



Student teachers' conceptual understanding of biodiversity loss in a multiple-source learning environment

Mirva Heikkilä, Miira Häkkinen, Anni Vidbäck, Mirjamaija Mikkilä-Erdmann & Ilari E. Sääksjärvi

To cite this article: Mirva Heikkilä, Miira Häkkinen, Anni Vidbäck, Mirjamaija Mikkilä-Erdmann & Ilari E. Sääksjärvi (11 Dec 2024): Student teachers' conceptual understanding of biodiversity loss in a multiple-source learning environment, Environmental Education Research, DOI: [10.1080/13504622.2024.2436110](https://doi.org/10.1080/13504622.2024.2436110)

To link to this article: <https://doi.org/10.1080/13504622.2024.2436110>



© 2024 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group



Published online: 11 Dec 2024.



Submit your article to this journal [↗](#)



Article views: 352







View related articles [↗](#)



View Crossmark data [↗](#)

Student teachers' conceptual understanding of biodiversity loss in a multiple-source learning environment

Mirva Heikkilä^a , Miira Häkkinen^a , Anni Vidbäck^a, Mirjamajja Mikkilä-Erdmann^a  and Ilari E. Sääksjärvi^b 

^aDepartment of Teacher Education, University of Turku, Turku, Finland; ^bBiodiversity Unit, University of Turku, Turku, Finland

ABSTRACT

Environmental content is becoming increasingly important in schools, but teachers may have difficulty grasping accurate knowledge. This study investigated how student teachers construct a conceptual understanding of biodiversity loss in an online environment. Sixty-five first-semester primary student teachers at a Finnish university were given the task of writing a synthesis of text from online sources to prepare for a primary school science lesson. The learning environment included texts that were relevant, irrelevant, and fake. A content analysis of their syntheses showed that they generally managed to define the phenomenon and adequately explain its causes and implications. However, they struggled to find different perspectives and write a coherent synthesis, as they used irrelevant and fake content instead of integrating text from multiple relevant sources. These findings indicate a need to develop teacher education to support student teachers in recognising the validity of sources on environmental issues and synthesising them into a coherent whole.

ARTICLE HISTORY

Received 8 July 2024
Accepted 20 November 2024

KEYWORDS

Biodiversity; biodiversity loss; scientific literacy; conceptual understanding; multiple-source reading; teacher education



SUSTAINABLE DEVELOPMENT GOALS

SDG4: Quality education

Introduction

Biodiversity refers to the variability of life at the levels of genes, species, and ecosystems (Audrin 2023; UN 1992). It is an urgent topic because of its globally advancing loss (IPBES 2019), which has far-reaching consequences for humans, including greater food insecurity, increased ecosystem vulnerability, and damaged connections between humans and nature, which collectively cause severe risks and threats to our livelihoods, health, and security, as well as to the economy (Dasgupta 2021; Gass et al. 2021; IPBES 2019). Thus, the World Economic Forum (2024) has classified biodiversity loss and ecosystem collapse among humankind's most severe risks over the next decade. The world's biodiversity is declining because of land- and sea-use changes, unsustainable use of wild species, human-induced climate change, pollution, and invasive alien species (Dasgupta 2021; Gass et al. 2021; IPBES 2019). As this is a hybrid phenomenon that unites the aspects of natural and social science (EDUFI 2024), biodiversity has become a central topic in environmental education (Audrin 2023; Van Weelie and Wals 2002).

Biodiversity education is widely considered an essential component of the protection of global biodiversity because it is critical in changing human attitudes towards nature (Gass et al. 2021). Biodiversity education is part of the broader concept of environmental education. More

CONTACT Mirva Heikkilä  mirva.heikkila@utu.fi  Department of Teacher Education, University of Turku, Assistentinkatu 5, 20014 Turku, Finland

© 2024 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group
This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. The terms on which this article has been published allow the posting of the Accepted Manuscript in a repository by the author(s) or with their consent.

precisely, often involving normativity, it belongs to sustainability education, which requires a participatory approach to learning (Lindemann-Matthies et al. 2009). In Europe, where topics connected to sustainable development are considered essential phenomena, environmental issues have been integrated across disciplines and are important content in science curricula from the early grades. For example, in the Finnish national core curriculum for the first and second grades, biology, geography, physics, chemistry, and health education are integrated into a subject called *Environmental Studies*, which includes the perspective of sustainability (EDUFI 2024).

Lindemann-Matthies et al. (2009) have argued that biodiversity education should not only be about nature and helping students understand a variety of plants and animals and their habitats but also requires a novel teaching approach that comprises the construction and critical use of knowledge, a critical analysis of the role of natural science, and an awareness of scientific and non-scientific aspects. This is because an understanding of ecological pathways does not directly lead to environmental awareness and action in solving problems (Lindemann-Matthies et al. 2009). Therefore, in the present study, the source texts include a variety of consequences relating to both nature and society that student teachers are asked to synthesise. In addition, biodiversity, like sustainability and climate change, is a topic that has given rise to the deliberate spread of fake information. Fake information on biodiversity loss includes, for example, the idea that it is not caused by humans but is part of an entirely natural development that is even beneficial for humankind.

Biodiversity loss is an example of a complex problem with socio-economic consequences that challenges teacher education, as these phenomena must be introduced in the classroom. Environmental education plays a strong role in primary schools and thus in teacher education (eg Lindemann-Matthies et al. 2009; UN 2024). Teachers play an important role in teaching basic conceptual content and facilitating pupils' understanding of current problems, such as biodiversity loss. Pupils' knowledge about phenomena is often based on everyday experience and is, therefore, so-called everyday knowledge (Vosniadou 2017). The role of teachers in educating future citizens is vital because they support pupils' construction of a scientifically accepted understanding of phenomena, ie scientific knowledge, and thus facilitate a conceptual change from everyday knowledge to scientific knowledge (Mikkilä-Erdmann et al. 2024; Södervik 2016). Hence, a primary teacher acts as a mediator between two worlds—the everyday world and the world of science (Mikkilä-Erdmann and Iiskala 2020).

However, in the current post-truth culture (Hauke 2019), teachers need scientific literacy to be able to find and construct coherent knowledge with which to teach complex phenomena. The concept of scientific literacy has several different definitions that reflect the aspects that are understood as the most central (Osborne 2023). Like Osborne (2023), we understand that regarding today's complex phenomena (such as biodiversity loss), in addition to knowing about the phenomenon, it is central to have the competency to examine the relevant available information critically and from multiple perspectives. Therefore, scientific literacy includes the development of a commitment to science (Norris and Phillips 2003), scientific content knowledge (Roberts 2007), and multiple-source reading skills (Britt, Richter, and Rouet 2014). Student teachers need scientific literacy (Britt, Richter, and Rouet 2014) to be able to actively search for new information, evaluate it, teach it to their future pupils, and enrich and revise their conceptual understanding (Vosniadou 2017) of several scientific concepts in the curriculum. In Finland, where primary teachers study in multidisciplinary universities, they are educated to base their work on scientific knowledge (Mikkilä-Erdmann et al. 2024).

Developing scientific literacy among student teachers through multiple-source reading and conceptual understanding

In the contemporary intensive knowledge environment, professionals, including teachers, are expected to engage in continued learning and knowledge development (Heikkilä 2022). Much

learning today takes place on the internet, which emphasises the importance of the ability to read multiple sources. Thus, an essential skill for future teachers is finding relevant and reliable online sources and synthesising them to form a coherent understanding of a topic to enable them to guide their pupils in understanding that topic. This skill requires scientific literacy.

Selecting and using multiple sources of information requires skills beyond single-text reading and comprehension. It involves several core processes: understanding the task; assessing one's information needs; selecting, processing, and integrating the information in the texts; constructing a task product (in this case, a synthesis); and assessing the quality of the product (Rouet and Britt 2011). Thus, to manage multiple-source reading, individual readers must implicitly formulate precise reading goals and regularly assess their current state of knowledge based on these goals (Rouet, Britt, and Durik 2017). Then, they must find relevant ideas from each source and recognise the connections between different texts (Perfetti, Rouet, and Britt 1999), which is not easy, as texts can either reinforce or contradict each other (Britt and Rouet 2012). Coherently synthesising different texts requires understanding the concepts, cause-and-effect relationships, and perspectives they contain (Britt and Rouet 2012). These processes are important for both student teachers and their future pupils.

In addition, integrating information from different sources into a written product has proven to be challenging, even in the highest educational grades (Britt and Aglinskas 2002; Mateos and Solé 2009). For example, in Mateos and Solé's (2009) case study of 45 Spanish students from high school to university, the participants struggled to form links between different sources and write a coherent synthesis. Instead, the students summarised each source and presented their summaries in sequence. According to Bråten et al. (2011), this failure to integrate information from multiple sources can lead to an understanding that is heavily influenced by unreliable sources or does not sufficiently consider different perspectives.

The proliferation of fake content on the internet significantly burdens online readers' understanding. Thus, they must be able to critically evaluate what and how they know and to explicitly appraise the quality and validity of their judgements (Lombardi and Sinatra 2013). These new requirements for the understanding of knowledge have arisen in the age of post-truth, in which emotional and personal beliefs often surpass factual and scientific arguments (Hauke 2019). Thus, separating reliable from unreliable information and relevant from irrelevant information is becoming increasingly difficult (Lombardi and Sinatra 2013) and requires effort and practice.

In today's online information context, student teachers should be able to construct a coherent conceptual understanding of various phenomena. Student teachers are usually familiar with didactic content, such as in science, but learning to teach that content requires extensive enrichment and revision of their knowledge. In the process of knowledge enrichment, learners add new information without changing their basic assumptions of reality and knowledge (Vosniadou 2017). When the reorganisation of their knowledge structure occurs at a deeper level, it is called revision (Mikkilä-Erdmann and Iiskala 2020). This requires several conceptual changes—that is, changes in one's existing knowledge and the organisation of such knowledge (Mikkilä-Erdmann and Iiskala 2020; Vosniadou 2017).

Student teachers should have basic knowledge of environmental issues from their science lessons in upper secondary school. However, their level of knowledge may vary greatly, with some having conceptual knowledge of other related concepts, such as climate change, and others not. These knowledge links are crucial because learners need to acquire an interrelated set of concepts that classify phenomena according to their deep relational structure (Lundholm 2017).

Given the importance of multiple-source reading in student teachers' acquisition of novel knowledge and skills, and of researchers' mapping out of the key challenges in student teachers' learning to further support them, our research question is as follows:

How do student teachers construct a conceptual understanding of biodiversity loss in a multiple-source learning environment?

Methods

Study participants

To answer our research question, we worked with 65 first-semester primary student teachers at the University of Turku Finland in 2023. The original number of participants was 73, but eight did not complete the study. The participants were enrolled in a five-year primary teacher education programme and majored in educational science, which comprised courses in educational science, teaching practice in the teacher training school, courses on research skills, and a bachelor's thesis (University of Turku 2024). In the programme, they were also required to study the respective school subject didactics, take minor subjects, and, finally, complete their empirical master's theses. The structures of the primary teacher education programmes in universities throughout Finland are basically similar. The context of Finnish primary teacher education is interesting for this study because it has been at the master's level for several decades and, due to its strong foundation in the university, should equip teachers with scientific literacy.

Ethical compliance

The study complied with the ethical principles of research with human participants and the ethical review in the human sciences in Finland published by the Finnish National Board on Research Integrity TENK (2023). According to these guidelines, a formal ethical review statement from a human sciences ethics committee was not required for this study. The participants submitted their written consent for the research. Participant identification codes were used for anonymity. After the task, a seminar was held to clarify the sources and discuss the participants' experiences. The participants were told that some of the texts were incorrect. The task was not assessed and thus did not affect the participants' grades, of which they were also informed. The entire course was assessed as passed/failed.

Data collection

We asked the student teachers to participate in a task in an online learning environment designed to be a controlled system for practising scientific literacy. The individual task was to write, in 200–350 words, a synthesis of texts that we put online. These syntheses served as the research data for this study. The task instructions were specifically as follows: 'You are working on biodiversity loss with your pupils. Prepare your lesson by explaining, based on scientific knowledge, what biodiversity loss means. Discuss its causes and implications from as many perspectives as possible.'

Each of the 10 texts on which the syntheses were to be based was 300–400 words long and had a title, a name of an imaginary author or organisation, a date, and a real reference list (please see supplemental material for more information: Table 1. *The source texts: Title, author/source, type, main arguments/content, and relevance*). The texts included different perspectives, which were additive in the spirit of multiple-source reading (Rouet and Britt 2011). However, four of the texts were relevant, four were irrelevant regarding the task question, and two were fake pseudoscientific texts. The relevant texts were based on scientific knowledge; they were shortened from texts received directly from the author of the texts (biodiversity researcher). The irrelevant and fake texts were based on internet sources. The authentic references used were marked at the end of each text.

Data analysis

We analysed the data through content analysis (Hsieh and Shannon 2005). We began by reading the syntheses thoroughly several times to gain a grasp of their quality levels. At the beginning

Table 1. The source texts: title, author/source, type, main arguments/content and relevance.

Title	Author/source	Type	Main arguments/content	Relevance in terms of the task
'The Loss of Insects Endangers Food Production'	'Periodical of Science'	Scientific text (in a popularised form)	<ul style="list-style-type: none"> • The loss of insects is part of the biodiversity crisis. • The reasons for the loss of insects are the destruction of habitats and the use of pesticides. • Food production requires insects to pollute plants. 	Relevant
'Halting the Impoverishment of Nature is Possible'	1) Ville Niinistö, Member of the European Parliament (former Minister for the Environment and Member of Parliament) 2) Ilari Sääksjärvi, Professor, University of Turku, Biodiversity Unit	Newspaper article based on scientific knowledge	<ul style="list-style-type: none"> • The impoverishment of nature has enormous consequences for the economy, security, health, and quality of life. • Pandemics are one of these consequences. • The causes for the impoverishment of nature include the growth of the human population and the overuse of natural resources. 	Relevant
'Biodiversity Loss as a Global Challenge'	1) Ilari Sääksjärvi, Professor, University of Turku, Biodiversity Unit 2) Kari Kaunisto, Adjunct Professor, University Researcher, University of Turku, Biodiversity Unit	Scientific text (in a popularised form)	<ul style="list-style-type: none"> • Biodiversity loss is a weakening of genetical biodiversity, the collapse of entire ecosystems, and the extinction of species. • Biodiversity loss is a human rights question: All people have the right to a healthy environment. • Biodiversity loss causes environmental migration. 	Relevant
'Logging and Its Consequences on the Amazon Rainforest'	'The University Blog'	Blog post based on scientific knowledge	<ul style="list-style-type: none"> • The largest rainforest of the world, the Amazon, is vital for the climate, biodiversity, and human diversity (indigenous people). • The Amazon is also the world's largest freshwater system. • The causes for the destruction of rainforests are, among others, fires that derive from agriculture and cattle breeding. 	Relevant
'The Finnish Climate Change Panel Gathers Scientific Knowledge on the Globe's Climate'	'Citizen Info'	Announcement	<ul style="list-style-type: none"> • The purpose of the Climate Change Panel is to promote interaction between science and politics regarding the climate. • The reports of the Climate Change Panel concern the consequences of climate change to the world's ecosystems, as well as actions that can restrict global warming. 	Irrelevant
'Biodiversity Loss Is True Also in Finland'	'Nature Power Blog'	Blog post	<ul style="list-style-type: none"> • Despite Finnish forest owners' worries about their incomes, forests must be protected because of biodiversity. • It is time to recognise Finnish people's role in accelerating biodiversity loss and in the exploitation of nature. 	Irrelevant

(Continued)

Table 1. Continued.

Title	Author/source	Type	Main arguments/content	Relevance in terms of the task
'How to Solve Biodiversity Loss'	'Science Events'	Advertisement	<ul style="list-style-type: none"> The speed of biodiversity loss is exceptional: Approximately one million plant and animal species will become extinct in the next decades. 'The Solvers of Biodiversity Loss', an event series by the University of Helsinki, discusses the significance of biodiversity loss and seeks solutions. 	Irrelevant
'Biodiversity Loss is One of the Biggest Threats to Nature'	'Nature and Environment Centre'	Survey Report	<ul style="list-style-type: none"> Consciousness of the state of nature has grown, especially in relation to biodiversity loss as a threat. The survey was ordered by the Finnish Ministry of Environment and the Finnish Environment Centre concerning participants' views of different threats to nature. 	Irrelevant
'What Loss of Species?'	Aron Lehtiniemi, Adjunct Professor, Environmental Studies Research Centre	Pseudoscientific text (mimicking scientific text)	<ul style="list-style-type: none"> The loss of species is completely natural and human activities on the planet are also natural. Nature will revive from species extinction. Fewer species on the planet is probably beneficial for humankind. 	Fake
'The Climate is Changing as Part of Natural Cyclicity'	'Research report, Global Climate Research, NASA Headquarters, Texas, USA. How the Earth is not Changing' (by Steven Reynolds/AFC, translated by Kaarlo W. A. Kannisto)	Pseudoscientific text (mimicking scientific text)	<ul style="list-style-type: none"> Global warming is not mainly caused by humans but is part of natural cyclicity. Warm air is more beneficial to humans than cold air. 	Fake

of the reading process, we developed a matrix of key aspects that enabled us to assess the student teachers' conceptual understanding of biodiversity loss based on previous literature on multiple-source reading (Britt and Rouet 2012; Britt, Richter, and Rouet 2014). These aspects were as follows: definition of biodiversity loss, causes and implications, different perspectives, and coherence of the sources used in the synthesis. The first two aspects, definition and causes and implications, concerned the conceptual understanding of biodiversity loss, whereas the latter two aspects, perspectives and coherence, especially required the use of several sources and revealed skills in multiple-source reading (Britt and Rouet 2012; Britt, Richter, and Rouet 2014). Each of the syntheses was scored on a scale of 0 to 3 on each of these aspects (see Table 2 for a detailed description of each score).

The first two authors of this study rated the syntheses. To ensure validity, they rated all the syntheses separately, without knowledge of each other's ratings. Thereafter, we compared their ratings and analysed the data in depth. This process enabled us to dig deeply into the participants' conceptual understanding of biodiversity loss and discover similarities and differences in their writing styles. After this phase, we created a table of all the ratings to analyse the following: (1) the scores of each participant and (2) the scores for each aspect of the topic.

Finally, we organised the syntheses according to each aspect and score (for example, we noted all the syntheses that were rated 3 for definition). This final phase enabled us to

Table 2. Analysis matrix.

Key aspect	0	1	2	3
Definition	Not defined	Defining elements presented implicitly	Basic definition that explained biodiversity and loss	Comprehensive definition that included at least two levels (species, ecosystems, and genes)
Causes and implications	Not mentioned	Some causes or implications mentioned but without reasoning	Some causes and implications presented /several causes or implications presented	Several causes and implications presented in a multifaceted and interrelated manner
Different perspectives	No perspective mentioned	One perspective mentioned	At least two perspectives presented	At least three perspectives discussed in some depth and in relation to each other
Coherence	Incoherent because irrelevant and/or fake content dominated	Accurate parts coherent as such, but some parts were irrelevant and/or fake	Accurate content but separate, not pulled together	Accurate content from several sources pulled together as a coherent whole in terms of multiple-source reading

concentrate especially on the differences of the syntheses in terms of each aspect. This many-phased analysis process turned out to be beneficial and necessary to paint a full picture of the rich and dense data.

Findings

Figure 1 presents the participants' scores for the different aspects.

Figure 1 shows that the student teachers generally managed to define biodiversity loss and synthesise its causes and implications. For these two aspects, 35 of the 65 participants had the highest score of 3 and, in addition, many had scores of 1 and 2 instead of 0.

For the latter two aspects, it was a different case. Only 17 participants were able to give different perspectives on biodiversity loss and thus scored 3. The same applied to the coherence aspect pertaining to the sources used, as only 24 participants wrote a synthesis, which was scored 3, and 15 participants—an alarmingly high number—had completely incoherent texts that were scored 0. This last observation is attributed to the use of fake content: Several participants could define biodiversity loss and synthesise some of its causes and implications; however, they also used fake content, which made the text incoherent as a whole. In the following sections, we present our findings for each aspect of biodiversity loss in the syntheses.

Definition

Biodiversity loss was fairly well-defined, as nearly all the student teachers could give a basic definition. The best score of 3 required that several defining aspects of biodiversity loss be mentioned, as participant 63 (P63) did in the following example:

Biodiversity loss refers to the accelerated decrease of diversity in nature and species caused by humans.
 ... An excessive waste of natural resources causes, among other things, loss and destruction of habitats.
 ... Biodiversity loss manifests as great mass extinctions of species on the whole globe.

The participant gave a clear and concise definition of biodiversity loss at the beginning of the synthesis. Not only was the weakening of species diversity mentioned but also the fact that it is caused by humans and that it is happening at an increasing speed. Later, the participant

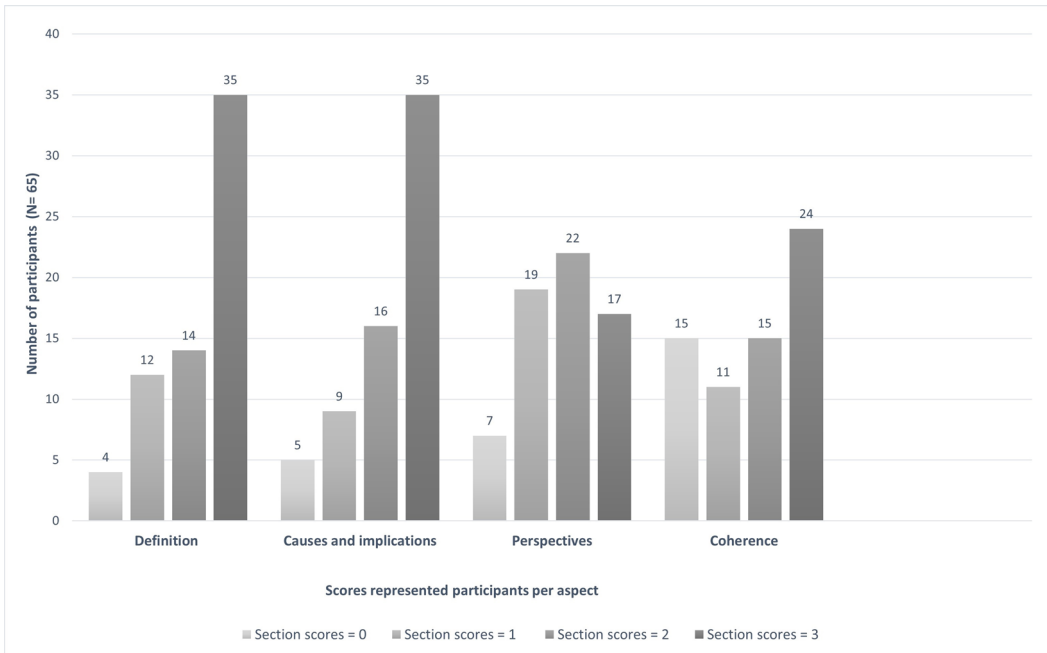


Figure 1. Scores (0–3) of the participants ($N=65$) according to the aspects identified in the analysis matrix.

added facts that also defined biodiversity: the weakening and destruction of habitats as well as mass extinctions. A high-quality synthesis often consists of an informative definition at the beginning and additive elements later in the text. The above example includes two levels of biodiversity loss: species and habitats. In contrast, P38 gave the following weak definition:

Biodiversity loss affects the whole of humankind and life on earth. According to research, we are already proceeding toward the sixth wave of extinction, and in light of many studies, it can be stated that we are already living it. The depletion of nature has been acknowledged to have an immense influence on the economy, safety, and health of humankind, as well as the quality of life. Biodiversity loss is influenced by an unsustainable exploitation of the globe's natural resources, leading to the depletion and even destruction of habitats.

This text does not include wording referring to a definition, such as 'biodiversity loss means...'. However, several sentences define biodiversity loss in different ways. The participant mentioned some facts that fall under the definition of biodiversity loss, such as mass extinctions and the weakening and destruction of habitats. However, although the facts are accurate and relevant, it would be problematic in environmental education if the student teacher could not clearly define the topic for their pupils.

Causes and implications

Several causes and implications were presented in four relevant sources, which helped the participants grasp the phenomenon. A high-quality synthesis of causes and implications can be formulated in different ways. Some participants concentrated on causes and provided only some implications, although both were required. Some listed several causes or implications, whereas others discussed fewer issues in detail. The use of multiple relevant sources that were tied together made for high-quality syntheses because different causes and implications were

presented from different sources. The following is part of the synthesis of P47, which was scored as 3:

Biodiversity loss is caused by, for example, unsustainable use of natural resources and destruction of habitats. In Finland, large numbers of endangered species live in forests that are being transformed through forestry. Also, pollution and invasive species influence biodiversity loss. Additionally, biodiversity loss is caused by climate change, which refers to an increase in greenhouse gases in the atmosphere and weakening of the carbon pool as a consequence of human actions. Ultimately, biodiversity loss is influenced by the growth of the population of humankind that has led to overconsumption of natural resources.

When species and habitats are destroyed, the number of individuals in a population decreases, and this leads to an increased risk of extinction. Biodiversity loss also erodes the hereditary diversity of species, and it may lead to the collapse of complete ecosystems. Biodiversity loss has immense implications for the economy, security, health and overall quality of life of humankind. Additionally, biodiversity loss influences, for example, the probability of pandemics. Moreover, environmental migration increases due to biodiversity loss.

The participant skilfully followed the guidelines, as the task was to present the causes and implications of biodiversity loss. In other words, a clear task model was used throughout the reading process. The participant used verbs such as 'to cause' and 'to influence' to highlight the versatile causes of the topic. The implications are presented as related to each other systemically, such as in the first sentence, where biodiversity loss is interrelated with the unsustainable use of natural resources and the destruction of habitats. In addition, expressions such as 'to lead' and 'implications' clearly signpost the synthesis according to the task. In addition, the presented issues are accurate and relevant. The participant used three relevant sources in the synthesis, but in this example, using two relevant sources alternately was sufficient for writing a genuine synthesis in terms of causes and implications.

The weak texts differed in their presentations. Some were long but too vague, indicating an undeveloped understanding of the topic. In contrast, some texts were relevant but lacked a thorough explanation of the causes and implications, which requires a greater effort. The following is an example of a synthesis from P50, which was scored 1 for this aspect:

Biodiversity loss is one of the greatest threats to our nature. One major factor influencing biodiversity loss is the unsustainable use of natural resources. It manifests now and in the future as depletion or the qualitative decline of habitats.

Biodiversity loss is caused by, among other things, climate change. Climate change refers to an increase in greenhouse gases in the atmosphere and to the weakening of the carbon pool caused by human action.

The participant concisely used expressions such as 'to influence' and 'to manifest' to highlight the causes and implications of biodiversity loss. This indicates the use of a clear task model. However, the causes and implications are scarce and only briefly presented. This was a good start, but without proper elaboration, the text could not be scored higher because the relevant texts provided multifaceted causes and implications of the phenomenon.

Different perspectives

According to the guidelines, the causes and implications of biodiversity loss were required to be presented from different perspectives. The following perspectives were presented in the four relevant texts: the increased risk of pandemics, environmental migration, general inequality, and problems with food security and freshwater. One text concerned threats to minority cultures. Perspectives could also be presented at a general level, for example, by mentioning climate change, the economy, health, and general security. The perspectives of humans or other animals could also be taken and, in the best case, of both. Thus, there were several possibilities for building a high-quality synthesis in this regard.

However, this proved to be difficult for the participants. It seemed that ‘perspective’ was understood as a different opinion. For example, in several syntheses in which fake content was used, such content was referred to as another ‘perspective’. However, concerning conceptual understanding, this indicated an undeveloped understanding of the coexistence of accurate and inaccurate information. This is problematic in terms of student teachers’ future work in teaching about the phenomenon.

However, some participants understood what ‘different perspectives’ meant, found several relevant sources, and discussed the perspectives in a concise and interrelated manner, such as P3:

According to the university blog, Amazon rainforests are a great carbon storage, where also resides the world’s largest freshwater system. Also, up to one-fourth of the whole world’s species live in the Amazon. Fires, logging, mining, cultivation, oil and gas exploitation, among other things, accelerate biodiversity loss in the Amazon. The depletion of nature affects the economy, safety, health, and quality of life. It can also cause environmental migration, as habitats are being destroyed. One of the most significant harms to species is the loss of insects, as we need insects to pollinate, to feed other organisms and as predators. Additionally, biodiversity loss increases the risk of pandemics.

This participant was one of the few who used the relevant sources that dealt with the Amazon. This perspective included the significance of freshwater and the wide variety of species in that area. The participant listed the implications of biodiversity loss for society in the following areas: economics, security, health, and quality of life. In addition, the text concerning insects was relevant but was discovered by only a few participants, including this one, who thereby found more perspectives on the topic. Moreover, perspectives on environmental migration and the increased risk of pandemics are mentioned but not discussed deeply. Altogether, while some participants remained at the level of nature in their perspectives, this participant synthesised various societal implications of biodiversity loss.

In the weak texts, the perspectives were either scarce or vague. P18 included much relevant knowledge but used irrelevant and fake sources, due to which the perspectives were not developed, as follows:

Among other things, the security, health, and economy of humankind are suffering from severe consequences due to biodiversity loss.

The list of different perspectives in this example is concise, but there was nothing more in the synthesis that would explain these consequences. Considering the incoherence of the synthesis due to the undeveloped conceptual understanding of the phenomenon and the use of fake sources, the text is not very convincing. Since teaching pupils to see different perspectives on a topic requires a more thorough approach, this presentation of different perspectives was superficial.

Coherence of the used sources

The coherence of the sources used was visible in terms of multiple-source reading in the syntheses that pulled accurate content together from several sources into a coherent whole. The syntheses that were scored 3 included only relevant sources or mostly relevant sources and more than one of them. Moreover, these syntheses did not use fake sources. Thus, they were coherent in both text and content and demonstrated skills beyond single-text reading and comprehension. The coherence of a synthesis was best evaluated by considering the synthesis as a whole; however, we present examples below to illustrate such coherence. In the synthesis from which the following excerpt was taken, P26 first presents the definition and the causes and implications appropriately, and then presents different perspectives, of which the following is the last part:

Biodiversity loss threatens food production, because insects are needed to pollinate plants. According to IPBES, as biodiversity loss goes on, pandemics will increase. The fast spread of viruses is a danger, especially in the Third World, among the most poverty-stricken segments of the population. The consequences of biodiversity loss seem to inconvenience first and most severely those who are in the weakest position. If habitats become uninhabitable, humankind will experience a historic mass movement of refugees. Vast flows of refugees will increase the other great risks of biodiversity loss, such as food security and pandemics. If all this is realised, humankind will have a high cost to pay for its previous actions.

The participant used several relevant sources and tied them up into a meaningful text in terms of multiple-source reading. This reflects a systemic understanding of the phenomenon gained through skilful selection, assessment, and application of the relevant sources. The text is an independent whole; it encompasses an idea for which the participant has established precise reading goals and has constantly assessed their current state of knowledge in terms of their initial needs and purposes.

In addition, the text reflects a valid conceptual understanding, as it includes key facts and does not include any unclear or irrelevant content. This conceptual understanding enabled the participant to concentrate on the quality of the text; consequently, the text is fluent, and the connections among the different perspectives are visible to the reader. The participant also ended with a clear concluding statement in relation to the facts described in the synthesis.

In contrast, the following is an example of an incoherent text that was scored 0. The text is long, but we present two passages that together show inconsistency. The participant put considerable effort into the task and grasped the definition, the causes and implications, and even the perspectives, which were scored 3. However, the problem is that the participant, P70, used everything, including irrelevant and fake content.

The diminishing of species has remarkable consequences on humans' health, security, quality of life and even economics. For example, the number of insects that regulate the populations of forest pests is of importance in terms of Finland's economy. ...

Although we live as sustainably as possible, we cannot completely avoid extinction of species and the spread of invasive species. Waves of extinctions are followed by rebirth; however, it takes millions of years. Thus, the disappearance of species can also be seen as the natural course of life and evolution.

The first passage contains relevant information. However, the participant concluded with fake content, which watered down the valid arguments. As the participant's task was to find information on biodiversity loss to teach to their pupils, we cannot accept this kind of conclusion. This example shows quite clearly that the phenomenon has remained blurred in the participant's thinking. Several controversial details are mixed, without a conceptual understanding of the phenomenon. Considering how urgent it is to act against biodiversity loss, this undeveloped understanding can be seen as a risk to environmental education.

Discussion

This study examined student teachers' conceptual understanding (Vosniadou 2017) of biodiversity loss from the perspectives of scientific literacy and multiple-source reading (Britt and Rouet 2012; Britt, Richter, and Rouet 2014) in an online learning environment. The findings convey a significant message for teacher educators, as well as for the broader domains of programme development and curriculum design within teacher education. They show that while the student teachers could generally give a basic definition of the topic and present its causes and implications, they did not succeed in multiple-source reading, as only a few of them could discuss the phenomenon from various perspectives, such as food security, freshwater, pandemics, environmental migration, and inequality. These findings are in line with those of previous studies (eg Britt and Aglinskas 2002) in which reading multiple sources proved challenging.

In addition, our findings confirm the difficulty experienced by student teachers in producing a synthesis (eg Mateos and Solé 2009). The student teachers had severe problems writing a coherent synthesis using several relevant sources and only relevant sources. Often, at least one irrelevant source was used. A source that reported Finnish people's survey answers on nature (see Table 1 for more information) was especially popular among the participants. This might be because the student teachers are oriented towards the human sciences rather than a purely natural scientific view, as their major is educational sciences. Thus, in general, this study strengthens the view of previous studies that failure to integrate knowledge from multiple sources leads to insufficient consideration of different perspectives (Bråten et al. 2011).

Although seven student teachers received full scores for each of the analysed aspects, 11 participants had a total score of less than 5 (out of a perfect score of 12) for the entire task, which is a worrying observation. We presupposed that student teachers might have alternative conceptions (Arrhenius, Bladh, and Lundholm 2024) of biodiversity loss, differing from scientific expert views and relating to their everyday experience and culture. However, we did not expect that many student teachers would be unable to find, acknowledge, and use such conceptions in terms of multiple-source reading. As implications for teaching, these findings indicate that student teachers need basic support in understanding the task, assessing information needs, selecting sources, and processing and synthesising information (Rouet and Britt 2011). Another striking observation is that some student teachers included everything in their syntheses: relevant, irrelevant, and fake content. They were, in a sense, efficient in synthesising and writing but lacked criticality. Therefore, in terms of implications for teaching, even those student teachers who appear to be skilful in a relevant area need help in recognising valid sources to gain conceptual understanding.

The amount of fake content used in general was also alarming. Further research could focus on this challenge by employing linguistic and narrative methods to analyse how fake content is used and referred to. In addition, the syntheses could be part of mixed-methods research, as the studies could include a survey of student teachers' science capital, such as what and how they think about science and what kinds of networks and facilities they possess that can foster science in their lives (eg DeWitt, Archer, and Mau 2016; Kaakinen et al. 2023). Moreover, previous research has called for including students' emotions and values in investigations to understand changes in their conceptual and epistemological thinking (Lundholm 2017). As this is parallel to analysing student teachers' actual written products (eg their syntheses) and their science capital, which reveal their attitudes towards science, it could create an even better opportunity to understand and support their learning of complex environmental phenomena, such as biodiversity loss.

A limitation of this study is that we did not have the possibility to follow how the participants' conceptual understanding developed during the years when they studied research skills as part of their degree in educational science and didactics in related subjects, such as science and civics. Moreover, we analysed a product in the current test situation, which was affected by the participants' motivations to perform the task. The findings are partly worrying, but it is important to note that the participants were at the beginning of their first semester. Therefore, while some excelled early in this task, others would have a chance to improve their conceptual understanding and multiple-source reading skills during their five-year degree. Longitudinal studies examining whether this would happen should be conducted in the future.

Conclusion

In conclusion, our findings indicate a need to further develop online learning environments in which student teachers can practice scientific literacy and multiple-source reading skills. This study recommends that student teachers be provided with supportive task environments, explicit

and complete representations of document sources, and guidelines on what to read and how to read to fully understand intertextual, complex contents (Britt and Rouet 2012). In line with previous literature (Bråten et al. 2011), student teachers need practice, especially in recognising the validity of sources and putting relevant sources together. Finally, this study strengthens the view that biodiversity loss is a complex concept to understand, thereby requiring the use of both the natural and social sciences in primary teacher education.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This research was funded by Strategic Research Council, Finland.

Notes on contributors

Dr. Mirva Heikkilä (PhD in Education) works as Senior Researcher at the Department of Teacher Education at the University of Turku, Finland. She examines learning and teaching in higher education and professional development in working life. She has specialised in studying the teaching profession and teacher education and published theoretical, methodological and empirical articles on those topics.

Miira Häkkinen is currently finalizing a dissertation on language education for working-age migrants in Finland and Germany. Her research interests derive from over a decade of professional experience in the global business environment of educational technology and work as a qualified freelance instructor for youth, adult, and mature language learners.

Anni Vidbäck (MAT, MSc) is a Doctoral Researcher at the University of Turku, Finland. Her research interests concern learning and teaching scientific literacy.

Dr. Mirjamaija Mikkilä-Erdmann is a Professor of Education at the University of Turku, Finland, and Academic Director of Research Infrastructure in the National Finnish Teacher Education Database (FinTED). She is a co-leader of FINSCI research consortium (www.finsci.fi). Her research profile is focused on learning and teaching research, especially teacher learning, scientific literacy and learning of complex phenomena.

Dr. Ilari E. Sääksjärvi is a Professor of Biodiversity research at the University of Turku. He is also leading the University of Turku Biodiversity Unit and BIODIFUL research consortium (www.biodiful.fi). His research profile is focused especially on tropical rain forests and multidisciplinary biodiversity research.

ORCID

Mirva Heikkilä  <http://orcid.org/0000-0002-6873-3943>

Miira Häkkinen  <http://orcid.org/0000-0001-7054-8686>

Mirjamaija Mikkilä-Erdmann  <http://orcid.org/0000-0003-1569-794X>

Ilari E. Sääksjärvi  <http://orcid.org/0000-0002-8107-5607>

References

- Arrhenius, M., G. Bladh, and C. Lundholm. 2024. "Causes, Processes and Consequences of Earthquakes. Investigating Swedish 12–13 Year-Old Students' Geographical Understanding." *International Research in Geographical and Environmental Education*: 1–17. <https://doi.org/10.1080/10382046.2023.2298555>.
- Audrin, C. 2023. "How Is Biodiversity Understood in Compulsory Education Textbooks? A Lexicographic Analysis of Teaching Programs in the French-Speaking Part of Switzerland." *Environmental Education Research* 29 (8): 1056–1071. <https://doi.org/10.1080/13504622.2022.2092597>.
- Bråten, I., M. A. Britt, H. I. Strømsø, and J.-F. Rouet. 2011. "The Role of Epistemic Beliefs in the Comprehension of Multiple Expository Texts: Toward an Integrated Model." *Educational Psychologist* 46 (1): 48–70. <https://doi.org/10.1080/00461520.2011.538647>.

- Britt, M. A., and C. Aglinskis. 2002. "Improving Students' Ability to Identify and Use Source Information." *Cognition and Instruction* 20 (4): 485–522. https://doi.org/10.1207/S1532690XCI2004_2.
- Britt, M. A., and J.-F. Rouet. 2012. "Learning with Multiple Documents: Component Skills and Their Acquisition." In *Enhancing the Quality of Learning: Dispositions, Instruction, and Learning Processes*, edited by J. R. Kirby and M. J. Lawson, 276–314. Cambridge, UK: Cambridge University Press. <https://doi.org/10.1017/CBO9781139048224.017>.
- Britt, M. A., T. Richter, and J.-F. Rouet. 2014. "Scientific Literacy: The Role of Goal-Directed Reading and Evaluation in Understanding Scientific Information." *Educational Psychologist* 49 (2): 104–122. <https://doi.org/10.1080/00461520.2014.916217>.
- Dasgupta, P. 2021. *The Economics of Biodiversity: The Dasgupta Review*. London: HM Treasury.
- DeWitt, J., L. Archer, and A. Mau. 2016. "Dimensions of Science Capital: Exploring Its Potential for Understanding Students' Science Participation." *International Journal of Science Education* 38 (16): 2431–2449. <https://doi.org/10.1080/09500693.2016.1248520>.
- EDUFI (Finnish National Agency for Education). 2024. *The National Core Curriculum*. 1 January 2015. <https://eperusteet.opintopolku.fi/eperusteet-service/api/dokumentit/9217998>.
- Finnish National Board on Research Integrity TENK. 2023. *The Finnish Code of Conduct for Research Integrity and Procedures for Handling Alleged Violations of Research Integrity in Finland 2023*. April 2023. https://tenk.fi/sites/default/files/2023-05/RI_Guidelines_2023.pdf.
- Gass, S., A. Mui, P. Manning, H. Cray, and L. Gibson. 2021. "Exploring the Value of a BioBlitz as a Biodiversity Education Tool in a Post-Secondary Environment." *Environmental Education Research* 27 (10): 1538–1556. <https://doi.org/10.1080/13504622.2021.1960953>.
- Hauke, E. 2019. "Understanding the World Today: The Roles of Knowledge and Knowing in Higher Education." *Teaching in Higher Education* 24 (3): 378–393. <https://doi.org/10.1080/13562517.2018.1544122>.
- Heikkilä, M. 2022. "Agency as Polyphony: Student and Primary Teachers' Narration Embedded in Theory and Practice." PhD diss., University of Turku. <https://urn.fi/URN:ISBN:978-951-29-8871-6>.
- Hsieh, H. F., and S. Shannon. 2005. "Three Approaches to Qualitative Content Analysis." *Qualitative Health Research* 15 (9): 1277–1288. <https://doi.org/10.1177/1049732305276687>.
- IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services). 2019. *Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. Edited by E. S. Brondizio, J. Settele, S. Díaz, and H. T. Ngo. Bonn, Germany: IPBES Secretariat. <https://doi.org/10.5281/zenodo.3831673>.
- Kaakinen, J. K., S. Havu-Nuutinen, T. Häikiö, H. Julku, T. Koskela, M. Mikkilä-Erdmann, M. R. Pihlajamäki, et al. 2023. "Science Capital: Results from a Finnish Population Survey." <https://doi.org/10.35542/osf.io/qgqzf>.
- Lindemann-Matthies, P., C. Constantinou, X. Junge, K. Köhler, J. Mayer, U. Nagel, G. Raper, D. Schüle, and C. Kadji-Beltran. 2009. "The Integration of Biodiversity Education in the Initial Education of Primary School Teachers: Four Comparative Case Studies from Europe." *Environmental Education Research* 15 (1): 17–37. <https://doi.org/10.1080/13504620802613496>.
- Lombardi, D., and G. M. Sinatra. 2013. "Don't Believe Everything You Think. Reappraising Judgments about Conceptions." In *Converging Perspectives on Conceptual Change. Mapping an Emerging Paradigm in the Learning Sciences*, edited by T. G. Amin and O. Levrini, 237–244. London: Routledge. <https://doi.org/10.4324/9781315467139>.
- Lundholm, C. 2017. "Conceptual Change and the Complexity of Learning." In *Converging Perspectives on Conceptual Change. Mapping an Emerging Paradigm in the Learning Sciences*, edited by T. G. Amin and O. Levrini, 34–42. London: Routledge. <https://doi.org/10.4324/9781315467139>.
- Mateos, M., and I. Solé. 2009. "Synthesising Information from Various Texts: A Study of Procedures and Products at Different Educational Levels." *European Journal of Psychology of Education* 24 (4): 435–451. <https://doi.org/10.1007/BF03178760>.
- Mikkilä-Erdmann, M., M. Heikkilä, T. Iiskala, and A. Warinowski. 2024. "Research-Based Teacher Education: A Finnish Perspective." In *Enhancing the Value of Teacher Education Research. Implications for Policy and Practice. Key Issues in Teacher Education: Policy, Research and Practice*, Volume 3, edited by V. Symeonidis, 42–61. Leiden: Brill. https://doi.org/10.1163/9789004689992_003
- Mikkilä-Erdmann, M., and T. Iiskala. 2020. "Developing Learning and Teaching Practices for Adults: Perspectives from Conceptual Change and Metacognition Research." In *Development of Adult Thinking: Interdisciplinary Perspectives on Cognitive Development and Adult Learning*, edited by E. K. Kallio, 123–140. London: Routledge. <https://doi.org/10.4324/9781315187464-8>.
- Norris, S. P., and L. M. Phillips. 2003. "How Literacy in Its Fundamental Sense Is Central to Scientific Literacy." *Science Education* 87 (2): 224–240. <https://doi.org/10.1002/sce.10066>.
- Osborne, J. 2023. "Science, Scientific Literacy, and Science Education." In *Handbook of Research on Science Education, Volume III*, edited by N. G. Lederman, D. L. Zeidler, and J. S. Lederman. London: Routledge, 785–816.
- Perfetti, C. A., J.-F. Rouet, and M. A. Britt. 1999. "Toward a Theory of Documents Representation." In *The Construction of Mental Representations during Reading*, edited by H. van Oostendorp and S. R. Goldman, 99–122. London: Lawrence Erlbaum Associates.

- Roberts, D. A. 2007. "Scientific Literacy/Science Literacy." In *Handbook of Research on Science Education*, edited by S. K. Abell and N. G. Lederman, 729–780. Mahwah, NJ: Lawrence Erlbaum Associates.
- Rouet, J.-F., and M. A. Britt. 2011. "Relevance Processes in Multiple Document Comprehension." In *Text Relevance and Learning from Text*, edited by M. T. McCrudden, J. P. Magliano, and G. Schraw, 19–52. Charlotte, NC: IAP Information Age Publishing.
- Rouet, J.-F., M. A. Britt, and A. M. Durik. 2017. "RESOLV: Readers' Representation of Reading Contexts and Tasks." *Educational Psychologist* 52 (3): 200–215. <https://doi.org/10.1080/00461520.2017.1329015>.
- Södervik, I. 2016. "Understanding Biological Concepts at University – Investigating Learning in Medical and Teacher Education." PhD diss., University of Turku. <https://www.utupub.fi/handle/10024/125029>.
- UN (United Nations). 1992. *Convention on Biological Diversity*. <https://www.cbd.int/doc/legal/cbd-en.pdf>.
- UN (United Nations). 2024. *The 17 Sustainable Development Goals*. <https://sdgs.un.org/goals>.
- University of Turku. 2024. *Degree Programme in Primary Teacher Education*. <https://opas.peppi.utu.fi/perustutkintokoulutus/kasvatustieteiden-tiedekunta/14002/13352?period=2024-2027>.
- Van Weelie, D., and A. Wals. 2002. "Making Biodiversity Meaningful through Environmental Education." *International Journal of Science Education* 24 (11): 1143–1156. <https://doi.org/10.1080/09500690210134839>.
- Vosniadou, S. 2017. "Initial and Scientific Understandings and the Problem of Conceptual Change." In *Converging Perspectives on Conceptual Change. Mapping an Emerging Paradigm in the Learning Sciences*, edited by T. G. Amin and O. Levrini, 17–25. London: Routledge. <https://doi.org/10.4324/9781315467139>.
- World Economic Forum. 2024. *The Global Risks Report 2024*. 19th ed. 1 January 2024. https://www3.weforum.org/docs/WEF_The_Global_Risks_Report_2024.pdf.