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Fieldwork Integration Into The Primary School Curriculum To Develop Complex Scientific Thinking

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Abstract

The study of complexity is an important part of science education. This paper presents a pedagogical option that includes potentially feasible field solutions for complex science teachers. This work aims to examine how fieldwork has appeared in the international literature over the past five years and to explore the algorithms that can be used to develop complex scientific thinking skills in children. This work can provide a basis for teaching science in other countries, as fieldwork can be adapted based on the learning results. We wish to draw attention to the need for a methodology for teaching fieldwork that includes examples of coenology and presents the relevant learning outcomes that could be achieved through fieldwork in primary schools.

Keywords:

Fieldwork, Networks, Thinking Skills, Outdoor Education

Introduction

Objectives for Understanding Systems, Complex Thinking, and Field Practice

Curricula are the defining units of educational systems that determine the direction and possibilities of the content of education. When we want to improve the content, for example, by integrating fieldwork with classroom teaching, it is necessary to review the curricula. Since this work aims to examine fieldwork in light of the development of systemic and complex thinking, it is essential to define the basic conceptual network.

A complex system has different smaller parts, that is, elements (Molnár et al., 2023), which perform specialized but not necessarily different functions and whose interactions result in an integrated response (Molnár et al., 2023). Many complex subnetworks are embedded in a master network at a higher level (Ngo et al., 2020).

The development of complex thinking is a cardinal issue in science education, as this challenge is always problem centered. We were curious to see whether the possibility of fieldwork in primary education is reflected in the international literature. As explained in this paper, we could not find any practical recommendations for fieldwork, therefore we set ourselves the challenge of reviewing the international

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literature to review the established use of fieldwork, and secondly, given the highly interdisciplinary nature of science in its approach to inquiry, we wanted to explore the literature background of complex thinking. Curriculum development can only be effective if it integrates knowledge from transparent literature studies, so we want to take this into account when formulating curriculum recommendations that science education professionals can put into practice. Thus, our work is multilevel, as we want to establish the theoretical background by a transparent literature review, and then, by looking for common nodes in different standards, such as the Hungarian and the US standards, we can make concrete recommendations for the development of field practice and complex thinking, all in the context of primary school. Therefore, we evaluate and synthesize the existing literature and propose a pedagogical approach to integrate fieldwork into science education. Synthesis of literature is essential to develop a curriculum that can be applied to the harmonized unity of fieldwork and complex thinking.

In this paper, our main objective is to examine how fieldwork has appeared in the international literature over the past five years and to explore the algorithms that can be used to develop complex thinking. Is it possible for the possibility of fieldwork in science education to provide a complex teaching methodology? Can fieldwork in science education provide a pedagogical methodology for teaching complexity?

Complex Thinking and Fieldwork

Developing system thinking provides an interdisciplinary approach to tackling interdisciplinary problems (Norris et al., 2022).

Maison et al. (2020) show that scientific subjects need to be strongly linked to the learning process in the environment. Considering the lack of studies relating to primary education, what can we take from the studies related to secondary and post-secondary fieldwork and systems thinking and apply to primary education? To answer this question, we wanted to look for a context in the available literature on how the development of complex thinking is applied in secondary schools and higher education, and whether all these knowledge and algorithms can be converted to the development of primary school, and whether fieldwork can be linked to all this in a way that meets the requirements of the curriculum. In the following we want to present a theoretical framework that is a prerequisite for complex thinking, in a way that will also be focused on field practice.

Conditions of Complex Thinking

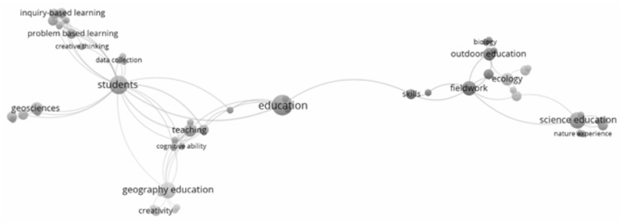
To be able to recommend an integrated approach, it is necessary to understand which basic- or higher-level thinking operations are involved in scientific thinking. We need to approach this from a critical perspective because we want to make our recommendations for curriculum development in primary schools. When reviewing the literature, field-based solutions have not been found in primary school practice, but they can represent a cardinal opportunity for the development of complex thinking. But what are the elements of thinking linked to science learning? This kind of learning is geared towards a systematic exploration of nature and, therefore, the basis for experiencing the joy of discovery and developing a scientific attitude. The joy of discovery is also an age-specific characteristic of primary school children, which curricula should help to capture, for example, by providing opportunities for children to carry out simple experiments to determine soil properties, record their results in drawings and/or writing, and thus learn the need to record and document data in nature. Since the direction of education is determined by the curriculum, the curriculum can contribute to scientific knowledge by enabling students to observe living and non-living materials in the environment, to make estimates of the size and age of deciduous trees in the forest, for example, while enriching their knowledge of species, measuring perimeter, and converting units of measurement during fieldwork. Based on the work of Momsen et al. (2022), three phases of system building are essential: 1. emergence, which means that complex systems evolve from the interaction of elements, 2. hierarchy, according to which complex systems are nested, and 3. control, which means the existence of feedback loops. Therefore, if we approach the use of fieldwork from the perspective of complex thinking, we need to synthesize the above-mentioned content when developing the curriculum. Ramírez-Montoya et al. (2022) suggests that complex thinking can be broken down into four main sub-competences: critical, systemic, scientific, and innovative thinking. Curriculum can contribute to the development of all of these by helping students understand living organisms and their communities as complex systems. The student will be able to distinguish the leaf shape of different plant species, draw it, and make a print of the trunk of a tree species, as allowed by the curriculum. According to Alsarayreh (2021), critical thinking involves extending the thinking process to make sense of context and has several components, such as interpretation, analysis, evaluation, interference, explanation, and self-regulation. These theoretical units should also form part of the curriculum linked to the field experience, as they provide the causal link between the part and the unit, but this requires conscious practical planning. It is important to note that critical thinking and problem solving are closely correlated. Critical thinking is relevant in many disciplines, including business education (Calma & Davies, 2021). Critical thinking helps to evaluate different situations and contributes to the systematization of thinking (Aktoprak & Hursen, 2022). Systems reasoning is the metacognitive system that students need to develop to analyze complex global systems. Metacognitive skills play a crucial role in cognitive activities and processes such as communication, language, perception, and attention retention (Amran et al., 2021). The development of reflective thinking is essential for a science-demanding identity (Guo et al., 2022; Ünver & Yurdakul, 2020). During fieldwork, learning conditions should be created in such a way as to give students the opportunity to reflect on the events and changes they experience, which is also part of the planning phase. There is a link between scientific thinking and mathematical skills in problem solving, elementary calculations, and estimates are essential for field education. According to Akben's work (2020), structured, semi-structured, and free problem solving activities also improve students' problem solving skills. Science learning can be effective if it is fundamentally related to everyday problems. Thus, the curriculum can support the development of all these components by enabling students to observe the main features of forest communities through experiential learning in fieldwork, as they are able to interpret the forest as a community, to recognize and explain the habitat-lifestyle-body structure relationships in forest communities, and to construct food chains based on the forest plant and animal species encountered, all through the mental application of the elements mentioned above.

Can Fieldwork Support The Development of Complex Thinking?

As shown in the previous unit, systemic thinking can be the result of the harmony of several mental processes. But can practical possibility support this process? What skills, abilities, and attitudes are required during field practice? Can the information from the results of secondary and higher education be applied to the implementation of fieldwork in primary schools? Thinking operations can be a milestone in making fieldwork fit into the curriculum. Fieldwork is a distinct group of research works that is represented in several disciplines. The definitive approach to fieldwork is to say that fieldwork is nothing more than activities carried out at least semi-outdoors in a self-contained, uncontrolled environment, which is very different from the confined environment of laboratory work (Brinitzer & Benson, 2022). When combined with a research-based approach, fieldwork can be an outstanding tool for experiential learning while developing critical thinking, problem solving, interpersonal skills, and affective skills (Praskievicz, 2023). Bloom's taxonomies are thus closely associated with the development of higher-order thinking skills (Foo & Foo, 2022). The relationship between the key concepts associated with work is illustrated in Figure 1.

Figure 1

Keywords of the studies and connection nodes (made with VOSviewer)



Learning to see the Earth as a system can develop competencies that help students to see the relationships between Earth systems and enable individuals to approach their own role in the complex whole in a reflective way. Therefore, it is necessary to emphasize that analytical and reflective thinking must be embedded in effective curriculum development. To understand the environment, students need to integrate several aspects: on the one hand, the interaction between the Earth's systems, such as the geosphere, the hydrosphere, the atmosphere, the biosphere, and, on the other hand, the human being is part of this system. This requires a higher level of thinking, such as the ability to think in systems (Vasconcelos & Orion, 2021).

Of particular importance in this context is the process of learning, which is a specific process mechanism in human society (Downey et al., 2022). So, it is already clear that the use of the previously mentioned thinking operations is reflected in the fieldwork. A biocoenosis is a unit that is a set of populations linked by direct or indirect relationships, so during the fieldwork, we can examine not only a single population but the interconnected relationship of populations, while living systems are also linked to abiotic systems such as soil, air, water and are in balance, so the relationship of cause and effect allows the development of complex thinking. However, additional skills can also be developed, including spatial skills (McNeal & Petcovic, 2020). Pfeifer et al. (2020) emphasize the role of the multicontext model of fieldwork, in which the harmony of knowledge and action plays a key role; this harmonious dual principle must also be followed by curricular requirements to develop complex thinking in students, but it also brings to life the need to provide space for outdoor activities alongside classroom teaching.

Systems can evolve into dynamic and self-sustaining networks in which regulation is an important guiding factor (Doostmohammadian & Rabiee, 2023). From a curriculum theory perspective, it is the central set of laws that determines its elements and their functioning, organizes the structure of the curriculum, and thus determines at each grade level, which elements must necessarily appear in the teaching of life communities. This must be developed in the minds of children, as it is necessary to know how or why forests, fields, lakes, etc., as communities, cannot return to their equilibrium state after the perturbations. In addition to classroom learning, fieldwork integrated into the curriculum can support the integration of theory and practice more strongly.

Fieldwork can be a good tool to improve complex thinking. From an epistemological point of view, the role of the observer (including the student who observes and analyzes in the field) is of particular importance in shaping knowledge, and the capacity to act is also distributed in a networked way, in which transdisciplinarity is of particular importance (Walsh et al., 2021; Blázquez-Salom & Blanco-Romero, 2020). Field activities are difficult to organize within the constraints of the school, but they are a way of activating the capacity for discovery and maintaining motivation, especially in science subjects where motivation to learn is significantly reduced (Aljuwaiber, 2022). To what extent can planned activities build on prior, learned, or new knowledge (Kervinen et al., 2020). In the case of new knowledge and concepts, there is an opportunity to observe the elements of a complex entity and the relationships between them (Ballantyne & Packer, 2002).

With advances in technology, Petersen et al. (2020) present the possibility of an expedition in a virtual environment. While virtual fieldwork undoubtedly contributes to the development of students' declarative knowledge, in this work, we want to emphasize the importance of immersion in a real nature. Virtual field trips support e-learning and can be a good complement to classroom instruction (Horota et al., 2023; Ocak et al., 2023). Fieldwork satisfies five essential educational development objectives: (1) environmental awareness, (2) knowledge transfer, (3) attitudes, (4) action skills, and (5) action experiences. A competency-based approach to science teaching in primary schools suggests that practical activities should be provided to children. This requires developing students' cognitive abilities, providing activities for cognitive processes, providing tasks for learners in a way that helps them to experience creative activities, and incorporating emotional elements in the cognitive process (Izatulloyevich, 2020).

Methods

Research Questions

To analyze the characteristics of complex thinking and fieldwork, two research questions were posed, as shown in Table 1.

Table 1

Themes and research questions (RQ)

Themes	Research questions (RQ)	Possible answers based on the literature
General characteristics of fieldwork	RQ1. What areas of competence can fieldwork develop?	Systematic thinking Complex thinking Critical thinking Innovative thinking
	RQ2. How can fieldwork be linked to primary education and curricula?	Curriculum analysis Key competencies

Bibliography Analysis

We considered review data collection to be important, as the theoretical basis for curriculum development requires the appropriate scientific information to be filtered. Based on the results, we intend to formulate our recommendations if we can find a link and get a relevant picture of the potential for developing fieldwork and complex thinking. Using a comprehensive literature search using three databases (Scopus, Web of Science, and Google Scholar), 648 studies were identified as relevant. Keywords used for the search were fieldwork, education, natural sciences, thinking skills, complex thinking, and primary school. The data retrieved from the searches were imported into a Microsoft Excel sheet and duplicates were removed. The following information was considered in the data extraction:

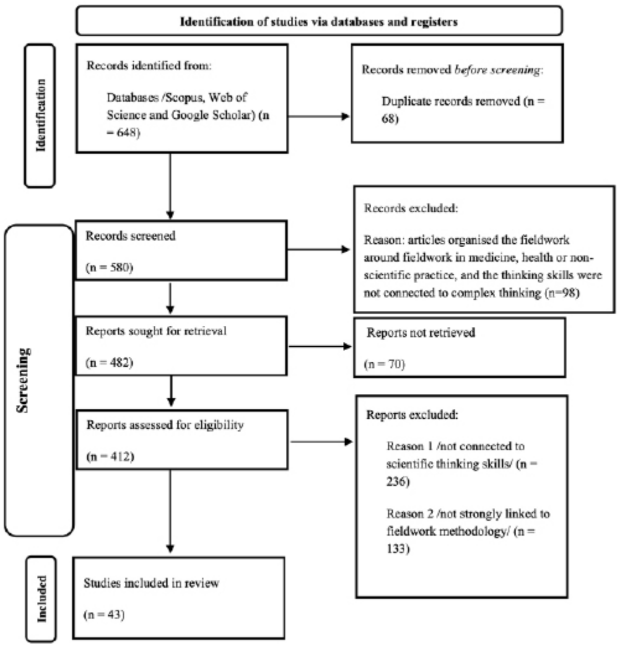
- study's characteristics,
- a bibliography including the first author,
- based on publications in the last five years.

After removing duplicates, 580 records remained. These were selected based on their titles, resulting in the exclusion of 98 reports, the exclusion was because the articles organized the fieldwork around fieldwork in medicine, health, or non-scientific practice, and the interpretations of thinking skills were not presented in a way that could be adapted to the work. The remaining reports were screened based on keywords, excluding another 70 reports. A total of 412 articles were selected to review their abstracts. After excluding another set of full-text articles for various reasons (370); only 43 articles made it to the final inclusion list, these articles have been the most effective in supporting the message of this work.

When selecting articles for the manuscript, the authors considered several criteria, including relevance, scientific reliability, and timely information. The focus was on fieldwork in education, fieldwork efficiency, and improvement of field education. Figure 2 illustrates the study selection process as per the PRISMA guidelines. In this work, the interpretation of the system theory background was not part of the review process, as the focus was on the pedagogical-psychological aspects.

Figure 2

The principle of a work-linked review process

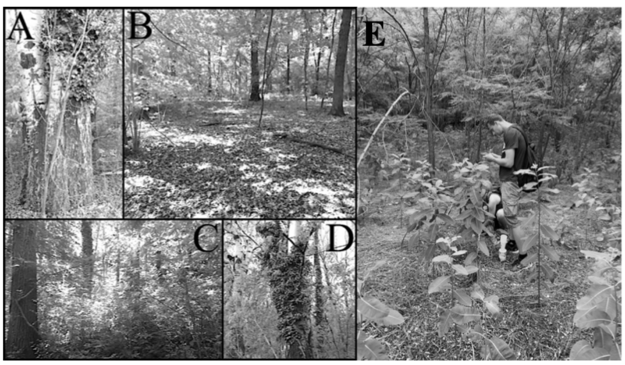


Potential Implementation Option for Field Education

The present work provides an opportunity to carry out a real-life habitat census in an outdoor educational setting with students, in a cooperative working format, where the roles of scribe, notary, timekeeper, and task manager are shared among the children, the teacher acting as facilitator. The pilot habitat is in the south-west part of the city of Hódmezővásárhely, Hungary. The pilot habitat is located close to the primary school, about 15 minutes away, so it is easily accessible on foot (Figure 3). There are residential buildings, a motorway, and a train line.

Figure 3

View of the studied forest: A: In the quadrat of the first group, with white poplar (Populus alba L.) in focus, B: In the quadrat of the second group, C: In the quadrat of the third group D: In the quadrat of the fourth group, E: working in the quadrat.



In the sampling area, 8 of the 10x10 m quadrats were designated; since this quadrat size correlates with the minimum areal size of the area, the individual plant species were assessed in the quadrats and categorized by the number of individuals and species. Families of plant species were also determined. The survey can be carried out by children working in groups and the results must be recorded in a common protocol. The students recorded the quadrat cover of seedlings and nonseedlings, which may provide them with perceptual experience of the buffering effect of forest air temperature.

Determination of The Age of Tree Species

We identified seedling and nonseedling tree species in the quadrats, then recorded the phylogenetic distribution of the nonseedling species and organized the data into a coenological table. Based on the mean diameter of the stem, the estimated age of the tree species studied within a given quadrat was determined following the work of Radó (Radó, 1999).

Associated Learning Outcomes

To adapt the work to education, we created a matrix in which we thematically identified the complex topic area to which the field study could be linked for primary school grades 5-6, and formulated learning outcomes according to Bloom's taxonomy. In outcomes-based education, learning outcomes must be clearly defined, as they determine the content and structure of the curriculum, the teaching methods and strategies, the assessment process, the learning environment, and the time allocation of the curriculum. They also provide a framework for the evaluation of the curriculum.

Limitations of The Work

The limitations of the methods described in the study are determined on the one hand by curricular requirements and on the other hand by the natural environment. However, to develop the skills and abilities needed to develop complex thinking skills related to natural sciences, it is necessary to educate and train children in nature. The methods described provide opportunities to develop thinking skills and complex scientific thinking, especially for primary school students. The limiting factor is the children's insufficient knowledge of the species, which requires pedagogical and methodological training, and the tools presented in this work make it possible to develop all these factors. The limit factor may be that we searched 3 databases for relevant literature.

Results

The results are organized thematically into three units to present the results of the literature review and to make recommendations for potential curricular improvements aimed at developing complex thinking by integrating fieldwork.

Research Questions

RQ1. What areas of competence can fieldwork develop?

Fieldwork starts with observation, which is the first step in thinking operations. The collected results need to be organized, recorded, and analyzed, which requires the student to be able to think in systems (Blázquez-Salom & Blanco-Romero, 2020; Brinitzer & Benson, 2022; Petersen et al., 2020; Vasconcelos & Orion, 2021; Walsh et al., 2021).

Environmental attitude is essential for critical thinking, as well as for experiencing the joy of exploration, while exploration is also dominant in the use of fieldwork (Janoušková et al., 2023; Maison et al., 2020). Critical thinking, analytical thinking, problem solving, and decision making skills are also important for the development of critical thinking and fieldwork (Momsen et al., 2022; Panthalookaran, 2022 Ramírez-Montoya et al., 2022). In all these processes, the individual learns that complex systems are formed by the interaction of elements and that these complex systems are also embedded in each other (Alsarayreh, 2021; Putri & Prodjosantoso, 2020). The thinking process is about finding connections, and complex, systemic, scientific, and innovative thinking, as well as problem solving skills, have been given a cardinal role in the critical thinking process and fieldwork activities (Akben, 2020; Aktoprak & Hursen, 2022; Calma & Davies, 2021; Guo et al., 2022; Moneva et al., 2020; Rini & Aldila, 2023).

Fieldwork is research-based and therefore necessarily develops critical thinking, problem solving, interpersonal skills, and affective skills (Praskievicz, 2023). As students need to be able to evaluate processes in the environment, primary school science teaching should provide children with hands-on activities. This requires developing students' cognitive abilities, providing activities for cognitive processes, and providing tasks for students to do in a way that helps them to experience creative activities. Fieldwork is interdisciplinary. Therefore, it enables the development of systemic thinking, since to interpret the processes and changes taking place in the field, on the one hand, scientific concepts have to be interpreted and then applied actively, but this also requires competences such as the competence of innovation and creative work. As fieldwork can arouse interest in interpreting phenomena in the living and non-living environment, it can vigorously develop learning competences, and field observations reveal unique phenomena for which, in addition to qualitative changes, the interpretation of quantitative changes is essential, thus developing mathematical and thinking competences.

RQ2. How can fieldwork be linked to primary education and curricula?

Scientific subjects should be strongly linked to the environment in the learning process (Maison et al., 2020) and, therefore, also to the curriculum. In our review process, we found no primary school field experience knowledge sharing over the past five years, mostly articles from higher education and secondary school experiences (Brinitzer & Benson, 2022; Brevik et al., 2022; Emery et al., 2021; Ghail & Standing, 2020; Horota et al., 2023; Ocak et al., 2023; Petersen et al., 2020; Wasieleski et al., 2021). It can develop competences in students that help them to see the connections between the systems of Earth and enable them to approach their own role in the complex whole in a reflective way (Vasconcelos & Orion, 2021), which also contributes to the development of spatial skills and higher-level thinking skills (McNeal & Petcovic, 2020; Oxenswärdh & Persson-Fischier, 2020; Siponen & Klaavuniemi, 2021). These skills can already be developed in primary school students, and as curiosity and the joy of discovery are age-specific, they can be linked to active activities in primary school.

They are also time-consuming for the teacher, but guided outdoor activities are an excellent way to motivate children. There is a close relationship between scientific and mathematical thinking and skills, which are closely associated with problem solving, observation, interpretation, analysis, synthesis, and evaluation of scientific processes. However, all this requires the systematic development of critical thinking, analytical thinking, reflective thinking, problem solving, and decision making skills (Calma & Davies, 2021; Guo et al., 2022; Janoušková et al., 2023; Maison et al., 2020; Momsen et al., 2022; Ramírez-Montoya et al., 2022; Walsh et al., 2021 Wasieleski et al., 2021). The curriculum should allow the teacher to ensure that the outcomes are met through methodological freedom in the form of extracurricular activities. This can only be achieved if the curriculum is flexible. The delivery of the curriculum can be validated through outdoor activities.

Table 2 provides a summary of the literature. The evaluation has been structured into three thematic groups according to the professional content, which allows us to link fieldwork and complex thinking.

Presentation of the data from the pilot sample in terms of learning outcomes

The following is an analysis of the diagrams of the average age of the species in each quadrat, which can mobilize the digital skills of students by allowing them to create the diagrams. The explicit development of mathematical skills is a direct objective, as they need to understand how to represent data and the need to use descriptive statistics (e.g., mean, standard deviation).

The average age can be approximated using the work of Radó. Using the average circumference of the plant individuals found in the quadrats, the age can be obtained from Radó's table according to the values given. In calculating the average age, we have plotted individuals that reached a height of 150 cm, so that their circumference could be measured in this plane, and individuals below this height are not represented in these average age diagrams. Of course, students can also record seedlings or individuals that have not reached 150 cm in height, thus obtaining a complete picture of biocoenosis.

Table 2.

Literature links between complex thinking and fieldwork

Summary aspects of professional trends in the literature	Literature linking the professional areas	
	Literature related to fieldwork	Literature related to complex thinking
System thinking requires basic analytical and systematic skills from learners, such as critical thinking, the joy of discovery, problem solving and decision-making skills, which are linked in the relevant literature. Students need to see that systems and elements are organized through interactions.	Blázquez-Salom & Blanco-Romero, 2020; Brinitzer & Benson, 2022; Petersen et al., 2020; Vasconcelos & Orion, 2021; Walsh et al., 2021; Janoušková et al., 2023; Maison et al., 2020; Momsen et al., 2022; Panthalookaran, 2022; Ramírez-Montoya et al., 2022; Alsarayreh, 2021; Putri & Prodjosantoso; 2020 Akben, 2020; Aktoprak & Hursen, 2022; Calma & Davies, 2021; Guo et al., 2022; Moneva et al., 2020; Rini & Aldila, 2023	Maison et al., 2020; Calma & Davies, 2021; Guo et al., 2022; Janoušková et al., 2023; Maison et al., 2020; Momsen et al., 2022; Ramírez-Montoya et al., 2022; Walsh et al., 2021; Wasieleski et al., 2021
Fieldwork is a research-based activity, so the development of interpersonal and emotional areas is an essential aspect of content development.	Praskievicz, 2023	McNeal & Petcovic, 2020; Oxenswärdh & Persson-Fischier, 2020; Siponen & Klaavuniemi, 2021
The demand for scientific thinking implies a complex vision through discovery, with active learning through action being of paramount importance. The mechanisms of scientific reasoning are also closely linked to analytical thinking.	Blázquez-Salom & Blanco-Romero, 2020; Brinitzer & Benson, 2022; Petersen et al., 2020; Vasconcelos & Orion, 2021; Walsh et al., 2021	Brinitzer & Benson, 2022; Brevik et al., 2022; Emery et al., 2021; Ghail & Standing, 2020; Horota et al., 2023; Ocak et al., 2023; Petersen et al., 2020; Wasieleski et al., 2021; Vasconcelos & Orion, 2021

Figure 4

Results representation of the pilot method with process tracing (1-4 quadrats)

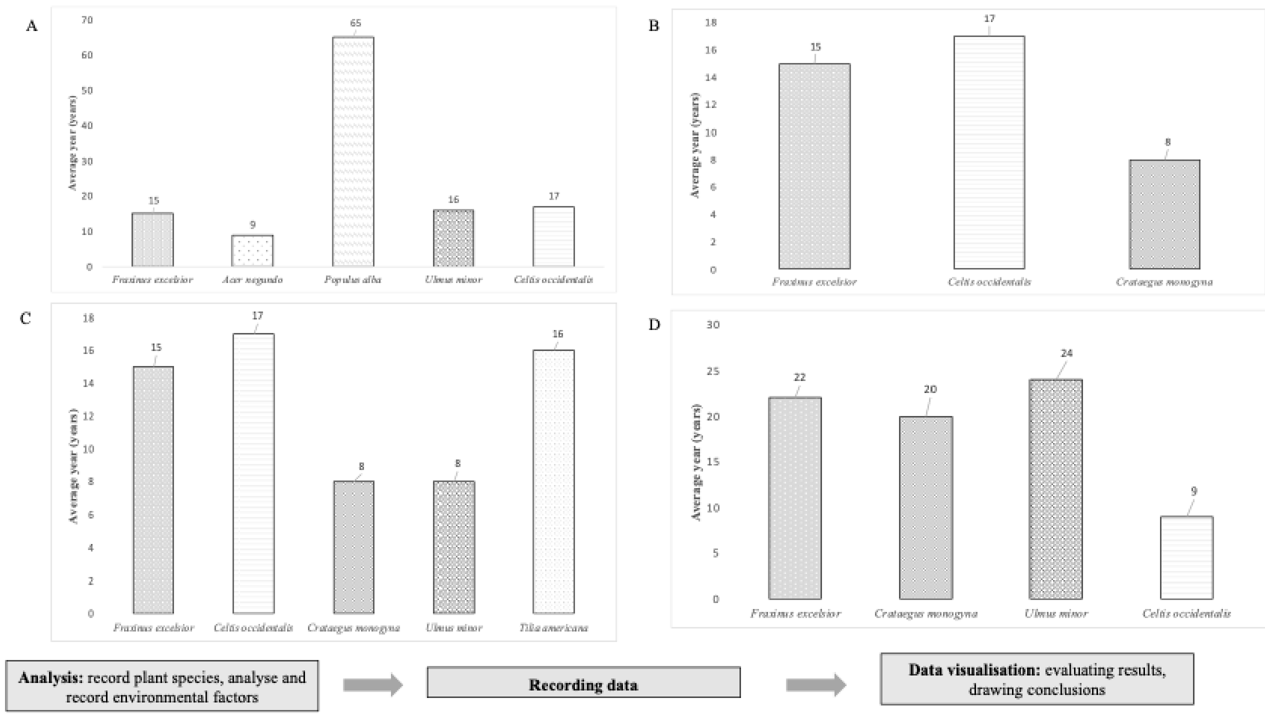


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Figure 4 shows the average age of the tree species in the four quadrats. In Figure 4 A, the white poplar is the oldest species in the quadrat studied. This species is also a typical tree of lowland forests. The green maple is the latest species to establish itself. This plant has been established in the Hungarian Great Plains since the 1960s, mainly in floodplain forests and acacia plantations, which can provide children with important information to develop a sense of responsibility for the environment. Figure 4 B shows that Crataegus monogyna (Jacq.) is the youngest plant species (children did not use the Latin names of the species), with older individuals that can be measured by quadratic metrics and have an average age. Analyzing the quadrats makes it possible to develop a habitat profile of the plant species. Tree species of similar age represent themselves in each community with a different appearance, which can mobilize children's explorative qualities.

When we look at communities in network theory, we distinguish between weak and strong connections. A network link is called weak if its removal or addition does not significantly affect a characteristic property of the network. Therefore, we can say that a network link is strong if the opposite is true. Another way of putting this is that a relationship is stronger the more likely it is that two elements that are related to each other are related to other elements that are not. Weak links play an important role in the life of networks. While strong links create small groups of closely connected elements, islands, weak links connect these islands together as a bridge. Thus, we can say that weak links hold the network together, stabilizing it (Molnár et al., 2023). Therefore, their role is essential if we want to create a functioning network. This is an exciting aspect that can be explored with the students, using the elements of quadrat four as a starting point (Figure 4 D). To what extent can the removal of certain individuals modify complexity, for example, if we consider the removal of a floodplain plant? Can environmental conditions change if an older species with a larger canopy is removed from the system? The students estimated the cover of a given plant species with and without seedlings in their quadrat, and this relationship helped them understand the relationship between cover and temperature and cover and soil moisture, among other things.

Curricular adaptation of field exercises in relation to the habitat under study

In the objective of this work, the necessity to implement field practice as a method is formulated; therefore, the following matrix summarizes the curricular units around which fieldwork and thus the experiential learning model can be fitted. In Table 2, we reviewed the curricular requirements of the 5th-6th grade science subject in primary schools in Hungary, and we have indicated where and with which curricular content it would be possible to apply field practice and with what content. We have tried to find a link between the Next Generation Science Standards for States, By States, and the curriculum we have developed. The links were provided by themes and complex thinking. When organizing the curriculum, it can be concluded that fieldwork can be implemented. The fieldwork can be applied according to the curriculum developed.

Knowledge transfer, which involves the need for the student to apply the acquired conceptual structure in a general way, plays a key role in this process. The first element of generalization, and later analogy, is comprehension, i.e., the student looks for systematic analogies, i.e., common elements or differences between concepts. The resulting concepts will be an overall pattern of experiences that interact with each other. It can be said that scientific concepts are general and abstract and can be linked to other general concepts and learned deductively. The complex nature of science also emerges, not only mathematical and biological thinking is developed, but also geographical, as the student must perceive the structure and type of soil, meteorological knowledge, and the use of spatial skills. The study is also of great value in that it enables children to interpret the study unit, but seeing the whole unit requires critical thinking since other conditions are already true for the entire structure of the biocoenosis. Logical operations using "if-then" statements are required to interpret the data as a complex unit.

We have also developed a more in-depth curriculum option, to provide a recommendation on how to implement fieldwork as a concrete curricular option. Table 4 shows the resources, student and teacher activities required and the standards to be achieved. The thematic areas of Table 3 can be linked to the recommendations presented in Table 4, which can be aligned with the pedagogical content of Table 2, as it underlines the close link between fieldwork and the possibility of developing complex thinking.

Table 3.

Specific curricular opportunities for fieldwork in relation to the Natural science subject according to the topics covered in the Hungarian curriculum. In the developed curriculum, the topics and content of the curriculum are adapted to the requirements in Hungary, and we have developed the possibility of adapting the fieldwork to these requirements to develop complex thinking. The complexity stems from the realisation that science itself is an umbrella term for a complex of disciplines with a complex knowledge base covering many areas. Scientific and mathematical skills and abilities are part of its domain of understanding, as solving problems requires a systems approach that allows for the ability to see and correctly interpret the interrelationships, i.e., to create causal unity. The aim of the curriculum developed is to provide the possibility of integrating fieldwork into the teaching of science subjects in primary school, the curriculum is adapted to the age-specific needs of students aged 10-12. In the table, we have tried to find a link between the Next Generation Science Standards (NGSS) for States, By States, and the curriculum developed in this work. NGSS also aims to provide local teachers with a flexible platform to motivate their students, which is a key objective of the pilot curriculum. The links can be interesting, as the Hungarian curriculum is mainly feeder type, while the NGSS is framework type, the didactic links that we have developed provide more scope for increasing students' activity.

Grades	Elements of the curriculum according to Hungarian legislation			Links between the Next Generation Science Standards for States, By States, and the Hungarian curriculum
	Study materials	Study contents	Didactical links to fieldwork depending on our experiments	
5th grade	Materials and their properties	The scope of the unit is to learn about the materials in the immediate environment, the composition of natural and man-made materials, their uses, and changes in composition. From the point of view of fieldwork, the main content is that the student learns about the properties of soil, its role in living systems (e.g., its role in communities), soil structure, soil formation, and soil degradation. Find the links between air, water, and soil to develop complex thinking.	Children: - recognize and identify the living/non-living properties of soil; - carry out soil tests, learn about natural processes of composting; - identify woody and herbaceous plants of the forest using simple adverbs; - carry out simple experiments to determine soil properties (color, texture, lime content, organic matter content), record findings in drawings and/or in writing, also in relation to plants and animals, use microscope to determine soil structure, living structure. As the students continuously observe the characteristics of the soil and living nature through experiential learning and understand the connections through analysis, complex thinking can be supported by fieldwork.	5-LS2-1 Ecosystems: Interactions, Energy, and Dynamics, the ability to understand the processes of matter-energy transformation also aims to develop complex thinking, including by requiring students to use model-building to interpret the movement of matter between plants-animals-environment. Communicating the mechanisms of natural events through a scientific approach is a support for complex thinking.
5th grade	Measurements, units of measurement, measuring instruments	The main knowledge content of the unit is that students learn about the measurable properties of living and non-living matter and can use different measuring instruments (e.g., length, volume, mass). Learn how to measure weather elements, record data, and plot them on graphs. Introduce the concepts of temperature, heat waves, weather, and climate.	Children: - observe living and non-living substances in the environment and classify them according to given or independently invented criteria; - can make estimates, for example, of the size and age of deciduous trees in a forest, while enriching their knowledge of species, measuring circumference, and converting units of measurement during fieldwork. Analytical and critical thinking should be applied to the field exercises, if they are linked to measurement, the results should be evaluated to draw adequate conclusions, so that the learning unit can support the development of complex thinking.	5-ESS2-2 Earth's Systems the link between the Hungarian system can be built based on measurement and mathematical standards. The students should provide evidence of the quantitative presence of freshwater and saltwater. The link can be made by developing a measurement toolkit to discuss the relationship between mass and volume. For this, even in the case of the Hungarian system, the use of mathematical and computational competence is necessary, which could also aim at developing complex thinking.

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Table 3. *Continue*

5th grade	Observing, experimenting, experiencing	The focus of this teaching unit is on the living conditions of plants, the process of precipitation formation, and the understanding of the basic processes of weather. The unit is an experiential unit primary.	Children: - recognize and observe living and non-living materials in the environment, grouping them according to given or independently invented criteria, making independent estimates, for example, of the age and size of tree species; - use photo books and smartphone applications to identify tree species and herbaceous plants; - learn about the living conditions of forest plants and the role of forests. By observing in the field, identifying plant species, and then placing them in the environment, analytical and reflective thinking is required, as well as decision making thinking skills, so that complex thinking can be developed.	5-ESS2-1 Earth's Systems can be linked to the Hungarian theme. The student, in an observational role, models the relationships between the geosphere, biosphere, hydrosphere, and atmosphere, and fieldwork can be used as an experiential learning unit, as biocoenosis treats the Earth's spheres as a unit. Models are intended to be tools for thinking, making predictions, and interpreting experiences, in some ways tools for thinking, making predictions, and interpreting experience. Conceptual models, which are the subject of this section, are, by contrast, explicit representations that are, in some ways, analogous to the phenomena they represent. In addition to theoretical model building, the fieldwork presented can turn theoretical model building into practical empirical model building.
5th grade	Basic cartographic skills, Topographical knowledge	In the teaching-learning unit, the student acquires knowledge about the characteristics of topography and its actual and relative position.	Children: - determine the direction in real space; - understand the relationship between the map and reality; - will be able to draw a thematic map of the forest, based on landmarks, and use it to orient themselves; - use a map or compass, use a smartphone to find directions, and take photographs of landmarks to locate them in real space. Identifying the actual situation, studying the habitat under study, using cartographic and topographical knowledge, and using spatial skills can support the development of complex thinking.	MS-ESS1-3 Earth's Place in the Universe is presented at the Middle School level. The interpretive potential associated with field practice can be seen at the scale level. Data can be derived from statistical information, drawings, photographs, models and linked to topographic features during the field exercise.
6th grade	The body structure of plants, The body structure of animals	In this unit, the student will acquire knowledge about the body structure of herbaceous and woody plants, learn Identify plants' life cycles, and be able to classify known plants according to given criteria. The student will also learn about animal physiology, the relationship between animal parts, and their functions. The student will identify the distinctive markings of vertebrates and invertebrates.	Children: - understand living organisms and their communities as a complex system; - is aware of the relationship between living conditions and body structure; - is aware that interference with living systems can have harmful effects, using concrete examples; - to distinguish the leaf shape of different plant species and draw a drawing of it and make an impression of the trunk of a tree species. As living organisms and environmental conditions form an inseparable unit, fieldwork supports complex thinking and the exploration of systemic relationships in the child's mind as part of the process of building knowledge.	MS-LS1-6 From Molecules to Organisms: Structures and Processes: In this unit, students will gather science-based evidence for the role of photosynthesis and the cycles of matter and energy. Based on their K-5 experiences, students can collect evidence of ecosystem processes, matter, and energy transitions during fieldwork and experience that forests are the result of cyclical changes.

Table 3. *Continue*

6th grade	Forest community and natural-environmental problems	In this unit, the students learn about the role of living and non-living factors in forest formation. The students recognize the links between vegetation and environmental needs. The students can group forest plants, to establish food webs in relation to the forest. Children observe the effects of pollution on local communities.	Children: - observe the main features of the forest communities of our country; - interpret the forest as a community of life; - recognize and explain the habitat-biota-body structure relationships in forest communities; - construct food chains and food webs based on the species of forest plants and animals encountered; - find animal tracks in the forest, take photos of them using a smartphone, share them, and make plaster casts of animal footprints. Observations in the field (plants, animals and their interactions with their environment), making food webs, already require the student to recognize the biocoenosis in a unified way, which supports systemic and complex thinking.	In MS-LS2-1 Ecosystems: Interactions, Energy, and Dynamics, the students seek evidence of how and in what ways resources are available to living things. With a focus on the causal links between the growth of individual organisms and the number of organisms in ecosystems in times of abundant and scarce resources, the opportunity to develop complex thinking can be supported by fieldwork. Collecting and interpreting data on a coenological basis supports the idea that living organisms are determined by environmental conditions MS-LS2-3 Ecosystems: Interactions, Energy, and Dynamics is a unit designed to collect evidence for interpreting the relationship between matter-energy flows between living and non-living things by describing phenomena. Fieldwork can support the description of the phenomena, which is a key to understand the matter-energy transport processes. MS-LS2-4 Ecosystems: Interactions, Energy, and Dynamics, through this unit, students will experience through fieldwork how changes in the physical or biological components of an ecosystem affect populations. Learn that ecosystems are dynamic in nature; their characteristics can change over time. MS-LS2-5 Ecosystems: Interactions, Energy, and Dynamics, the students evaluate competing design solutions to maintain biodiversity and ecosystem services, understanding forest ecosystem services and their role in maintaining biodiversity through field-based solutions.
6th grade	Earth's external and internal forces and processes	To develop the present complex thinking and the knowledge related to the field exercise, the students will be aware of the processes of soil formation, the processes and problems of soil degradation. Teaching the relationship between climate and hydrology is also a key point of the content unit.	Children: - conduct simple experiments to determine soil properties (color, texture, lime content, organic matter content), recording their findings in drawings and/or writing, the need to record, and the ability to document data; - understand the composting process and the organisms involved and their role; - be able to place soil formation processes in the natural cycle of the forest; - can be familiar with the process of soil degradation and the role of forests in reducing soil degradation. Empirical exploration of the properties of soil and the connections between the living things that inhabit it create opportunities to develop complex thinking.	In MS-ESS2-2 Earth's Systems, students seek evidence-based explanations of how Earth science processes have affected the surface of the fold. This unit of study covers the Hungarian context as well, as the focus is on the external and internal forces of the Earth, and the interpretation of temporal scales is also covered.

Table 3. *Continue*

6th grade	Basic atmospheric phenomena and processes	Students learn about the elements of climate and the characteristics of climate zones. Children learn about the relationship between weather pictograms and weather reports.	Children: - can name the elements of the climate and the seasons; - can name the climate elements and describe the changes in the climate; - carry out weather observation tasks in the forest (measuring rainfall, humidity, temperature) and record their findings in writing, on graphs, or in drawings; - observe changes in animal behavior as the weather changes, recording their experiences. By observing specific weather factors in the field and recognizing their impact on a given habitat, students engage in analytical, problem-solving, and critical thinking; while collecting data in the field, they also experience the joy of discovery, the harmonious presence of which supports the development of complex thinking in natural science.	In MS-ESS2-5 Earth's Systems, students collect data on climate and weather changes. They can interpret changes in the parameters that determine weather: temperature, pressure, humidity, precipitation, and wind. Students can examine weather diagrams and maps and adapt them to local conditions through fieldwork.

Table 4

Possibility of concrete pedagogical recommendations for the development of field practice and complex thinking. For the development of practical exercises and solutions, Table 2 can provide an overview of the pedagogical background for practitioners.

Pedagogical and methodological recommendation			
Learning about the forest as a community of life through fieldwork, implementation plan			
For children aged 10-12			
For classroom activities before fieldwork			
1.	Human resources:		Time required for classroom activities before fieldwork
		1 Science Teacher	135 min (3x45 min)
		Fifth or sixth grade students, 24 students in total	
2.	Materials for classroom activities:		
		Theoretical basis of the context of the forest as a community: deciduous trees of the forest, with particular reference to the tree species in the forest under study, insects in the forest, birds in the forest canopy, the role of shrubs in the forest community, large game in the forest, rodents and predators in the forest.	45 min needed to learn about deciduous trees in the forest, to understand the leveling of the forest, to understand the downward flow of material, the Radó's table is presented. 45 min needed for an overview of the forest insects and birds.
		The Radó table is presented, using the average trunk circumference values of the given tree species to calculate the possible age of the species.	45 min needed to learn about the mammals of the forest, students can use the Radó's table to find out the possible age of each tree species.
Students who demonstrate understanding can:			
Understand the processes of matter-energy conversion in the context of biocenosis. Ability to identify that living and non-living environmental elements (soil, water, air) and environmental factors (solar radiation, temperature, precipitation) are interrelated in a mutually determining way. Clarification: Students should be able to think in a process, recognize the main plant species from a picture, identify a plant by its leaves, bark and flowers, recognize animal species from a picture and be able to form food webs. Note: Children do not need to know or explain molecular processes.			

Table 4. *Continue*

For fieldwork activities			
			Time required for fieldwork activities
1.	Human resources:		135 min (3x45 min)
		2 Science Teacher	
		Fifth or sixth grade students, if working in 8 groups, 4 students per group, 24 students in total.	
2.	Materials for outdoor activities:		
		Measuring tape (200 cm long), four marker columns per quadrat to indicate the quadrat, a record of observations and data (trunk circumference can be recorded), writing instruments, plant identification books with photos.	The time is needed to get to the forest with the children, to be able to select, measure and mark the quadrats, to identify the tree species with the help of the plant identifiers, to record the seedling and non seedling individuals and to record the data by measuring the trunk diameter of the tree species.
Students who demonstrate understanding can:			
Ability to make simple estimates under field conditions. Understands that the community of life functions as a complex unit. Ability to model and interpret forest functioning and processes. Understand that the forest changes along the dimension of time. Ability to determine the age of individual tree species. Have a complex approach to understanding processes in nature. Clarification: students should be able to work in a disciplined way, experience natural processes, and ecological services.			
For classroom activities after fieldwork			
			Time required for classroom activities after fieldwork
1.	Human resources:		135 min (3x45 min)
		1 Science Teacher	
		Fifth or sixth grade students, 24 students in total	
2.	Materials for classroom activities:	1 computer per team with spreadsheet software (e.g., MS Excel)	45 min required to digitize the data. 45 min required to display data on graph, find the possible age of the tree species from the tree trunk circumference in the table by Rado. 45 min required to interpret the diagrams and present the data: when interpreting the data, pay attention to the oldest tree species, their role in the community, whether they are invasive species, the role of a forest in regulating microclimate, the ecological services that the community can provide (e.g. temperature buffering, water retention).
	Key outcome findings from the fieldwork:		
		Children should be able to digitize data collected in nature. Students should identify plant species and discover their role in the community. Students should be able to graph the age of the plant species found in their quadrat and present the results of the graph orally to their classmates. Students can formulate factual statements from data derived from independent exploration. For students, thinking operations (reflective thinking, analytical thinking, critical thinking) are organized in a complex way. Students make inferences about the time dynamics of the community of life.	
Students who demonstrate understanding can:			
Understand the dynamics of the community of life over time. Ability to present results through evaluative communication. Ability to construct and interpret diagrams. Ability to interpret the role of species in a community. Clarification: students should be able to digitize data, calculate the mean.			

Discussion

Human dignity as a value can only be ensured by a healthy environment, which must be made visible to children, tapping into their curiosity to explore. To maintain a state of motivation and health, we need to create optimum conditions between the natural environment and the social environment, which is also a personal need.

During evolution, terrestrial parameters enabled the formation of complex structures that are realized in living material patterns (Volvenko, 2012). However, the fact that living material patterns require abiotic and biotic conditions, and this can also be clearly traced along the lines of living communities (Cushman, 2023).

The key to understanding a system is for students to be able to understand the processes taking place in the system, the events that control and control the system on an experiential level (Molnár et al., 2023), for example, experiential learning, specifically field practice, can be a pivotal point; in this respect, we strongly recommend the use of fieldwork, which not only contributes to the development of students' competences by developing complex thinking, but also makes school work more variable. The element-system-environment cannot be separated from each other, they are closely related. In this context, it is also important to understand the functioning of biocoenoses, it is necessary to map this in the minds of the students. The complexity stems from the realization that science itself is an umbrella term for a complex of disciplines with a complex knowledge base covering many areas. Scientific attitude consists of three components: beliefs, feelings, and actions. This kind of triple unit is given in the development of complex thinking, closely linked to a scientific attitude. Feelings of pleasure in learning influence students' attitudes toward science subjects (Maison et al., 2020). In science education, it is necessary to develop scientific knowledge, critical thinking, analytical thinking, problem solving, and decision making skills (Janoušková et al., 2023), as these higher skills can be the basis for complex thinking (Panthalookaran, 2022). This is also important because complex systems, by their very nature, can be described as a power function, forming a scale-independent state (Vermeulen et al., 2020). In the teaching of complex natural sciences, this is a very important observation, because knowledge can also be built up in networks. This is, of course, also reflected in the teaching of life communities, since networks can take the form of a matter-energy flow system or even food webs (Cushman, 2023). A system is itself an entity composed of different elements; that is, it is nothing more than a total set of interrelated elements, kept in operation by the interrelationship between them (Molnár et al., 2023), an interpretation that is also true for biocoenoses, so students need to develop a mental representation that allows them to interpret the processes in living communities as a complex unit. Fieldwork can provide all of this, since outdoor activities necessarily require complex thinking, from the execution of the workflow through the execution of the tasks to the interpretation of the data.

This also requires integrative skills; for example, the development of reading skills can be combined with the development of aesthetic awareness (Alijonovna & Gozalkhan, 2022). In actual fieldwork, the student should be able to evaluate changes in the phenomena and physical processes in his/her environment. All these micro- and macro-processes can be truly learned by experiencing nature directly. What is there to observe? What needs to be measured? What should be observed next? The answers to these questions must be declared during the field exercise. There is also a significant role for data science, a rational and objective way of using the data collected (Emery et al., 2021). The logging and recording of recorded data are of cardinal importance, as Ghail & Standing (2020) point out. Critical thinking requires learners to gain experience and reflection, to actively reason by analysing and synthesising information generated or acquired, in a way that guides their actions. It can be developed from many aspects, such as through science picture books (Putri & Prodjosantoso, 2020).

The results and locations obtained should be professionally documented. It is important to plan the exercise, to prepare for the planned experiments, to check the equipment, even by making checklists. After the observations have been made, it is important to interpret and evaluate the documented results. This can be done with or without the help of preliminary questions using graphs, tables, photographs, and your own conclusions (Izatulloyevich, 2020). Another advantage of fieldwork is that it gives students a complete picture of the world, allowing them to gather knowledge holistically, whereas in the case of classroom lessons, they learn new knowledge in a subject-by-subject, lesson-by-lesson format, which they later must integrate. Although classroom learning is mostly an individual activity, fieldwork is a group activity.

During fieldwork, the teacher must play a variety of roles. These roles include specialist, teacher, and colleague. The teacher must see the children not only as students, but also as colleagues during fieldwork. Thus, participatory work, practice-based work, and context-based work are necessary for appropriate action (Islind & Norström, 2020). Taylor et al. (2021) emphasise the importance of a holistic approach in all this. Observations and results derived from the natural sciences can potentially also enhance knowledge in organizational theory (Wasieleski et al., 2021).

Technical and mathematical, digital skills and abilities are part of its domain of understanding, as solving problems requires a systems approach that allows for the ability to see and correctly interpret the interrelationships, i.e. to create a causal unity of the part-part. In their absence, processes and the forces that drive the system may become incomprehensible, and we are less likely to be able to provide relevant responses to the problems that inevitably arise. The various branches of science are also an integral part of everyday life, providing practical solutions to help individuals navigate their daily lives by understanding complexity.

As shown in the matrix presented in the results, there were many opportunities for the implementation of field sessions to satisfy the requirements of the curricula (Table 3 and Table 4).

Experimental learning is of particular importance because the students must examine and individually perceive the changes that can take place in each living community; these can help to understand the complex relationships that can also be evaluated as a service of the relevant living community (Van Driel et al., 2001).

This work may provide a basis for the teaching of science and biology in other countries, as the methodology can be adapted based on the learning results. Such educational settings provide an opportunity for children to understand the complex system of natural processes and its network structure, since, for example, plant ecology (botanical surveys, plant identification) can be used to assess and monitor the internal dynamics of communities, to characterize quantitatively the changes in the state of organization under study, the spatial and temporal transition states of vegetation, i.e., the phenomena represented by the associations of living organisms, i.e., their structure, composition, living conditions, life cycles, and the environmental factors that determine them. Using the quadrat method, we can also perform vegetation and entomological analysis by marking quadrats of a certain size in the sample area and evaluating individuals in the association. The delivery of complex curricular content is difficult to support by traditional methods (Molnár et al., 2023). Biocoenoses, as systems, can be understood as complex interwoven networks, whose nodes and network relationships are governed by interconnecting functions, such as the relationships between partners involved in competition and predation (Volvenko, 2012). One of the goals of fieldwork can be to identify the initial state, the final state, and the changes that trigger the process by identifying the changes, thus enabling students to understand the dynamics of the succession sequence. Students can learn about the biotic communities of a habitat, the characteristics (physical, chemical, biological) that cause changes in the habitat, and the factors that create and maintain them (Gosset et al., 2016). Through fieldwork, students gained skills in plant identification and illustration, scientific nomenclature, and ecological research (Bowcutt & Caulkins, 2020). Fieldwork can activate and apply thinking skills and knowledge that are already present in primary school students. The curriculum developed can provide a basis for developing the building blocks of complex thinking, e.g. critical thinking, problem-solving skills, part-whole causality assessment.

Learning outcomes can also be translated into procedural skills related to field practice. This requires that the unity of theory and practice develops a coordinated knowledge of the conceptual framework network in the students (Figure 5). High levels of problem solving, and thinking are also associated with high levels of critical thinking (Moneva et al., 2020). The need for critical thinking in conjunction with the development of media literacy is emphasized by Tommasi et al. (2023).

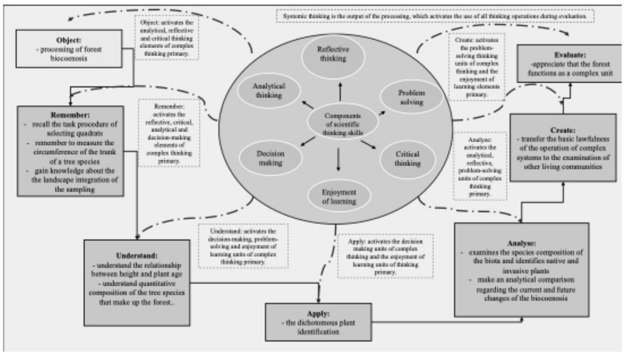

Figure 5 A scheme of complex thinking through the example of fieldwork. The figure shows the learning outcomes (in squares) in during fieldwork, which can be interpreted as a process: the initial step is object, then remember, understand, apply, analyze, create and finally evaluate processes are activated to acquire knowledge, skills and attitudes. However, the circular process also requires the application of scientific thinking skills, so the thinking skills broken down into their components are shown in the pie chart, with dashed lines indicating that scientific thinking skills need to be linked to each learning process.

Fieldwork is also significant because it can harmoniously develop the unity of theory and practice. Thinking skills associated with scientific cognition are complex skills that can be used to explain, interpret, and clarify processes, they require scientific process skills (Rini & Aldila, 2023). Natural scientific thinking is also fundamentally complicated by the need to apply the investigator's methods in the process, hence the use of quantitative methods, objectivity, and determinism. However, the system is further complicated if we approach thinking from a disciplinary perspective, because while physics, for example, investigates idealized laws, biology thinks in terms of mechanisms (Siponen & Klaavuniemi, 2021). Oxenswärdh & Persson-Fischier (2020) refer to critical thinking and problem solving as transversal skills, as today's knowledge economies place a strong emphasis on these skills, since fieldwork is interdisciplinary, we consider it necessary to integrate it into the curricula, already in the primary school system.

If we approach a problem with a complex aspect, as well as its solution or processing, systems thinking can prevail on the way to the solution. The conditions provided by the field practice support this well, also by not immobilizing the students within the walls of the school, but by implementing effective learning in nature through action and observation.

Conclusions

The complexity of social and scientific systems can be described as specific patterns of interwoven networks (Albert & Barabási, 2000). These networks are always determined by the environment and the systems that operate within them (Albert & Barabási, 2000). In this way, basic scientific regularities can be understood, for example, ecological concepts which must necessarily be developed as a complex entity in children's minds.

The limitation of this work is, on the one hand, the need to adapt the fieldwork to the curricular requirements, and, on the other hand, the present work describes a possible methodological presentation of the study of forest communities for students aged 10-12 years. It can be of particular importance for the development of complex scientific thinking. The purpose of this paper is to present a pedagogical option that includes potentially feasible field solutions for biology and complex science teachers. In our view, real-life problems are given, and students cannot solve them through one-plane thinking, it is complex thinking that allows students to interpret multiple perspectives, but this is not always available in the classroom, and the curriculum aims to emphasize this. We wish to draw attention to the need for a methodology to teach fieldwork, field exercises, and the complex vision that can be reflected in pedagogical practice, including examples of coenology, and presenting the relevant learning outcomes that can be achieved through fieldwork in primary schools.

Disclosure statement

The authors report that there are no competing interests to declare.

References

Akben, N. (2020). Effects of the problem-posing approach on students' problem solving skills and metacognitive awareness in science education. *Research in Science Education*, 50(3), 1143-1165. https://doi.org/10.1007/s11165-018-9726-7

Alijonovna, M. & D. Gozalkhan, Y. (2022). Implementation of interdisciplinarity in the teaching of reading and natural sciences. *Galaxy International Interdisciplinary Research Journal*, 10(12), 1628-1632. https://internationaljournals.co.in/index.php/giirj/article/view/3309/3057

Aljuwaiber, A. (2022). Changing attitudes through interactive learning: The impact of teaching total quality management on students' everyday lives. *Journal of Education for Business*, 97(6), 365-375. https://doi.org/10.1080/08832323.2021.1967840.

Albert, R. & Barabasi, A. L. (2000). Topology of evolving networks: local events and universality. *Physical Review Letters*, 85(24), 5234-7. https://10.1103/PhysRevLett.85.5234.

Alsarayreh, R. S. (2021). Developing critical thinking skills towards biology course using two active learning strategies. *Kıbrıslı Eğitim Bilimleri Dergisi*, 16(1), 221-237. https://10.18844/cjes.v16i1.5521

Aktoprak, A. & Hursen, C. (2022). A bibliometric and content analysis of critical thinking in primary education. *Thinking Skills and Creativity*, 44, 101029. https://doi.org/10.1016/j.tsc.2022.101029

Amran, M. S., Zain, S. M., Jamaludin, K. A., Surat, S. (2021). Thinking About Behavior: Perspective on Meta-Behavior in Education. *Frontiers in Psychology*, 2, 727116. https://doi.org/10.3389/fpsyg.2021.727116

Ballantyne, R., & Packer, J. (2002). Nature-Based Excursions: School Students' Perceptions of Learning in Natural Environments. *International Research in Geographical and Environmental Education*, 11 (3), 218–236. https://doi.org/10.1080/10382040208667488

Blázquez-Salom, M., Blanco-Romero, A. (2020). Fieldwork in ground zero, Mallorca. A methodological fieldwork proposal for a geographical analysis of tourist areas. *Investigaciones Geográficas-Spain*, 75, 43-59. https://10.14198/INGEO2020.BB

Bowcutt, F. & Caulkins, T. (2020). Co-teaching Botany and History: An interdisciplinary model for a more inclusive curriculum. *Isis*, 111(3), 614-622. https://doi.org/10.1086/711071

Brevik, E. C., Krzic, M., Muggler, C., Field, D., Hannam, J., Uchida, Y. (2022). Soil science education: A multinational look at current perspectives. *Natural Sciences Education*, 51(1), 1-21. https://doi.org/10.1002/nse2.20077

Brinitzer, C. & Benson, E. (2022). Introduction: What Is a Field? Transformations in Fields, Fieldwork, and Field Sciences since the Mid-Twentieth Century. *Isis*, 113(1), 108-113. https://doi.org/10.1086/718147

Calma, A. & Davies M. (2021). Critical thinking in business education: current outlook and future prospects. *Studies in Higher Education*, 46(11), 2279-2295. https://doi.org/10.1080/03075079.2020.1716324

Cushman, S. A. (2023). Entropy, Ecology and Evolution: Toward a Unified Philosophy of Biology. *Entropy (Basel)*, 25(3), 405. https://doi.org/10.3390/e25030405

Doostmohammadian, M., & Rabiee, H. R. (2023). Network-based control of epidemic via flattening the infection curve: high-clustered vs. low-clustered social networks. *Social Network Analysis and Mining*, 13(1), 60. https://doi.org/10.1007/s13278-023-01070-3

Downey, R. M., Downey, K. B., Jacobs, J, Korthas, H., Melchor, G. S., Speidell, A., Waguespack, H., Mulroney, S. E., Myers, A. K. (2022). Learning design in science education: perspectives from designing a graduate-level course in evidence-based teaching of science. *Advances in Physiology Education*, 46(4), 651-657. https://doi.org/10.1152/advan.00069.2022

Emery, N. C., Crispo, E., Supp, S. R., Farrell, K. J., Kerkhoff, A. J., Bledsoe, E. K., O'Donnell, K. L., McCall, A. C., Aiello-Lammens, M. E. (2021). Data science in undergraduate life science education: A need for instructor skills training. *BioScience*, 71(21), 1274-2187. https://doi.org/10.1093/biosci/biab107

Foo, S. C. & Foo, K. K. (2022). Purposeful field trip: impact on experiential learning opportunities and critical thinking skills. *Pertanika Journal of Social Sciences and Humanities*, 30(1), 1-30. https://doi.org/10.47836/pjssh.30.1.01

Ghail, R. C. & Standing, J. R. (2020). Development of an engineering geology field trip for civil engineering students. *Quarterly Journal of Engineering Geology and Hydrogeology*, 53(1), 74-87. https:// doi.org/10.1144/qjegh2019-013

Gosset, A., Ferro, Y., Durrieu, C. (2016). Methods for evaluating the pollution impact of urban wet weather discharges on biocenosis: A review. *Water Research*, 89, 330-54. https://doi.org/10.1016/j.watres.2015.11.020

Guo, X., Hao, X., Deng, W., Ji, X., Xiang, S., Hu, W. (2022). The relationship between epistemological beliefs, reflective thinking, and science identity: a structural equation modeling analysis. *International Journal of STEM Education*, 9(1), 40. https://doi.org/10.1186/s40594-022-00355-x

Horota, R. K., Rossa P., Marques A., Gonzaga L., Senger K., Cazarin C. L., Spigolon A., Veronez M. R. (2023). An immersive virtual field experience structuring method for geoscience education. *IEEE Transactions on Learning Technologies*, 16(1), 121-132. https://doi.org/10.1109/TLT.2022.320708

Islind, A. S. & Norström L. (2020). Learning sustainable work through critical design: a case study of a hackathon to prepare the future workforce. *The Journal of Workplace Learning*, 32(8), 641-65. https://doi.org/10.1108/JWL-05-2020-0082

Izatulloyevich, O. F. (2020). Methods of teaching natural sciences to primary school pupils on the basis of a competent *PalArch's Journal of Archaeology of Egypt / Egyptology*, 17(7), 11513-11526. https://archives.palarch.nl/index.php/jae/article/view/4533

Janoušková, S., Pyskatá Rathouská, L., Žák, V., Urválková, E. S. (2023). The scientific thinking and reasoning framework and its applicability to manufacturing and services firms in natural sciences. *Research in Science & Technological Education*, 41(2), 653-674. https://doi.org/10.1080/02635143.2021.1928048

Kervinen, A., Uitto, A., Juuti K. (2020). How fieldwork-oriented biology teachers establish formal outdoor education practices, *Journal of Biological Education*, 54(2), 115-128, https://doi.org/10.1080/00219266.2018.1546762

Maison, M., Haryanto, H., Ernawati, M. D. W., Ningsih, Y., Jannah, N., Puspitasari, T. O., Putra, D. S. (2020). Comparison of student attitudes towards natural sciences. *International Journal of Evaluation and Research in Education*, 9(1), 54-61. http://doi.org/10.11591/ijere.v9i1.20394

McNeal, P. M. & Petcovic, H. L. (2020). Spatial thinking and fluid Earth science education research. *Journal of Geoscience Education*, 68(4), 289-301. https://10.1080/10899995.2020.1768007

Moneva, J. C. Miralles, R. G., Rosell, J. Z. (2020). Problem solving attitude and critical thinking ability of students. *International Journal of Research-GRANTHAALAYAH*, 8(1), 138-149. http://doi.org/10.29121/granthaalayah.v8.i1.2020.261

Molnár, Zs., Gyuris, Á., Radács, M., Nemes, P., Bátori, I., Gálfi, M. (2023). Complex natural science and the challenges of its education in the 21st century. *Cogent Education*, 10, 2. https://doi.org/10.1080/2331186X.2023.2240166

Momsen, J., Speth, E. B., Wyse, S., Long, T. (2022). Using systems and systems thinking to unify biology education. *CBE—Life Sciences Education*, 21(2), es3. https://doi.org/10.1187/cbe.21-05-0118

Ngo, S. C., Percus, A. G., Burghardt, K., Lerman, K. (2020). The transsortative structure of networks. *Proceeding of The Royal Society A Mathematical, Physical and Engineering Sciences*, 476(2237), 20190772. https://doi.org/10.1098/rspa.2019.0772

Norris, M. B., Grohs J. R., Knight D. B. (2022). Investigating student approaches to scenario-based assessments of systems thinking. *Frontiers in Education*, 7, 1055403. https://doi.org/10.3389/feduc.2022.1055403

Ocak, F., Döker, M. F., Ünsal Ö. (2023). Use of web-based GIS applications in Geography teaching-The implication from Türkiye. *Journal of the Geographical Institute Jovan Cvijic SASA*, 73(1), 65-77. https://doi.org/10.2298/IJGI2301065O

Oxenswärdh A. & Persson-Fischier U. (2020). Mapping master students' processes of problem solving and learning in groups in sustainability education. *Sustainability (Switzerland)*, 12(13), 5299. https://doi.org/10.3390/su12135299

Panthalookaran, V. (2022). Beyond Bloom's taxonomy: the emergence of entrepreneurial education. *Higher Education for the Future*, 9(1), 45-61. https://doi.org/10.1177/23476311211046176

Petersen, G. B., Klingenberg, S., Mayer, R. E. Makransky, G. (2020). The virtual field trip: Investigating how to optimize immersive virtual learning in climate change education. *British Journal of Educational Technology*, 51(6), 2099-21150. https://doi.org/10.1111/bjet.12991

Pfeifer, L., Soreghan, M., Feille, K., Soreghan, G., Weissmann, G., Ibarra, R.. (2020). Activation of the multicontext model in a field-based program for traditionally underserved students. *Journal of Geoscience Education*, 69(1), 85-95. https://doi.org/10.1080/10899995.2020.1838850

Praskievicz, S. (2023). Field-based local stream research in undergraduate classes: an inquiry-based approach. *Journal of Geography in Higher Education*, 47(4), 677-684. https://doi.org/10.1080/03098265.2022.2065667

Putri, M. A. & Prodjosantoso, A. K. (2020). Improving critical thinking skills and scientific attitudes by using comics. *Psychology, Evaluation, and Technology in Educational Research*, 2(2), 69-80. https://10.33292/petier.v2i2.13

Radó, D. (1999). Bel- és külterületi fasorok EU-módszer szerinti értékelése. *Lélegzet*, 7-8., 2-12.

Ramírez-Montoya, M. S., Castillo-Martínez, I. M., Sanabria-Z, J. Miranda, J. (2022) Complex thinking in the framework of Education 4.0 and Open Innovation—A systematic literature review. *Journal of Open Innovation: Technology, Market, and Complexity*, 8(1), 4. https://doi.org/10.3390/joitmc8010004

Rini, E. F. S. & Aldila, F. T. (2023). Practicum activity: analysis of science process skills and students' critical thinking skills. *Integrated Science Education Journal*, 4(2), 54-61. https://doi.org/10.37251/isej.v4i2.322

Siponen, M. & Klaavuniemi, T. (2021). Demystifying beliefs about the natural sciences in information systems. *Journal of Information Technology*, 36(1), 56-68. https://doi.org/10.1177/0268396220901

Taylor, J., Jokela, S., Laine, M., Rajaniemi, J., Jokinen, P., Häikiö, L., Lönnqvist, A. (2021). Learning and teaching interdisciplinary skills in sustainable urban development-The case of Tampere University, Finland. *Sustainability*, 13(3), 1180. https://doi.org/10.3390/su13031180

Tommasi, F., Ceschi A., Bollarino S., Belotto S., Genero S., Sartori R. (2023). Enhancing critical thinking skills and media literacy in initial VET students: a mixed methods study on a cross-country training program. *International Journal for Research in Vocational Education and Training*, 10(2), 239-257. https://doi.org/10.13152/IJRVET.10.2.5

Ünver, G. & Yurdakul B. (2020). Developing reflective thinking through theory-practice connection; [Yansitici düsünmeyi kuram-uygulama bağlantisi yoluyla geliştirme]. *Pegem Egitim ve Ogretim Dergisi*, 10(1), 77-102. https://doi.org/10.14527/pegegog.2020.004

Van Driel, J. H., Beijaard, D., Verloop, N. (2001). Professional Development and Reform in Science Education: The Role of Teachers' Practical Knowledge. *Journal of Research in Science Teaching*, 38 (2), 137–158. https://doi.org/10.1002/1098-2736(200102)38:2<137::AID-TEA1001>3.0.CO;2-U

Vasconcelos, C. & Orion, N. (2021). Earth science education as a key component of education for sustainability. *Sustainability*, 13(3), 1316. https://doi.org/10.3390/su13031316

Vermeulen, R., Schymanski, E. L., Barabási, A. L., Miller, G. W. (2020). The exposome and health: Where chemistry meets biology. *Science*, 367(6476), 392-396. https://doi.org/10.1126/science.aay3164

Volvenko, I. V., (2012). Extremal principles and goal functions of biocenotic systems. *Biophysics*, 57, 350–362 https://doi.org/10.1134/S000635091203.

Walsh, Z., Böhme, J., Wamsler, C. (2021). Towards a relational paradigm in sustainability research, practice, and education. *Ambio*, 50, 74–84. https://doi.org/10.1007/s13280-020-01322-y

Wasieleski, D., Waddock, S., Fort, T., Guimarães-Costa, N. (2021). Natural sciences, management theory, and system transformation for sustainability. *Business & Society*, 60(1), 7-25. https://doi.org/10.1177/0007650319898384