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Review

Teaching Methods in Biology Education and Sustainability Education Including Outdoor Education for Promoting Sustainability—A Literature Review

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Abstract: There are very few studies concerning the importance of teaching methods in biology education and environmental education including outdoor education for promoting sustainability at the levels of primary and secondary schools and pre-service teacher education. The material was selected using special keywords from biology and sustainable education in several scientific databases. The article provides an overview of 24 selected articles published in peer-reviewed scientific journals from 2006–2016. The data was analyzed using qualitative content analysis. Altogether, 16 journals were selected and 24 articles were analyzed in detail. The foci of the analyses were teaching methods, learning environments, knowledge and thinking skills, psychomotor skills, emotions and attitudes, and evaluation methods. Additionally, features of good methods were investigated and their implications for teaching were emphasized. In total, 22 different teaching methods were found to improve sustainability education in different ways. The most emphasized teaching methods were those in which students worked in groups and participated actively in learning processes. Research points toward the value of teaching methods that provide a good introduction and supportive guidelines and include active participation and interactivity.

Keywords: biology education; sustainability education; environmental education; education for sustainable development; outdoor education; primary schools; secondary schools; pre-service teacher education; literature review

1. Introduction

One of the international goals for the future is the construction of a sustainable society [1]. A sustainable society is considered to be a society that has reached sustainability through a process called sustainable development. Sustainable development as a concept is heavily context-dependent in social, cultural, and environmental situations [2]. Brundtland's report defines sustainability as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [3]. According to Diesendorf [4], this definition emphasizes the long-term aspect of the concept of sustainability and introduces the ethical principle of achieving equity between the present and future generations. It does not mention the natural environment explicitly, focusing only upon human needs or wants. However, the report makes it clear that these "needs" include the conservation of the natural environment. More recently, it has been given a broader definition which conveys that there are three principal dimensions: an ecological, economic and social one [5]. In the teaching and learning of sustainable development, the ecological dimension refers to the natural one and includes all living things, resources and life-supporting systems. Its goal is conservation. The economic dimension comprises jobs and income, and its goal is appropriate development. The social dimension involves people living together. Its goal is peace, equality and human rights. In addition to these three dimensions, there is also a fourth one, the political dimension. It has to do with politics, policy and decision-making as a goal of democracy [5]. The ecological issues are important in biology education, e.g., in Finland, Sweden and Denmark, they form the core content in the curricula of biology for basic education. All biology curricula emphasize different biotopes and ecosystems, lifecycles of plants and animals, and life-supporting processes, such as photosynthesis, respiration and biodiversity, but they do not mention the other dimensions of sustainability [6–8]. For this reason, we stress the ecological aspect in this study. Our aim is to find out and describe useful teaching methods in biology education and sustainability education (SE) including outdoor education (OE) for promoting sustainability in primary and secondary schools and teacher education. As far as we know, there are no previous studies from these perspectives.

An ongoing debate over the last three decades has been how the role of education should be conceptualized when creating sustainability and a sustainable future. Sustainability and a sustainable future are here understood as the goals of sustainable development. The relationships between environmental education, education for sustainable development, and sustainable development education have been discussed. Environmental education and education for sustainable development are interpreted in different ways around the world, according to context [9]. Some authors argue that education for sustainable development is a part of environmental education [10] or a perspective of environmental education [11], or that environmental education has developed into education for sustainable development [12]. In Agenda 21, it has been stated that environmental education is a continual, life-long learning process to raise public awareness and action globally, nationally and locally in every area in which humans impact the environment [13]. Important distinctions between the goals of environmental education were made by Lucas [14]—"in," "about" or "for" the environment—in order to avoid misunderstandings about the intended type of environmental education.

According to UNESCO [15], education for sustainable development is about enabling people to constructively and creatively address present and future global challenges and create more sustainable and resilient societies. Learning in education for sustainable development often includes only knowledge, values and theories related to sustainable development. However, it also means "learning to ask critical questions; learning to clarify one's own values; learning to envision more positive and sustainable futures; learning to think systematically; learning to respond through applied learning; and learning to explore the dialectic between tradition and innovation" [13]. Thus it offers learners a context for developing active citizenship and participation, embracing the complexity of the interdependencies of ecological, societal, and economic systems [16]. The overall goal of the UN Decade of Education for Sustainable Development (2005–2014) was to integrate the principles, values, and practices of sustainable development into all aspects of education and learning [17]. In Finland, sustainability is included in the curriculum for basic education at all educational levels. How this has been done is described in more detail in another article of this special issue [18].

Sustainable development education again is based particularly on environmental and ecological sciences and focuses on the interaction between ecological and social systems. It encourages students to critically reflect on the ideas of sustainable development and the values that underlie them, and to create solutions to achieve concrete goals in a variety of unpredictable situations [19].

As noted above, both environmental education, education for sustainable development, and sustainable development education share a vision of quality education and a society that lives in balance with Earth's carrying capacity. They are thus integrated and represented in all dimensions of sustainable development. In this study, we use the term sustainability education (SE) [20] because it catches all forms of environmental education, education for sustainable development, and sustainable development education.

2. Theoretical Background

Many of the topics in biology education are closely linked to the content of SE. These kinds of contents exist especially in the fields of ecology, biodiversity, conservation and system biology. According to Palmberg et al. [21], the ability to identify species is important for a better understanding of biodiversity and issues concerning the environment and sustainability, not only for comprehension of certain branches of biology (e.g., ecology, evolution, genetics). However, taxonomy is often a forgotten field in school curricula. Biological phenomena connected to socio-scientific issues, such as climate change, need to have an integrative and interdisciplinary approach to be thoroughly taught and learned. When biology education is given in connection to SE, teaching methods such as experiential, collaborative, process-based and problem-based experimental learning and computer-assisted methods can be useful.

2.1. Common Educational Principles Promoting Sustainability

To achieve the goals of SD, active teaching methods such as the process-based instruction, problem-based learning, and OE are recommended by several researchers [19,22,23]. Process-based instruction focuses upon developing students' independence in learning and problem solving by providing a framework into which curriculum activities can be placed [24]. In problem-based learning, students use "triggers" from a problem case or scenario to define their own learning objectives. Subsequently they do independent, self-directed study before returning to the group to discuss and refine their acquired knowledge [25]. Problem-based learning and experience-based learning in authentic environments are main ideas also in OE [22,26]. There is, however, no definitive description of authentic learning. Educators must make their own interpretations of what creates meaning for students in the classroom [27]. In this study, we do not take the term authentic environment to mean only environments outside the classroom; instead we take it to mean teaching strategies which make student experiences as authentic as possible compared to what happens in real life. In order to do so, the information to be studied and the environment in which learning takes place must be meaningful to the students. In addition, it also means that teachers should support the students to be reflective. Different learning environments and current and contextual tasks used in problem-based learning and OE support self-efficacy, autonomy, engagement, and meaningful learning as well as foster creativity and flexibility [28]. Collaborative learning can be supported e.g., by searching information [29] and producing knowledge in groups [30], by evaluating learning, action, and knowing together [31].

The ever-growing importance of complex problem solving and knowledge construction in modern society emphasizes the need for collaborative activities and settings in schools to foster learning and collective competencies [32]. Collaborative learning is seen as an active process resulting in jointly processed knowledge better than the knowledge produced by an individual (e.g., [33]). This is especially the case concerning environmental issues, which should be solved to support sustainable development. Recently, the collaborative and inquiry-based study approaches have been investigated in the computer-assisted study environments in science. Studies have indicated that inquiry-based learning can be applied to the context of computer-assisted collaborative learning and that collaborative technology facilitates high-level cognitive and social interaction while students work together toward deeper understanding (e.g., [34,35]). These skills are important when solving multifaceted environmental problems in order to work toward a more sustainable lifestyle.

2.2. Teaching Principles and Methods in Biology Promoting Sustainability

Biodiversity, climate change, the sustainable use of natural resources, health, cultural heritage, multiculturalism, and global welfare are important contents in the planning of a sustainable future. The effects of students' own behavior should be discussed and sustainable actions practiced in local surroundings. An important goal is to learn negotiation, problem solving and decision-making skills through discussions about ecological, social, economic, and ethical principles concerning local and global responsibility in their own life. Through memorable, experiential, and active processes, students learn to discuss their own value selection and to evaluate phenomena and sources of information critically [36–38].

In biology education, selected teaching methods should support learning biology, learning to do biological science and learning about biological science [39]. Several biological topics require approaches promoting experimental problem-solving and process-based skills [40,41]. The focus is on science investigation processes and the goal is to reach valuable learning results, and students therefore need crucial science content knowledge as well as autonomous learning [42]. This, however, seems to create difficulties for the so-called working memory, which again impairs the self-regulation competencies [43]. Therefore it is important to implement teaching methods including both autonomous learning and instructional activities, and to vary the level of openness of experimental tasks. The implementation of problem-based active learning models have positive effects on students' academic achievements and their attitudes to science courses [44], while implementation of problem-based learning and group investigation encourages students to think critically through planning, arguing, stating questions and problems, and providing solutions to environmental problems [45].

Biological field-based activities, e.g., fieldwork and field trips, provide students with authentic and interactive experiences and experiential learning opportunities, which increase students´ interest and enhance their learning [46]. Students´ engagement in field-based activities plays an essential role in learning biological issues. Fieldwork provides students with a chance to observe nature and the environment and to use scientific inquiry to test ideas and concepts they have learned in the classroom. According to Hart and Nolan [47], fieldwork had a positive effect on students´ knowledge, attitude and behavior, crucial factors also in promoting sustainability.

2.3. Teaching Principles and Methods in Sustainability Education Promoting Sustainability

According to the World Bank [48], "[t]he achievement of sustained and equitable development remains the greatest challenge facing the human race." Recently, the sustainable development goals represented a focus on the role of education in achieving a more humane world [49]: "education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship, and appreciation of cultural diversity and of culture's contribution to sustainable development." This requires an ecological or participatory worldview [50]. It is important to understand the interlinkages between the three pillars of sustainable development (economic growth, social development, and environmental protection) and the consequences of human choices. It means that people's ways of thinking should change toward more holistic, systemic and integrative modes [51].

Human societies and ecological systems are interconnected so that they are co-adaptive, reacting to each other and to previous interactions and reactions in a network of feedbacks [19]. Consequently, the approach of education must be complex, transdisciplinary, and broad [52]. However, current learning processes and practices are generally not aligned with this kind of education [53] (p. 21); [54].

The focus of SE is on the interaction between social and ecological systems requiring interdisciplinary thinking skills [21]. Practical problem-based learning develops this kind of understanding [52]. SE aims to foster students' ability to apply knowledge in a variety of unpredictable situations. Students are encouraged to critically reflect on the ideas of sustainable development and the values that underlie them, and create solutions to achieve concrete goals in their unique situation [21]. Typical for SE is that educators offer a wide range of conceptual and material content, illustrate interconnections and interdependence, and stress dynamic rather than fixed structures and processes [55]. Furthermore, hands-on experiences can be incorporated into the curricula [52]. OE is seen as an effective way of getting hands-on experiences because it integrates concrete experiences, interests, emotions, and values [56].

2.4. Outdoor Education and Meaning of the Place Promoting Sustainability

Fieldwork and field trips in biology involve many different goals, contents and learning environments [57–59] and therefore also vary in effectiveness and learning outcomes. A common feature, however, is that all activities are arranged in authentic, often natural environments, where students can connect their theoretical thinking with experiences of various kinds of real nature. Fieldwork and field trips are examples of outdoor learning, or its synonyms outdoor learning activities and outdoor activities [22,28]. In addition to outdoor activities, outdoor education includes overall interdisciplinary aspects of the world outside the school. It can be arranged, e.g., as adventure education, adventure/wilderness therapy, experiential education, outdoor leadership, outdoor environmental education, outdoor recreation or expeditions (e.g., [22,28,60]).

Developing a relationship with nature is an important precursor to understanding sustainability (e.g., [61,62]). This is why different approaches to outdoor education and outdoor learning (see overview in [26]), and especially fieldwork, field trips and nature studies, are important ways of improving ecological literacy [57,58], i.e., "understanding the key ecological systems using sound ecological thinking, and also understanding the nature of ecological science and its interface with society" [63]. Other important outcomes of outdoor learning are, e.g., connectedness to nature [64,65], positive environmental attitudes [66,67], and environmental consciousness [22,68]. Outdoor nature experiences then again are the most important factor connecting with interest in biology [69]. Several research results confirm significantly better learning results for students when they get first-hand experiences and studies in authentic learning environments, like farms [70] and natural environments [57,59,61,62].

3. Research Aim and Questions

An important question concerning biology education and SE including OE is how they can promote sustainability. As far as we know, there are no previous studies discussing this question based on comparison and evaluation of different teaching methods. The aim of this study is therefore to identify and describe useful teaching methods in biology education and SE including OE for promoting sustainability. The results are used for developing curricula and instructions of biology education in basic and teacher education.

The research is guided by the following research questions:

(1) What are the teaching methods used in biology education and SE including OE for achieving the sustainable development goals in primary and secondary schools and in teacher education?

To get answers to the first research question, we analyzed described teaching methods, objectives for the development of psychomotor skills, emotions and attitudes, knowledge and thinking skills to be learned, learning environments, and how achievements were evaluated.

(2) What are the features of the useful teaching methods in biology education and SE including OE for achieving sustainable development goals?

To get answers to the second research question, we analyzed features of useful teaching methods and what kind of implications there were for developing curricula and the teaching of biology.

4. Material

The material was selected applying the method presented by Àlvarez-Garcia et al. [71]. For a systematic review, we identified peer-reviewed journal articles using a consistent search strategy, established the criteria for the selection of articles to be considered, and analyzed them based on clear and precise criteria and dimensions [72].

The articles were searched using scientific databases such as ERIC, Web of Science, and SCOPUS. The search strategy was based on a systematical organization, categorization and selection of keywords related to biology education and SE. A word search was thus conducted in relation to the terms biology education, teaching methods, sustainable development, environmental education, education for sustainable development, outdoor education, fieldwork, excursions and study trips, problem-based learning, project-based learning, experimental learning, experiential learning, game-based learning, value-based learning, place-based learning, collaborative learning, computer-supportive learning, inquiry-based learning, and teacher training. All searches were done in English, Finnish, Swedish and German. Using these keywords, a common search strategy was developed for the various databases consulted, adapting it to the characteristics of the given platform. For each database, a hierarchical search strategy was applied, starting from the simplest expression (one term) to the most complex form (combinations of terms). Depending on the requirements of each database, the search fields were basically limited to the title and abstract of the articles. Also manual examinations of key research journals in biology education and SE including OE were used as well as reviews and bibliographies.

The following criteria were used to select material for the more detailed analyses of teaching methods:

(a) Scope: National and international research;
(b) Type of research: Empirical research on teaching methods in biology education and SE including OE;
(c) Period: 2006–July 2016;
(d) Target groups: students in primary schools, secondary schools and pre-service teacher education;
(e) Languages: Finnish, Swedish, English or German;

Although we are well aware of the existence of other types of documents that could have been analyzed, such as dissertation theses, research reports, books and book chapters and conference proceedings, we limited the review to academic papers published in peer-reviewed journals because they have been subjected to rigorous review and are, therefore, high-quality documents. We also eliminated articles that do not specifically refer to teaching methods in biology education or SE including OE.

(f) Quality: Academic papers published in peer-reviewed journals.

5. Methods

The study is a qualitative survey with quantitative features [73,74]. At first, we examined the selected 17 journals concerning biology education and SE. They included in total 29 articles that mentioned teaching methods. From these, we selected 16 journals with 24 articles to be analyzed in detail (Table 1).

Table 1. The selected journals and the analyzed articles.

The Selected Journals	The Analyzed Articles
Environmental Education Research	[75–77]
Eurasia Journal of Mathematics, Science & Technology Education	[78]
International Journal of Environmental and Science Education	[79]
International Journal of Science Education	[80–82]
International Research in Geographical and Environmental Education	[83]
Journal of Adventure Education & Outdoor Learning	[84]
Journal of Biological Education	[85]
Journal of Education for Sustainable Development	[86]
Journal of Environmental Education	[87]
Journal of Science Teacher Education	[88–92]
Journal of Sustainable Development	[93]
Journal of Sustainability Education	[94]
Journal of Teacher Education for Sustainability	[95]
Nordic Studies in Science Education	[96]
PLoS ONE	[97]
Sustainability—Open Access Journal	[98]

In the analysis, we followed the method of qualitative content analysis [99–102]. Inductive content analysis was used to analyze teaching methods, learning environments and features of useful teaching methods and implications [99,101]. Deductive content analysis was used to analyze psychomotor skills, emotions and attitudes, knowledge and thinking skills and also evaluation methods [99].

In order to ensure the reliability of the process, all three members of the research team first conducted the selection of information units, the categorization and the subsequent analysis independently. The analysis process was dialogical by nature. The final decisions were made through e-mail discussions where each researcher argued why the content of the article should be placed into a certain category or categories. The discussion continued until consensus was reached and clear arguments were found. The generalizability of our results relates to the selection of analyzed data. To ensure that our categorization decisions were based on comprehensive understanding of the article, we decided to read the whole article before categorizing it. We also based our analysis on what the authors of the articles had explicitly written rather than what we in some cases thought we could read between the lines as being the authors' intentions. As such decisions always include elements of subjective interpretation, joint discussions about each article were essential in deciding which aspects of the instructional process the article emphasized. This procedure ensured that decisions were not based on a single person's first impression of an article but on well-argued joint discussions. Because of the dialogical nature of the analysis, we did not see a need for calculating an inter-rater reliability. Researcher triangulation was an essential part of our analysis process. Our research group consisted of experts from biology education, environmental education, sustainable development education, and educational sciences, and all researchers are experienced teacher educators and researchers.

6. Findings and Discussion

There are many articles concerning studies and comparisons of teaching methods in relation to other issues in the studies of biology and sustainability education. Teaching methods can be seen as objective-oriented activities and flow of information between teachers and students. Studies of teaching methods are important because teaching methods influence all types of learning in the cognitive, affective and psychomotor domains [103,104]. The choice of teaching methods depends on what kind of teaching approach is preferred. Traditional instruction in biology is deductive and comprises the principles and methods used for instruction to be implemented by teachers to achieve the desired learning or memorization by students. In this kind of teacher-centered approach to learning, teachers are authorities and students' primary role is to passively receive information through lectures and direct instruction. Learning is measured using objectively scored tests and assessments [104,105]. Alternative teaching approaches are inductive where instruction begins e.g., with observations, experimental data to interpret or a real-world problem to be solved. In this student-centered approach to learning, teachers and students play an equally active role in the learning process. The teacher's primary role is to coach and facilitate student learning and overall comprehension of material. Learning is continuously measured using both formal and informal forms of assessment, including group projects, student portfolios, and class participation [104]. The selection of teaching methods is affected by the learning objectives. The clearly specified learning objectives also provide the goals at which the curriculum is aimed, they facilitate the selection and organization of content, and they make it possible to evaluate the outcomes of the learning [105]. Several good features are emphasized in the analyzed teaching methods and have implications especially for developing curricula and teaching for sustainability.

6.1. Teaching Methods

In total, 22 different teaching methods were found in the analyzed articles (Figure 1). The most common teaching method was students working in groups and participating actively in learning processes. Nowadays, this is also used in science education [44]. The most frequently mentioned teaching methods were outdoor education and fieldwork, experimental, interactive and experiential learning. Teachers' presentations and teaching discussions were also popular. They were used mostly when introducing students to the work and toward objectives.

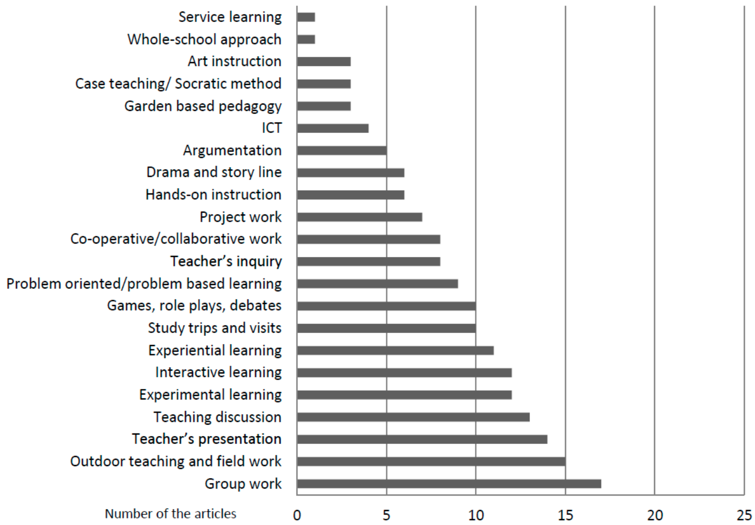

Figure 1. Teaching methods found in the analyzed articles.

Previous studies have shown that in active teaching-learning processes, retention of knowledge is significantly increased [106,107], there is enhanced motivation and higher-order learning [108] and development of practical skills [27]. Substantial evidence also exists that indicates that well-planned, taught, and guided outdoor teaching and fieldwork can have a positive impact on long-term memory due to memorable experiences. Residential experience can lead to individual growth and improvements in social skills. More importantly, there can be reinforcement between the affective and the cognitive domains. However, students are different: some of them like fieldwork and some do not. Poor fieldwork is likely to lead to poor learning. Some researchers also present a health warning concerning OE [27].

There are also barriers and opportunities for OE and fieldwork at schools and in teacher education. These include e.g., fear and concern about health and safety, teachers' lack of confidence in teaching outdoors, curriculum requirements limiting opportunities for outdoor learning, and shortage of time, resources and support. Research into students' experiences of outdoor learning activities suggests that there are several factors that can facilitate and/or impede learning in outdoor settings. These include the structure, duration and pedagogy of OE programs, the characteristics, interests and preferences of students, and the nature and novelty of the outdoor learning settings [28].

Problem-oriented/problem-based, co-operative/collaborative and argumentation as teaching methods were emphasized in more than one-fifth of the articles. These teaching methods are important in students learning processes and can enhance learning when they are used together and connected to information and communications technology. Collaboration supports students to make their own thinking visible [109,110] and helps them to learn from argumentation [111]. Argumentation has been shown to support higher-order and critical thinking, and engagement in science learning [112]. Higher-order and critical thinking is important to enhance understanding of socio-scientific issues connected to biology and sustainable development education. Collaborative reading within an argumentative discussion supports students to understand the text in more depth [113].

Whole-school approaches and service-learning approaches can be seen as part of place-based learning in local environments and communities through the use of local features, phenomena, and issues as context and scaffolding for content [114,115]. These were scarcely represented in the reviewed literature. However, they should be taken more into account also in biology education because they can generate a broader public interest and perhaps motivate local, state, and national policy makers to advocate for the integration of SE within the school curriculum [116]. They can also produce greater confidence, stronger motivation toward learning, and a greater sense of belonging and responsibility. In addition, through these, students can develop more positive relationships with each other, with their teachers and with the surrounding communities [28].

6.2. Objectives for the Development of Psychomotor Skills, Emotions and Attitudes

Learning in the psychomotor domain is associated with physical skills such as speed, dexterity, grace, the use of instruments, expressive movement, and the use of the body in dance or athletics. The psychomotor domain addresses skill development relating to manual tasks and physical movement as well as the operation of equipment, such as computers and laboratory tools [117,118]. Its subdomains are perception, set, guided response, mechanism, and complex overt reaction. Perception refers to the ability to apply sensory information to motor activity and set to the readiness to act [117,119]. Guided response comprises the ability to imitate a displayed behavior or to utilize trial and error [117]. Mechanism refers to the ability to use learned skills intendedly in different actions without supervision [117,119]. Complex overt reaction has to do with the ability to skillfully perform complex patterns of actions [117,119]. The three first subdomains were well represented in the articles (Figure 2) whereas the two last ones were not.

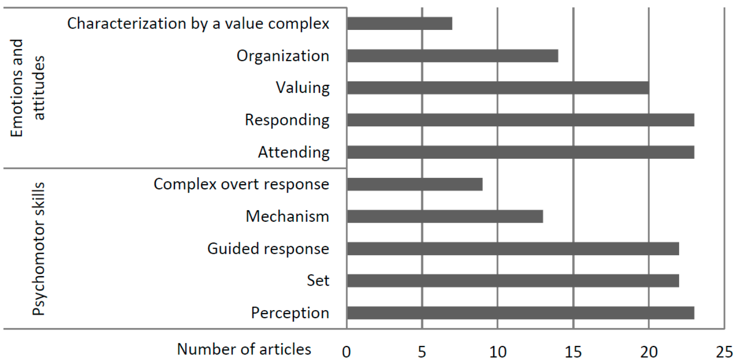

Figure 2. The objectives for the development of the psychomotor skills (categorized according to the model of [117,119]) and objectives for development of emotions and attitudes (categorized according to the model of [119,120]).

Kearney [121] defined affective learning as "an increasing internalization of positive attitudes toward the content or subject matter." Feelings, emotions, and attitudes belong to the affective domain which has five subdomains. The lowest subdomain has to do with attending or receiving. It includes the awareness of feelings and emotions as well as the ability to utilize selected attention. The next subdomain involves responding or reacting to phenomena, which means active participation of the student. The third subdomain has to do with the ability to see the value of something and to express it. The fourth subdomain, organization, includes the ability to prioritize values and to create a unique value system. The uppermost subdomain is characterization. It is the ability to internalize values and let them control one's behavior [119,120]. Rodriguez et al. [122] suggest affective learning subsumes student motivation and promotes greater learning because "affective learning motivates students to engage in task-relevant behaviors."

The three lower subdomains were well represented in the articles, but the upper ones were not taken into account as often. A deficiency concerns the pedagogies. It is easy to assert that the affective domain is important in science education. However, it is usually not clear what types of behavior should be looked for in students when their feelings, appreciations, attitudes, and values are evaluated. Compounding the difficulty is the general uncertainty about the definition or specification of the phenomena related to science education that we expect students to exhibit feelings and attitudes about [123]. Research shows that teachers are not familiar with student-centered teaching methods. They often think that students understand content knowledge of science subjects without any theoretical background or support given by a teacher [124]. Good quality learning demands that the teacher has knowledge and competency to plan and carry out meaningful instruction.

According to Kärnä et al. [123], having students work together in a carefully structured environment of cooperation and support can allow feelings to emerge and both cognitive and affective changes to begin [125]. Emotionally supportive environments can be fostered by creating a community of learners, providing helpful feedback, and creating opportunities for peer interactions that limit competition [126]. Although positive emotions such as enjoyment of learning, hope for success, and pride of a given task are commonly associated with positive learning outcomes, recent research indicates that this connection is much more complicated than initially proposed [127]. According to Kärnä et al. [123], Finnish pupils' attitudes toward biology correlated with different performance levels. Pupils' perceptions of their own competence had the highest correlation with successful performance in the assessment. Attitudes became even more positive with better grades in different natural sciences. Pupils with the poorest performance levels in a subject liked the subject the least and did not perceive it to be as useful as those of their peers who performed the best in the assessment. One reason can be that students with negative emotions such as anxiety, anger, and shame may learn less, because they are more likely to use poor processing skills such as memorization or rehearsal of content, and also more likely to withdraw from a class when faced with difficulties and failure [128].

6.3. Knowledge and Thinking Skills to Be Learned

According to Krathwohl [129] there are four kinds of knowledge: fact (factual) knowledge, concept (conceptual) knowledge, method (procedural) knowledge, and metacognitive knowledge. Factual knowledge includes basic elements (knowledge of terminology and knowledge of specific details) that students must know to be acquainted with a discipline or solve problems in it. Conceptual knowledge means interrelationships among basic elements within a larger framework that enable them to function together. It includes knowledge of classifications and categories, knowledge of principles and generalizations, and knowledge of theories, models, and structures. Procedural knowledge means understanding how to do something. It includes methods of inquiry, and criteria for using skills, algorithms, techniques, and methods, knowledge of subject-specific skills and algorithms, knowledge of subject-specific techniques and methods and knowledge of criteria for determining when to use appropriate procedures. Metacognitive knowledge means knowledge of cognition in general as well as awareness and knowledge of one's own cognition. It includes strategic knowledge, knowledge about cognitive tasks, including appropriate contextual and conditional knowledge, and self-knowledge. Of these types of knowledge, metacognitive knowledge was the least represented one in the reviewed articles (Figure 3).

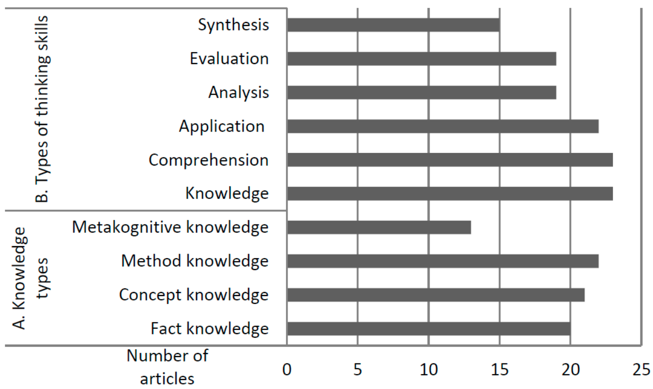

Figure 3. Types of knowledge (categorized according to the model of [129]) and types of thinking skills (categorized according to the model of [129,130]).

Types of thinking skills were analyzed using the hierarchy of the cognitive domain. Bloom [118] defined cognitive learning as dealing with "recall or recognition of knowledge and the development of intellectual abilities and skills." The cognitive domain comprises six subdomains concerning the development of our mental skills and the acquisition of knowledge. The subdomain of knowledge has to do with the ability to recall data and/or information. Comprehension means the ability to understand the meaning of what is known and to demonstrate understanding by describing, paraphrasing, etc. The subdomain of application is the ability to utilize an abstraction or to use knowledge in a new situation. Analysis involves the ability to differentiate facts and opinions and to break down a problem into its constituent parts. The subdomain of synthesis means the ability to integrate different elements or concepts in order to form a sound pattern or structure so that new meaning can be established. The uppermost subdomain, evaluation, includes the ability to make judgments about the importance of concepts [118,129,130]. In dealing with the cognitive domain, it is relatively easy to specify desired types of student behavior and the phenomena on which they impinge, i.e., the subject-matter content of science instruction. Teachers and researchers are also used to specifying the types of behavior desired of the student in acquiring and using science content [123].

The subdomains of knowledge, comprehension, and application were well represented in the articles, as well as those of analysis and evaluation (Figure 3). Synthesis was taken into account the least. It requires creativity: putting elements together to form a coherent or functional whole, reorganizing elements into new patterns or structures through generating, planning, or producing. It involves the generating of new ideas, products, or ways of viewing things. It is considered the most complex form of thinking [118]. Studies analyzing classroom tests have found that most teacher-made tests require only recall of information [122]. However, when teachers are asked how often they assess application, reasoning, and higher-order thinking, both elementary [37,131] and secondary [38] teachers claim that they assess these cognitive levels quite often. The reason that recall-level test questions are so prevalent is that they are the easiest kind to create. They are also the easiest kind of questions to ask spontaneously in the classroom.

6.4. Learning Environments

Since learning environments have been developed to support the selected teaching methods, they both have an effect on learners' achievements. The most often used learning environment were classrooms, which were mentioned in 22 out of 24 articles. Introductions, guidelines, and discussions concerning learning experiences and results of observations and experiments were often carried out in the classrooms, in addition to traditional teacher presentations and inquiries. Outdoor and field environments were mentioned in 14 articles. Different visiting places, such as museums, gardens, and nature parks, were the third most common learning environments (mentioned in 11 articles). Such places appear to be good learning environments because students' learning results are significantly better when they get first-hand experiences and studies in authentic learning environments [57,59,62,70]. One reason can be that emotionally supportive learning environments engage students in adaptive learning strategies such as elaboration, organization, and critical thinking [114].

Laboratory environments were found in only five articles, although laboratories are places where students can meet real scientists and learn how research is done. In school laboratories, students can develop their experimentation skills when planning and carrying out small studies. The internet and electronic discussion forums were mentioned in two articles. Computer-assisted teaching-learning processes offer a useful way for cognitive process-oriented instruction, during which the teacher's role is to activate students' mental activities and to support self-regulatory strategies for learning [130,132].

6.5. Evaluation Methods

Evaluation methods were analyzed using a common categorization of the teaching and learning evaluation types [119,133]. Summative and diagnostic evaluations were the most popular methods (found in 18 and 17 articles, respectively). Formative evaluation was used only in 10 articles. Comprehensive evaluation is an important part of teaching and learning processes, and summative assessment should be complemented by formative and diagnostic assessment. The prevailing evaluation culture should develop from a measuring culture to a development and supporting culture [121,134,135]. Evaluation comprises values and beliefs, which affect conceptions of evaluation goals and aims that guide evaluation practices [136]. Instead of teacher-centered evaluation, more such methods where students can learn actively should be used [135,137,138].

6.6. Features of Useful Teaching Methods and Implications

The most emphasized feature of useful teaching methods was the activity, participation, and interactivity of the students (Figure 4).

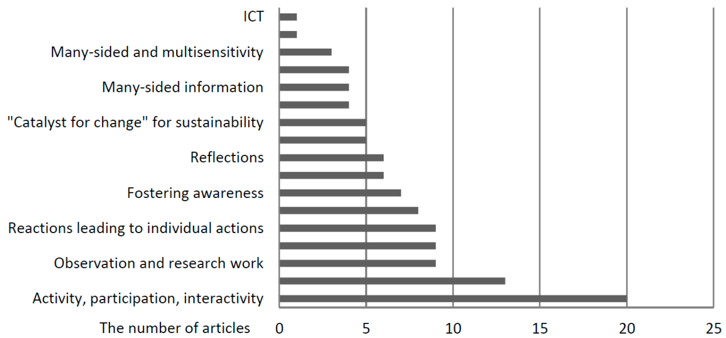

Figure 4. The features of useful teaching methods.

The review gives a clear endorsement for the provision of a certain kind of biology education approach. This research emphasizes the value of teaching methods which have a good introduction and supportive guidelines and include active participation and interactivity (Figure 5). The results support Rickinson's research [26]. First-hand experiences, locality and place-based education, and OE are also emphasized. Conversely, systematic teaching of sustainable development, teachers as role models, continuing development of EESD (Environmental Education for Sustainable Development), positive feedback, and whole-school approaches were not popular (mentioned only twice). Moreover, neither continuous teacher and staff education nor differentiation were popular, having been mentioned only in one article together with the ideas that SE should be taken into account at all education levels, and that there should be enough time for SE. The reason could be similar to those that Rickinson reported in his study, e.g., that the aims of SE are not always realized in practice, the different types of barriers faced by individual students and teachers in learning and teaching SE, and familiarity with the SE setting [26].

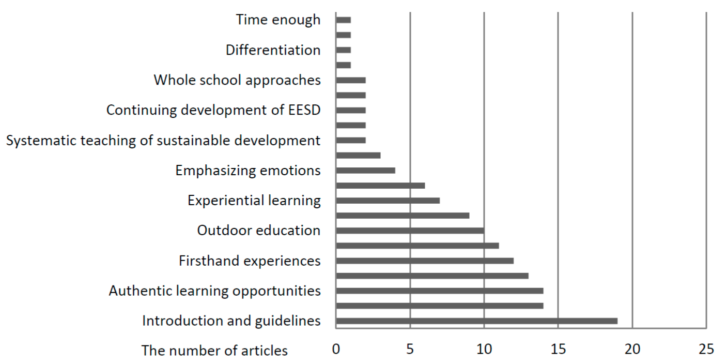

Figure 5. Implications concerning the analyzed teaching methods (EESD = Environmental Education for Sustainable Development).

7. Main Conclusions and Implications

The study aimed to identify and describe useful teaching methods in biology education and sustainability education (SE) including outdoor education (OE) for promoting sustainability. Although our analyses of recent research on teaching methods and their evaluation included several details, a holistic view of the educational processes is needed for the understanding of all effects. All teaching methods are, of course, context- and subject-dependent, and cannot therefore be arranged as a list of the most or least effective methods. The analyses, however, provide ideas of how to use these methods together for promoting sustainability aspects in teaching, and also of how to evaluate the whole process for the purpose of curricula development. The study emphasizes especially the value of inductive teaching methods with student-centered approaches in authentic environments with first-hand experiences. Like previous research [44,46,47], the analyses also emphasized fieldwork and field trips, including problem-based activities, as factors increasing students' interest in and knowledge of sustainability. Fieldwork appeared to have positive effects also on students' attitudes and behavior concerning sustainability [66,67]. Students' relationships with and connectedness to nature [64–66], environmental consciousness [23,59,68], and interest in biology [69] are all important factors in any attempt to create a sustainable future [57,58,61,62].

An issue to be taken more into account is the whole-school approach. According to Wyn et al. [49], it can bring benefits to school communities, enhancing the development of school environments where students feel safe, have a sense of belonging and develop the skills needed to participate fully. The results of the analyses also emphasized a great need for several comparative studies of teaching methods and their careful evaluations in relation to the expected results.

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