy with artistic approaches

Finally, 18 articles were identified that describe educational methods to increase the ecological literacy in school. They are listed in Appendix II.

Appendix II – Articles reviewed

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