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Teaching Methods in Biology Promoting Biodiversity Education

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Abstract: The aim of this qualitative survey was to investigate what kind of teaching methods have been used in biology to promote biodiversity education (BDE) and how the methods support biodiversity (BD) learning. We found, in total, 317 international scientific articles published since 2000 which described the teaching methods regarding BDE and the teaching, and/or the learning. From these ones 12 articles specifically addressed the teaching methods of BD. The content of these articles was analysed in detail. The detailed analysis was based on (a) the categories of the teaching methods used, (b) the conception of learning in the Finnish National Core Curricula for Secondary schools and (c) the revised Bloom's taxonomy and Stanny's verbs concerning the levels of taxonomy. The most used teaching methods were hands-on instruction, experiential learning, and teacher presentation. The least used ones were games, roleplay, debates, service learning, study trips, and visits. In all the articles, various teaching methods used during the lessons were described. The items concerning the teaching methods, which supported students learning were active participation and interaction—mentioned in all the articles—followed by observation, experimental work, experiential learning, and techniques for increasing environmental awareness. The understanding of the different perspectives of BD and the development of self-evaluation were addressed in only four and two of the articles, respectively. The four types of knowledge were supported by the used teaching methods in nine articles jointly. The lower levels of thinking skills were well-supported by the used teaching methods. The highest level of thinking skills, such as synthesis and evaluation, received the least amount of attention.

Keywords: biodiversity; Bloom's taxonomy; level of knowledge; teaching methods; thinking skills

1. Introduction

The aim of our study is to investigate the current teaching methods in biology that promote biodiversity education (BDE) and how they support biodiversity (BD) learning. In this study, the teaching methods cover various methods of teaching biology and items (subordinate to teaching methods) include the skills which support students' learning. For example, Barney, Mintzes, and Yen [1] emphasize that teaching diversity within species is crucial when raising public awareness of the significance of nature conservation. BD has been discussed in terms of three essential aspects: species, genes, and ecosystems [2]. Currently, however, it has been proposed that, in addition to these three aspects, BD also includes human cultural diversity [3]. BD emphasizes the interrelated nature of the living world that is changing constantly through evolution, therefore, the role played by humanity in the interrelation is significant.

The most fundamental needs and requirements of human society are supported by BD. Essential services provided to the society include material goods, such as medicines, food, and fibres, as well as various services required to underpin ecological functions, such as flood control, climate regulation, nutrient cycling, maintaining hydrological cycles, cleaning water and air, soil formation and soil storage [4], pollination and pest control, carbon sequestration and storage [5]. All of these are interwoven with cultural, social, aesthetic, and ethical values [6], as well as emotional and recreational nature experiences [7,8]. Consequently, BD is one of the major pathways to sustainability [9] and, according to Dikmenli [10], the protection of BD is defined as one of the basic roads to it.

There is a decreasing trend in BD due to human actions on this planet [11,12]. BD is threatened by various human activities or their effects: human-induced changes in land cover that decrease and fragment the habitats of various species, invasive alien species, pollution, overuse of natural resources and climate change, as well as a range of socio-scientific factors [13,14]. All these issues have led to an increasing awareness of the importance of preserving BD not only for the well-being of humans [4,13] but also for moral reasons to preserve it for its own sake [13]. At the same time, the knowledge of species and the interest in identifying species in their ecological context have significantly declined worldwide [15–20].

Many researchers state that knowledge of species, an interest in nature and experiences with it are the factors that best promote an understanding of BD, environmental issues, and a sustainable lifestyle [21–26]. However, as far as we know, no previous studies discussing the teaching methods in relation to the factors supporting BD learning and understanding, have been published until now.

2. Theoretical Framework

2.1. The Concept of BD: A Definition

In the most simplified terms, BD is defined as the genetic, species, and ecosystem diversity [27]. This definition also agrees with the formal statement of the Convention on Biological Diversity in 1992 [2], where BD was defined as 'the variability among living organisms from all sources including inter alia, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part of: this includes diversity within species, between species and of ecosystems. "Biological resources" includes genetic resources, organisms or parts thereof, populations, or any other biotic component of ecosystems with an actual or potential use or value for humanity'. Since the Convention on Biological Diversity was adopted at the Rio 'Earth Summit' in 1992, BD has been discussed regarding three essential aspects: species, genes, and ecosystems. Species diversity refers to the variety of species within a region, and genetic diversity refers to the variation of genes within species [2]. Ecosystem diversity relates to the variety of habitats, biotic communities, ecological processes and the diversity within ecosystems. An ecosystem is defined as 'a dynamic complex of plant, animal, and micro-organism communities and their non-living environment interacting as a functional unit' [2]. Examples of ecosystems are forests, grasslands and rivers.

In a broad sense, BD means a diversity of living organisms in terms of genomes, individuals, species (species diversity), populations, different ecotypes (a form or race of a species occupying a particular habitat), subspecies, communities, ecosystems, different reactions of a community as a whole to the environment, and biomes [11,13,28]. There is now a consensus within the scientific community that BD has a fundamental role to play in ecosystem functioning and in underpinning essential processes, such as resource capture, biomass production, and nutrient recycling [29].

Biodiversity emphasizes the interrelated nature of the living world that is changing constantly through evolution. It is of value for cultural and recreational purposes. Especially in the past two decades, the conservation perspective has been presented, as well as the demand to take into account the landscape. Without the continuity of a landscape, animals are not able to reach areas they normally do, for example. The continuity of the landscape can be destroyed by man. Further, a variety of

ecological, economic, ethical, spiritual, and cultural values are related to BD and its conservation [30]. All these aspects are important parameters of sustainability when reflecting the interaction of ecological, economic, and social issues.

The understanding of inter-ecosystem interactions is still evolving. Greater understanding of what people know about the species that they live alongside or exploit is important to gain access to the knowledge base that results in positive drivers for conservation [31]. Additionally, understanding the negative aspects of perceptions due to incomplete knowledge or understanding, which results in the intensification of conflict paradigms and, potentially, local extinctions, is important [32]. Possessing at least basic animal and plant identification skills is often emphasized as a prerequisite for understanding and appreciating BD because species is the fundamental unit of BD [20,25]. Consequently, research efforts have been made to explore the public's understanding of the multidimensional concept of BD. The study of Lindemann-Matthies [33] has shown that environmentally bound BD, as part of sustainable development, is undefined and is not even a well-known concept among children. Other studies have also confirmed that the BD concept is not always understood, or it is understood incorrectly among students and teachers [9,10,26,34].

Social meanings of the BD concept are important and connected in biosphere reserves [35]. The study by Cerda and others found that the term BD encompasses a spectrum of concepts from the purely ecological to the more anthropocentric. Respondents appealed to generic points of view (e.g., plants and animals without specifying the species and life reservoir) and many had holistic views when expressing concepts related to BD. Concepts such as ecological complexity were mentioned less frequently.

2.2. Knowledge, Attitudes, and Values Concerning BD

The public's understanding of BD seems to have declined significantly during the past few decades [10,36,37]. The layperson's definition and understanding of BD is not based on scientific knowledge [38], but derived from their daily practice and experiences, as well as their emotions and knowledge of their surroundings [39]. Additionally, students and teachers do not understand what BD means and what it includes [9,10,15,40]. Most student teachers understand the basic concepts of species diversity and ecosystem diversity, but many of them did not know the concept of genetic diversity at all. Moreover, many of the student teachers do not understand that the actions of human beings lead to BD loss [10].

Perceptions of the environment are reflected in attitudes and in individual or collective behaviours. Among others, Smith and Mackie [41] consider attitudes as learned and, therefore, changeable. Perceptions of nature are structured by experiences, cultural norms, and values [42,43]. Dunlap and Van Liere [44] found that those who expressed less concern about the environment tended to exhibit anthropocentric values, and those more concerned about environmental quality tended to exhibit biocentric values (that the non-human world has an inherent value). However, biocentric values, by being indifferent to the preferences and needs of most people, convince few to follow them [45]. Thus, a biocultural perspective has been suggested as a 'middle way'. It incorporates not only the materialistic benefit of nature but also the benefits derived from people's inclination to value nature for its aesthetic, emotional, moral, and other qualities, as described in the concept of 'biophilia' [43,45]. This means that the values concerning ethical relations with nature are bounded by the biological requirements of the human species, but particularly influenced by culture, learning, and an individual's experience [45].

The close relationship between environmental attitudes and awareness is seen as being due to education [37,46]. BD is, however, a complex scientific concept and difficult to teach in schools. The interdisciplinarity of environmental issues can present disagreements concerning subject content and values, and conflicting interests can cause differences of opinion and emotional reactions. A student's attitudes affect how credible she/he thinks issues to be studied are. Suspicious or passive attitudes concerning environmental studies prevent the development of scientific and critical thinking

skills [47]. The biological topics that commonly arose in the study concerning the opinion of the Finnish student teachers were species identification, species knowledge, and understanding the functions of nature and ecosystems [48]. The ongoing education of the people should promote awareness, knowledge transfer, and the acquisition of a sense of values, behaviours, and skills necessary for the preservation of the environment [49].

2.3. Knowledge and Understanding of BD in Respect to Species Identification and Sustainability

The most fundamental issue for understanding BD is species knowledge and species identification, such as their alterations, extinction, ecology, and ecosystem issues. According to Lindemann-Matthies [50], species knowledge and identification are important not only in evolutionary biology, ecology, and genetics but also in everyday life, for example, to recognize poisonous plants and animals or harmful invasive species, it is essential to know in what kind of places plants and animals live, breed, and grow and what their relation is to the living environment. Moreover, Orr [51] and Puk and Stibbards [52] emphasized another important aspect that needs to be developed in peoples' knowledge of the environment as it relates to plants and animals: material cycling and energy flow.

The preservation of BD forms the core of sustainability [9]. Thus, the protection of BD is a prerequisite for sustainable development [10]. In understanding the role and meaning of BD from the perspective of sustainability, systems thinking is important. 'Systems thinking' is an acknowledgement that 'everything affects everything else in the natural world' [53]. However, systems thinking as an educational teaching method is conspicuously absent in teacher education [54]. There are several reports of teacher education programmes that totally lack or contain very few sustainability subjects [55–57]. Dikmenli [10] found problems concerning student teachers' understanding of what the sustainability of BD means. Palmberg and others [54] showed in their study that the majority of the Nordic student teachers did not understand how species, species identification, and BD are connected to sustainability.

2.4. BDE and Teaching Methods in Connection with Species Identification and Sustainability

Education plays a crucial role in the relationship between peoples' environmental awareness and their attitudes [37,46], as well as their knowledge about organisms and the development of their attitudes and behaviours towards them [20,58,59]. Therefore, it is worrying that studies from different countries such as Finland, Germany, and Sweden [18,60–62] indicate that people do not often notice plants and cannot identify species. For example, Yli-Panula and Matikainen [63] show in their study that students and student teachers have a poor knowledge of invertebrates. BDE is also hampered by the fact that the BD concept is abstract and diverse and, therefore, difficult to understand [20]. Students can only understand that it means species diversity and that BD loss is only caused by ecological factors, although other forms of BD and other aspects of sustainable development (economic, social, and ethical ones) also have effects on sustainability [64]. In addition, due to the interdisciplinarity of environmental issues, disagreements concerning subject content and values and conflicts of interest can cause differences of opinion and emotional reactions. A student's attitudes also affect how credible she/he thinks the issues to be studied are [47]. Bebbington [15] and Palmberg [61] have shown that some students think that naming organisms is not important, and they have little interest in learning identification skills.

In biology education, selected teaching methods should support learning biology, learning to do biological science, and learning about biological science [65]. This means understanding interrelations of a system's constituent parts and how the system works and also understanding the concept sustainability [66,67]. Internationally, sustainability is emphasized often as an essential aim of education. Sustainability education for its part is characterized by a holistic approach when it comes to content and a pluralistic approach when it comes to teaching [68]. Biodiversity education, in turn, can be seen as an important part of sustainability education while sustainability education is one instrument among others (e.g., technical innovations and restrictions by law) for achieving a sustainable

future [61]. Helldén and Helldén [69] stated that the direct experience of BD in early childhood is important for developing the understanding of this complex topic later on. Students need regular contact with the natural environment in a school context, especially those children who do not have access to nature as part of their everyday lives [70]. According to Kellert [71], distinguishing children's direct, indirect and symbolic experience of natural systems and processes forms a logical starting point in considering the childhood development of attitudes towards nature.

Experiential learning outdoors was suggested by the majority of Nordic–Baltic student teachers as the most efficient learning for species identification. They also stressed BDE teaching methods that include experiential learning indoors, project work and experimental learning [26]. Species identification is very important for citizens today and for sustainable development. Palmberg and others [26] recommended that teaching and learning methods for the identification and knowledge of species and sustainability should always include experiential and project-based teaching and learning methods in authentic environments. This idea is supported by new research conducted by White [72]. White shows that active participation in bird feeding and monitoring in an urban school-based environmental education project seemed to improve children's awareness, environmental knowledge (i.e., species identification), and attitudes towards local wildlife.

3. Research Aim and Questions

The fundamental question regarding education in general and in biology is how it can aid BDE in supporting the sustainability of BD. To the best of our knowledge, there are no previous studies evaluating, comparing, and discussing what are the teaching methods which promote BDE and how they support BD learning. Because of its extensiveness, BD is a challenging issue to teach; therefore, teaching and learning methods supporting BD learning should be studied.

This study is based on the following research questions:

(1) What are the educational levels (P = primary school, S = secondary school, U = university) which were presented in the analysed articles (n = 12) in connection with the teaching methods in BDE?

We ran an analysis to determine the ideas concerning useful teaching methods for the development of BDE at different educational levels.

(2) What are the aspects of BD that are taught using different kinds of teaching and learning methods?

To get answers to the second research question, we analysed the described aspects (species, genetic, and ecosystems diversity) of BD.

(3) What kind of items concerning the teaching methods are included to support BD learning?

To get answers to the third research question, we analysed the teaching methods and their objectives for promoting BD learning.

(4) What are the levels of the knowledge taught in biology concerning BD?

To get answers to the fourth research question, we analysed the levels of the knowledge concerning BD [73].

(5) What are the objectives for the thinking skills that promote BDE in regard to the teaching methods?

To get answers to the fifth research question, we analysed the levels of thinking skills using Bloom's extended taxonomy [73–75].

The results are used for developing the curricula and in the instruction of biology education in school and teacher education.

4. Materials and Methods

4.1. Selection of the Articles

In this qualitative survey that integrates quantitative items, we first found 317 international academic articles mentioning BD teaching, BD learning, BDE, or sustainable development education

and BD. However, only 18 articles concerned biology education and teaching methods. When we examined these articles more carefully, we found that six articles described teaching and learning BD only at a general level and therefore they were not taken into account in the final analysis. So, twelve articles were selected for the final detailed analysis on the basis that they specifically addressed the teaching methods of BD (Appendix A).

The material was selected by applying the method presented by Àlvarez-Garcia and others [55]. 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 analysed them based on clear and precise criteria and aspects [76]. The articles for the analysis were sourced from scientific databases such as ERIC, Science Direct, and Education Database. The search strategy was based on a systematical organization, categorization, and selection of keywords related to biology education. A word search was conducted in relation to the terms biodiversity, biodiversity education, biodiversity teaching, teaching biodiversity, teach biodiversity, teaching methods, learning biodiversity, learn biodiversity, digital, mobile technology, mobile application, GIS (geographic information system), ICT (information and communication technology), genetic biodiversity, and environmental education. 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 using Boolean operations). Depending on the requirements of each database, the search fields were basically limited to the title and abstract of the articles. Additionally, manual examinations of key research journals in biology education were performed. All searches were done in English.

When selecting material for the analyses of teaching methods, the following criteria were used:

(a) Scope: national and international research;
(b) Type of research: empirical research on teaching methods in biology education;
(c) Type of research: empirical research on teaching that gives concrete support to the development of curricula and teaching;
(d) Period: 2000–2017;
(e) Target groups: students in primary schools, secondary schools, and students in university biology courses;
(f) Language: English;
(g) Quality: academic papers published in peer-reviewed journals.

Although we are well aware of the existence of other types of documents that could have been analysed, such as dissertations, theses, research reports, books, book chapters, and conference proceedings, we limited the review to academic papers published in peer-reviewed journals. We also eliminated articles that did not specifically refer to teaching methods in biology education. The selected journals supported teaching and learning processes and the development of biology curricula.

4.2. Analysing Methods

The different aspects of BD taught to the students were subjected deductively to a theory-based content analysis [77] and then classified into three different categories: species diversity, genetic diversity and ecosystems diversity. A deductive content analysis was used to analyse the objectives of the items concerning the teaching methods and the levels of the thinking skills [78].

Three predefined measuring instruments were used when analysing BD teaching methods described in the articles. They were created by two research articles and were individually based on a table of teaching methods presented by Palmberg [79]. In the rare case of conflicting determinant factors, it was discussed and decided that the found determinant factor would remain valid as there were only two analysts, and so the deletion of the controversial point would have been as unreliable as adding it. The measuring instruments used in the analysis were (1) different kinds of teaching methods,

(2) items concerning the teaching methods that promote BD learning and (3) Bloom's taxonomy levels of knowledge and thinking skills that the presented teaching method aims to achieve.

Measurement instrument 1 included the following types of teaching methods:

- teacher's presentation
- teacher's inquiry
- teaching discussion
- group work
- games, roleplays or debates
- inquiry-based learning
- problem-oriented/problem-based learning
- different teaching methods together
- other teaching methods

The data were first analysed deductively based on the measurement instrument 1. Thereafter all the other teaching methods were analysed inductively. Attention was paid also to the matter if different teaching methods were used together.

Measurement instrument 2 included the items concerning the teaching methods that promote BD learning, and they were chosen on the basis of the Finnish National Core Curriculum for Basic Education 2014 [80]. The following items were used:

- techniques for increasing environmental awareness/sensitivity
- developing observation and research skills
- active participation and interaction
- developing self-evaluation
- enabling emotional experiences
- developing experiential learning skills
- developing ICT skills
- developing problem-centred learning skills
- raising the ability to understand different perspectives
- taking into account the previous level of knowledge of the students

The material was first coded deductively based on the items concerning the teaching methods found in NCC [80] and then inductively based on the items found in the articles.

To analyse the objectives of thinking skills, measurement instrument 3, based on the extended Bloom's taxonomy, was used [74,75]:

- remember
- understand
- apply
- analyse
- synthesise/create
- evaluate

The levels of knowledge were analysed based on Bloom's new taxonomy [75,81] according to Aksela, Tikkanen, and Kärnä [73] (Table 1). In this analysis, the next knowledge level always includes the previous one/the previous ones, e.g., concept knowledge includes fact knowledge, and method knowledge includes both fact and concept knowledge.

Table 1. The new taxonomy of Bloom based on Aksela et al. [73].

Knowledge Level	Criteria
Fact knowledge	Terminology of biology
Concept knowledge	Classification of biological knowledge; theories, models, structures
Method knowledge	Problem solving, research methods and techniques
Metacognitive knowledge	Making summaries, self-knowledge

Further, to analyse the levels of thinking skills which may have been achieved via the teaching methods and which had been introduced in the articles, an evaluation using the verbs defined by Stanny [81] was performed (Figure 1). If the taxonomy level was not clearly stated in the article or was not represented in verb form, Stanny's verbs were applied as background information to support interpretation, so that it was possible to determine the levels of thinking likely to be acquired via the teaching method.

Knowledge	*f*	Understand	*f*	Apply	*f*	Analyze	*f*	Evaluate	*f*	Create	*f*
cite	17	classify	18	act	19	analyze	24	appraise	22	arrange	22
define	21	compare	11	apply	22	appraise	11	argue	12	assemble	14
describe	14	convert	13	calculate	10	categorize	19	assess	17	combine	14
identify	20	defend	12	choose	11	classify	10	choose	10	compose	19
label	21	describe	22	compute	10	compare	24	compare	18	construct	29
list	27	discuss	21	construct	13	contrast	19	conclude	13	create	19
locate	10	distinguish	12	demonstrate	20	criticize	11	criticize	11	design	24
match	14	estimate	11	dramatize	16	diagram	12	critique	14	develop	18
memorize	10	explain	28	employ	16	differentiate	20	defend	15	devise	13
name	22	express	17	illustrate	18	discriminate	11	estimate	15	formulate	18
outline	11	extend	11	interpret	15	distinguish	21	evaluate	16	generate	11
recall	24	generalize	11	manipulate	10	divide	12	judge	25	invent	10
recite	12	identify	14	modify	12	examine	18	manage	15	modify	10
recognize	14	infer	15	operate	17	infer	14	prepare	12	organize	21
record	13	interpret	17	practice	15	outline	10	rearrange	19	plan	21
relate	11	locate	10	prepare	11	point out	12	reconcile	12	prepare	12
repeat	20	paraphrase	22	produce	13	question	12	set up	15	produce	13
reproduce	11	predict	12	relate	12	relate	17	synthesize	16	rate	21
select	16	recognize	11	schedule	11	select	12			revise	12
state	23	report	10	show	13	separate	10			write	17
		restate	15	sketch	17	subdivide	10				
		review	15	solve	19	test	14				
		rewrite	12	use	25						
		summarize	20								
		translate	21								

Figure 1. The verbs of Bloom's taxonomy of knowledge, understanding, application, analysis, synthesis, and evaluation, as presented by Stanny [81]. These verbs were used as support for the analysis.

In order to ensure the reliability of the process, two members of the research team first conducted the categorization and the subsequent analysis independently. The analysis process was dialogical in nature. The discussion continued until consensus was reached and clear arguments were found. If the taxonomy level was not clearly stated in the article or was not represented using Bloom's verbs, Stanny's [81] verbs were applied as a means to support the analyses so that it was possible to determine the level of thinking. The generality of our results relates to the selection of the analysed data.

As such, decisions always include elements of subjective interpretation, joint discussions between the two researchers about differences in their analysis concerning the articles were essential. 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.

5. Results

5.1. Selected Journals and Articles in Relation to the Educational Levels

Most of the investigated journals and articles presented teaching methods concerning secondary school BDE, followed by primary school BDE (Table 2).

Table 2. The analysed articles (*N* = 12) and the educational level (P = primary school, S = secondary school, U = university) presented in them.

The Selected Journals	Educational Level	Number of the Analysed Article
ALT-J Research in Learning Technology	U	9
Environmental Education Research	P	4
i-manager's Journal on School Educational Technology	P, S	11
Journal of Biological Education	P, S	5
Journal of College Biology Teaching	U	2
Studies in Educational Evaluation	P	7
The American Biology Teacher	S, P, S, S, S	1, 6, 8, 10, 12
The Science Teacher	S	3

5.2. Levels of Biodiversity

In half of the 12 articles, more than one level of BD was considered, but only in one article were all three levels of BD present. Species identification was included in most of the articles (in a total of 11 articles, except for article number 11). Genetic diversity was mentioned in one article which dealt with teaching the importance of seed banking (article 3) and in another article (article 8) where different breeds of dogs were illustrated.

The topics included in ecosystem diversity teaching were geospatial exploration (article 12), conservation programs (4), environment exploration, animal shows and museum sessions (article 7), images of different types of easily recognizable ecosystems (article 8), and real-world exercises with devices (article 9). In article number 11, it was clearly stated that the teaching method, the study environment, and the studied subject were related to BD but they did not show the type of BD.

5.3. Teaching Methods Used and Integrated Items that Promote Biodiversity Learning

In total, 19 different kinds of teaching methods were found in the analysed articles (Table 3). Both teacher-centred and learner-centred teaching methods were used to teach BD. It was common (in 11 articles) for different teaching methods to be combined to promote learning BD. The most commonly chosen teaching methods to promote BD learning were hands-on instruction, experiential learning, teacher presentation, group work, ICT and interactive learning. Typical teaching methods for biology, including problem-oriented, experimental, long-term projects, and outdoor/field and inquiry-based learning were employed by teachers in their BDE. Outdoor learning and field work included activities arranged in authentic, often natural environments in the virtual world or in real nature. They were separated from study trips and visits to, for example, museums or zoos. Additionally, different types of equipment were used, e.g., mobile devices with snorkelling activities for moving fish species identification or observing invertebrate or plant species density in different urban habitats.

Table 3. The teaching methods in the analysed articles (*N* = 12).

Teaching Methods	Article Number	Total
Different teaching methods together	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12	11
Hands-on instruction	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12	11
Experiental learning	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	10
Teacher presentation	1, 2, 3, 4, 5, 6, 8, 9, 10, 12	10
Group work	1, 2, 3, 4, 5, 6, 9, 10, 12	9
ICT	1, 2, 3, 5, 6, 7, 9, 11, 12	9
Interactive learning	1, 2, 5, 6, 7, 8, 10, 12	8
Problem-oriented/problem-based learning	1, 2, 3, 5, 8, 9, 10, 12	8
Experimental learning	1, 2, 5, 6, 9, 10, 11	7
Project work	1, 2, 4, 5, 6, 9, 10	7
Outdoor learning, field work	1, 4, 5, 6, 9, 10	6
Argumentation	2, 3, 4, 9, 10	5
Inquiry-based learning	1, 2, 3, 6, 10	5
Case teaching	3, 8, 9, 10, 12	5
Teaching discussion	6, 8, 10, 12	4
Teacher inquiry	3, 8, 12	3
Co-operative/collaborative learning	1, 4, 8	3
Games, roleplays, debates	4, 6	2
Service learning	6	1
Study trips and visits	7	1

The items concerning the teaching methods (Table 4) promoting BD learning were connected to teaching via various multifaceted teaching and learning methods.

Table 4. The items concerning the teaching methods promoting biodiversity (BD) learning (*N* = 12).

Items of the Methods that Promote BD Learning	Article Number	Total
Active participation, interaction	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	12
Developing observation and research skills	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12	11
Developing experiential learning skills	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	10
Techniques for increasing environmental awareness	1, 3, 4, 5, 6, 7, 8, 9, 10, 12	10
Developing problem-centred learning skills	1, 2, 3, 5, 8, 9, 10, 12	8
Taking into account the previous level of knowledge of the students	1, 3, 5, 8, 9, 10, 11, 12	8
Enabling emotional experiences	1, 4, 5, 7, 8, 9, 11	7
Development of ICT skills	1, 2, 5, 9, 12	5
Raising the ability to understand different perspectives	1, 7, 8, 12	4
Developing self-evaluation	3, 4	2

Active participation and interaction between students or between students and teachers, developing observation and research skills, as well as experiential learning skills and techniques for increasing environmental awareness, were seen to be most important items concerning teaching methods. Additionally, developing problem-centred learning skills and taking into account the previous level of knowledge of the students were regarded as important items. In addition, it was considered to be crucial to offer emotional experiences during the learning period.

Active participation was used in teaching species identification, classroom discussions, and exploring the surrounding environment or museums. Experiential learning skills were fostered, for example, via collecting data for student research and collecting a seed bank and species identification in field observations. Examples of how 'to take into account the students' prior level of knowledge' were pre-tests and the careful introduction to the subject studied, enabling the students' individual progression within the subject of learning.

5.4. The Levels of Knowledge and of Thinking Skills Regarding Biodiversity Teaching

All four types of knowledge (fact, concept, method, and metacognitive) were jointly supported in teaching in nine articles (Table 5). The concept of the knowledge depended on the topic learned. Some examples were gene bank, plant loss, plant richness, habitat, carrying capacity and limiting factors.

Table 5. The level of knowledge and objectives for thinking skills [73] in the teaching methods concerning biodiversity in the articles (N = 12).

		Article Number	Total
Level of knowledge	Fact knowledge	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12	11
	Concept knowledge	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12	11
	Method knowledge	1, 2, 3, 5, 7, 8, 9, 10, 12	9
	Metacognitive knowledge	1, 2, 3, 7, 8, 9, 10, 11, 12	9
Level of thinking skills	Remembering	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	12
	Understanding	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	12
	Application	1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12	11
	Analysis	1, 2, 3, 5, 6, 7, 8, 12	8
	Synthesis	1, 2, 3, 8, 12	5
	Evaluation	3, 4, 6, 7, 9	5

Even the higher levels of knowledge (method and metacognition) were present in almost all articles. Method knowledge was taught, for example, by establishing plots in the field and collecting data from them, and via inquiry-based experimental plant BD labs, seed banks, and dichotomous key investigations, animal shows (investigation of calm behaviour towards different kinds of animals, e.g., snakes, invertebrates), investigations of the practical value to BD or the authentic study of the BD of fish in the Mediterranean Sea. An example of metacognitive knowledge could be in learner-oriented virtual learning (article 11): 'Why does your bird live in this ecoregion? What resources, habitat etc. appear to make this a suitable "home" for this bird?'

The lower levels of thinking skills, such as remembering, understanding, and application, were supported in teaching. Examples of remembering were comparing data, understanding patterns, processes, and relationships of living organisms and describing species. For the application, data for the students' own research were collecting and species identification charts were applied in identification tasks and report making. The higher level thinking skills were present in 5–8 articles. The analysing thinking skills were stimulated by analysing the collected data, pictures, or diagrams, and, for example, pointing out the consequences of climate change. Synthesis (creating) was promoted through constructing a herbarium, creating one's own seedbank and planning and discussing ways to decrease the loss of BD. Evaluation was involved in students' activities on the basis of their participation in the study processes and their self-evaluation concerning documents they generated. However, the highest levels of thinking skills—synthesis and evaluation—received the least amount of attention.

6. Discussion

The aim of this qualitative survey was to investigate what kind of teaching methods in biology have been used to promote BDE and how the teaching methods support BD learning. Firstly, we analysed the teaching level of BD and its aspects because BDE concerns these ones. The BD concept is difficult to grasp because of its complexity [20]. This also came up in our study. In all 12 investigated articles, all the aspects of BD (species identification BD, genetic BD, and ecosystems BD) were presented in some way. In half of them, more than one aspect of BD was discussed, but only in one article were all three aspects presented. Based on our results, species identification is especially important. It was included in most of the articles (in a total of 11 articles, except for article number 11). Thus, the findings support the previous studies among students [49] and student teachers [26,48].

Genetic diversity was mentioned in only two articles. However, it is an essential concept to be taught. Lower genetic variation depresses individual fitness, resistance to disease, and parasites and flexibility in coping with environmental challenges. It also decreases the mean fitness of populations, resilience, and long-term adaptability [82]. The topics that included ecosystem diversity teaching familiarized students, for example, with their local ecosystems. This finding supports the educational ideas of Finnish primary and secondary level biology curricula, where species identification, understanding of the structure and function of different ecosystems, the importance of living environments for BD, and the conservation of BD are emphasized [80]. In addition, emotional experiences during the learning period were mentioned to be the most crucial. This finding can be seen as very important in the view of BDE. Namely, in previous studies, it has been stated that emotions broaden the discourse about the construction of an ecological identity, e.g., Reference [83].

Secondly, teaching methods and items concerning them for promoting BD learning in different educational levels were analysed. All teaching methods are context- and subject-dependent which means that the choice of teaching methods depends on what kind of teaching approach is preferred. Both teacher-centred and learner-centred teaching methods to teach BD were present. Additionally, a combination of different teaching methods was commonly used. The most commonly chosen teaching methods to promote BD learning at all educational levels were hands-on instruction and teacher presentation. Outdoor/field and inquiry-based learning were also used but more often at the secondary and primary levels than at the university level. These are examples of teaching methods through which students can get direct experiences of BD, and they are therefore important ways for developing the understanding of BD [69]. In addition, projects that offered contact with natural environments were used at all educational levels. This teaching method is particularly relevant for those students who will rarely have access to nature [70]. In the interdisciplinary and multidisciplinary projects, where students identify and analyse components in their project and then critically reflect on how everything is connected to everything else in the complex system, students learn to think in holistic ways cf. [54]. Palmberg and others [26] recommend that teaching and learning methods for identification and knowledge of species and sustainability should always include experiential and project-based teaching and learning methods in authentic environments. According to their results, hands-on instruction was shown to be the source of increasing environmental awareness, not only at the primary and secondary school levels but also in universities.

Games, roleplay, debates, and study trips and visits were rarely used as teaching methods and only used at the primary and secondary levels. According to some studies, they have multiple benefits for all educational levels. For instance, games are efficient learning activities when engaging students in active participation and interaction [84]. Roleplay in science teaching and learning—-as with 'active', 'experiential' or 'child-centred' learning—-encourages students to be physically and intellectually involved in their lessons, allowing them to both express themselves in a scientific context and to develop an understanding of difficult concepts [85]. Additionally, in-class debates cultivate the active engagement of students, placing the responsibility of comprehension on their own shoulders [86]. Field trips, for their part, can be used as successful teaching methods, for example, in presenting selected environmental concepts [87]. Through service learning, students can familiarize themselves with local environments, phenomena, and issues as a context for a subject content that supports meaningful learning [88].

Items concerning the teaching methods, such as raising environmental awareness and developing self-evaluation, were discussed in only a few of the articles. However, it would be important to encourage a change from passive and suspicious attitudes to more active and positive ones, and they can also support scientific and critical thinking skills, which Aarnio-Linnavuori [47] argues is highly important.

Thirdly, we analysed the levels of BD knowledge that are taught. All four types of knowledge (fact, concept, method, and metacognitive) were used in BDE. The concept of the knowledge depended on the topic learned. The higher levels of knowledge (method and metacognitive) were also present

in almost all articles. These findings support the previous studies. According to Yli-Panula and others [48], Finnish student teachers see species identification, species knowledge and understanding of the functions of nature and ecosystems to be important to teach. Lindemann-Matthies [50], for her part, states that species knowledge and identification are important both for scientists and other professionals in biology but also for lay people. The reason for this statement is that material cycling and energy flow are dependent on plants and animals [51,52]. Thus, understanding the importance of the protection of BD is a prerequisite for sustainable development [10], and from the perspective of sustainability, all aspects of BD are essential to research and teaching cf. [35].

Fourthly, the levels of thinking skills and the objectives for thinking skills promoting BDE with respect to teaching methods were analysed. The lower levels of thinking skills, such as remembering, understanding, and application were supported in teaching. The higher levels of thinking skills were also presented in many articles. However, the highest levels of thinking skills—synthesis and evaluation—received little consideration. Perceptions of nature are structured by experiences, cultural norms and values [42,43]. They are reflected in attitudes and in individual or collective behaviours. Attitudes are seen as learned and therefore changeable. BDE is a way to change them. It has been shown that there is a significant relationship between environmental attitudes and awareness due to education [37,46]. Environmental values can be roughly divided between those relating to the orderly operation of an ecological system and those relating to the human use of it [89]. This means that values and ethic relations towards nature are bounded by the biological requirements of the human species, but particularly influenced by culture, learning, and individual experience [45]. Environmental education (and BDE as a part of it) should nevertheless foster value development reflecting the identification with the ecological system and pride in the skills of living harmoniously within it. In education, enjoyment and wonder, creativity and far-sightedness, sharing and self-control, as well as knowledge and understanding, should be fostered [89].

7. Main Conclusions and Implications

This study investigated the kinds of teaching methods that promote BDE and how they support BD learning. Our goal was to determine ideas for developing curricula and the instruction of biology education in basic and teacher education. We found that all teaching methods are useful when they are related with the contexts and objectives of teaching, studying, and learning processes and when the previous knowledge and skills of the students are taken into account. The analyses give hints of how to use these teaching methods for promoting the sustainability aspects in BDE.

Because BD [9] and the protection of BD [10] have been identified as major pathways to sustainability, a certain level of species knowledge is necessary for understanding basic ecological concepts and processes, e.g., References [60,90,91]. Therefore, species identification and knowledge of species should have a central role in teaching and learning about BD and sustainability [92]. This study also supports this idea. As in previous studies [69,79], especially student-centred teaching and learning methods, what develops experiential learning skills in authentic environments is seen to be at the core of BDE. Unlike what was found in previous studies [84–87], the analyses did not find an emphasis on games, roleplay, debates, and study trips and visits as teaching methods for increasing students' interest in and knowledge of environmental issues.

An issue to be taken more into account is service learning. According to Gruenewald [88], service learning is a useful method for familiarizing students with the local environment. It connects living environments meaningfully to the lives of students and to the communities they come from.

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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Appendix A

The investigated articles

1. Almeida, S.; Bombaugh, R.; Mal, T. Involving school children in the establishment of a long-term plant biodiversity study of an urban green space. *Am. Biol. Teach.* **2006**, *68*, 213–220.
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