*Biology> Big idea BOE: Organisms and their environments > Topic BOE2: Organisms in their environments*

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| **Key concept (age 11-14)** |
| **BOE2.1: Ecosystem components and dynamics** |

**What’s the big idea?**

A big idea in biology is that all organisms, including humans, depend on, interact with and affect the environments in which they live and other organisms that live there.

**How does this key concept develop understanding of the big idea?**

This key concept helps to develop the big idea by exploring the idea that the environmental conditions in different ecosystems, and in different parts of an ecosystem, affect and are affected by the organisms that live there.

The conceptual progression starts by checking understanding of what is meant by the biotic and abiotic components of an ecosystem. It then supports the development of the ideas that abiotic conditions vary within an ecosystem, that the organisms that live in an ecosystem interact with and change their environment, and how this can lead to changes within communities within ecosystems.

**Using the progression toolkit to support student learning**

Use diagnostic questions to identify quickly where your students are in their conceptual progression. Then decide how to best focus and sequence your teaching. Use further diagnostic questions and response activities to move student understanding forwards.

**Progression toolkit: Ecosystem components and dynamics**

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| **Learning focus** | The environmental conditions in different ecosystems, and in different parts of an ecosystem, affect and are affected by the organisms that live there. | | | | |
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| **As students’ conceptual understanding progresses they can:** | **C o n c e p t u a l p r o g r e s s I o n** | | | | |
| Identify abiotic and biotic components of an ecosystem.  **P** | Recognise that there are different environmental conditions in different ecosystems, and this affects what lives there.  **P** | Recognise that there are different environmental conditions within ecosystems, and this affects what lives there. | Describe ways in which animals change the environment they live in. | Describe how changes in environmental conditions may lead to population change in ecosystems.  **B** |
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| **Diagnostic questions** | Starter for ten | Ecosystems | Inside an ecosystem | Animals and their environment | Reasons why |
| What makes up an ecosystem? | What happens next? | Through the food web |
|  |  |  |  |  |  |
| **Response**  **activities** | Biotic or abiotic? | Where do you live? | From floor to canopy | Out and in | The wolves of Yellowstone National Park |
| The X factors | Flames | Reindeer of Saint Pauls Island |
| Urban fox | No more microorganisms | All change |

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| Key: | | | |
| **P** | Prior understanding from earlier stages of learning | **B** | Bridge to later stages of learning |

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| **Starter for ten** | **What makes up an ecosystem?** | **Ecosystems** | **Inside an ecosystem** | **Animals and their environment** |
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| Word association | Classifying/sorting | Confidence grid | Simple multiple choice | Two-tier multiple choice |
| **What happens next?** | **Reasons why** | **Through the food web** | **Biotic or abiotic?** | **Where do you live?** |
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| Simple multiple choice | Simple multiple choice | Confidence grid | Classifying/sorting, discussion | Discussion, card sort |

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| **The X factors** | **Urban fox** | **From floor to canopy** | **Out and in** | **Flames** |
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| Discussion | Discussion, talking heads | Discussion | Discussion | Practical PEOE |
| **No more microorganisms** | **The wolves of Yellowstone National Park** | **Reindeer of Saint Pauls Island** | **All change** |  |
|  |  |  |  |  |
| Talking heads, discussion | Discussion | Application and practice | Discussion |  |

**What’s the science story?**

An ecosystem is made up of a biological community and the physical environment in which the community lives and upon which it depends. Feeding relationships, which can be depicted using food chains and food webs, are one aspect of interdependence within ecosystems. Additional aspects of interdependence include that some producers depend upon consumers to pollinate them and to disperse their seeds, and that all organisms depend upon decomposers to break down dead organic matter. A change in the size of one population will affect the sizes of other populations in the same community.

Conditions may not be the same in all parts of an ecosystem; differences in, for example, the amounts of light, water, shelter and substances in the soil create different habitats in which different populations of organisms live. The actions of organisms can affect the environmental conditions in a habitat by adding substances to, and removing substances from, the soil, water and air. Some changes can leave individuals within populations, and some entire populations, more or less well adapted to survive and thrive there.

**What does the research say?**

*The concepts of biotic, abiotic, habitat and ecosystem*

Research suggests that students lack awareness and understanding of the interactions between the living (biotic) and non-living (abiotic) components of ecosystems. Work conducted by Adeniyi (1985) found some students aged 13-15 years old believed there was no interaction between living and non-living things in an ecosystem. Brehm et al. (1986) found that even some college students perceived that ecosystems consisted only of living things, and Prokop’s (2007) work with students aged 11-12 found that whilst students perceived living things as major components in ecosystems, they considered the abiotic components to be less essential than living things.

Word association tests have been used by researchers to identify misunderstandings about basic ecological concepts. Yucel and Ozkan (2015) using this technique found that students aged 12-14 when presented with the word ‘environment’ failed to mention non-living things other than air. Analysis showed that some of the words used by students, including ‘ecosystem’ and ‘biodiversity’, were being used because they were familiar from everyday life but without understanding of their scientific meanings. Zak and Munson (2008) used concept maps to determine elementary preservice teachers’ understanding of ecology; they discovered that concepts such as abiotic and biotic were frequently not used, suggesting that unfamiliarity and failure to use these terms is not unique to young students.

For students to appreciate and understand that humans have an impact on ecosystems they must first appreciate that humans are part of an ecosystem. Work conducted by Casper and Balgopal (2018) found that many students used the word ‘natural’ when referring to ecosystems, and that those students who defined ecosystems as natural “usually excluded human society and/or the built environment from ecosystems”. An assessment of middle school student understanding of ecological concepts found that when asked ‘What is an ecosystem?’ most students understood that an ecosystem was “a habitat” or a place where an organism lives; very few students elaborated on this with only 24% giving more sophisticated responses. Most students did not demonstrate an understanding of the interaction of multiple living and non-living parts or “a sense that these parts have varying levels of speciality” (Jordan et al., 2009). A study of 16-17-year olds found that the terms ‘ecosystem’ and ‘community’ were considered synonyms in the context of habitats. Students considered ecosystems as a larger region, and size was used as a decisive factor in discriminating between areas (Sander, Jelemenska and Kattmann, 2006).

Yücel and Özkan (2015) identified common misunderstandings related to habitats, including that habitats are only forests, or that habitats are places where only fish and other animals live. They also found that students confused the concept of ‘ecosystem’ with ‘habitat’, a confusion also observed by Adeniyi (1985) and Sander et al. (2006). Sander et al. observed the misunderstanding that the dependence of organisms on climate and other abiotic factors was one-directional; they noted how students felt that organisms, except for humans, had no influence on the change of climate.

*Interdependence of organisms (including humans) and environments*

All organisms live as members of populations in a community within an ecosystem; and all organisms compete with and are dependent upon each other for survival. A number of authors have noted the importance of learning about the interdependence (or “connectedness”) of organisms within ecosystems. As Allen (2014) has pointed out, “Anyone who is not able to fully appreciate the far-reaching impacts of changes to a single population may trivialize a media report about an endangered species, only believing that species alone is under threat, when the likelihood is that many members of an ecosystem will be adversely affected”. Many researchers have recognised the difficulties that school children have in reaching this kind of understanding, which seems to be due to misunderstandings of key ideas including how the biotic and abiotic components of ecosystems are organised, that they interact, that they are interdependent/connected, that ecosystems exist in a state of balance, and that this balance can be perturbed by changes over time (e.g. Grotzer and Bell Basca, 2003; Sander et al., 2006).

There is a common misunderstanding that humans are separate from ecosystems; Odum (1977) argued that “we are abysmally ignorant of the ecosystems of which we are dependent parts”. This could create or reinforce dangerous misunderstandings such as that our actions do not affects ecosystems, that changes in environments and non-human populations of organisms will not affect us, and that we could somehow survive without the organisms upon which we depend.

In addition, all living organisms depend upon decomposers that can break down dead organic matter and make essential elements available for reuse. Research has found that school children generally do not appreciate the important roles of microorganisms in decomposition and the recycling of carbon, nitrogen and other elements, with many associating microorganisms only with disease and associating decay only with rotting food (Brinkman and Boschhuizen, 1989; Leach et al., 1992). In one study in Isreal, almost one third of teenagers said they would eliminate all microorganisms from Earth if possible (Barenholz and Tamir, 1987).

Research in the UK, USA, Portugal and Sweden has suggested that students’ ideas about what happens to dead organic matter generally follow a progression from age 5-6, as follows (Sequeira and Freitas, 1986; Smith and Anderson, 1986; Helden, 1992; Leach et al., 1992):

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| **Age (years)** | **Thinking on what happens to dead organic matter** | **Thinking on the products of decomposition** | **Category of thinking about conservation** |
| 5 | No ideas. | There are no products, or products not considered. | Non-conservation |
|  | It simply disappears. |
| It breaks down over time by undefined ‘natural processes’. |
| It breaks down (or ‘rots’) of its own accord, and birds/rodents/insects/’bugs’ eat it. | Enriches/fertilises the soil/ground. | Partial conservation |
| Unspecified ‘microorganisms’ cause it to break down. | ‘Forms soil’ (and thus the Earth is continually getting bigger). |
| It is decomposed by bacteria and fungi. | Produces soil minerals. | Conservation |
| 16 | Decomposers use it as food. | Produces soil minerals, carbon dioxide and water. |

There is evidence that incorrect teleological explanations of interdependence – namely that some organisms exist specifically for the benefit of others (e.g. to feed them) – persist in students up to tertiary level (Brumby, 1982).

Food webs are key concepts that enable the development of understanding of more complex ecological principles and environmental issues, including population management and food security (Alexander, 1982). As Allen (2014) has pointed out, “Anyone who is not able to fully appreciate the far-reaching impacts of changes to a single population may trivialize a media report about an endangered species, only believing that species alone is under threat, when the likelihood is that many members of an ecosystem will be adversely affected”.

Griffiths and Grant (1985) drew a distinction between students’ ability to recall that populations in a food web interact, and their ability to apply that principle to predict possible effects of a change in one population on others in the same food web.

Research has shown that when students are asked to predict possible effects of a change in a population within a food web, they tend to focus only on single food chains within the web, struggle to trace changes through more than one chain, struggle to think about the impact of a change in a population more than one trophic level away, and are more able to trace changes upwards through a chain than downwards (Webb and Boltt, 1990; Leach et al., 1992; Gotwals and Songer, 2010; Griffiths and Grant, 1985; Barman, Griffiths and Okebukola, 1995). These authors and others have identified specific misunderstandings about changes in food webs that are commonly held by school children, including that:

* a change in the size of a population will only affect another population if they are related as predator-prey;
* a change in the size of a population will only affect other populations in the same food chain within a food web (and will not affect populations in other food chains within the food web);
* if the size of one population changes, all other populations in the food web will change in the same way (e.g. a decrease in one population means all other populations will also decrease).

These misunderstandings were also observed in elementary students when presented with an ecology concept test (Ozkan, Tekkaya and Geban, 2004). A study by Jin et al. (2019) investigated students’ ability to explain the interdependent relationships in ecosystems. Students were presented with real world phenomena about relations in ecosystems and their responses were graded based on the content within their explanations. Only 3% of the students were able to discuss mechanisms in their answers, and the majority of students were unable to “use systems thinking concepts to construct a causal mechanism that explains phenomena about interactions in ecosystems”. 33% of the students were able to identify distant relations and interactions in ecosystems but were not able to construct explanations, whilst most students (57%) simply explained the relationships in terms of individual organism needs.

Research therefore suggests that students may not see indirect or distant connections, and Hogan’s (2000) investigation into how students used systems thinking to reason about food web perturbations also found that they rarely recognised feedback loops and indirect relations in ecosystems.

**Guidance notes**

Many studies highlight the importance of experiencing the natural world first hand and the need for students to undertake work outside the classroom (Munson, 1997). Ballantyne and Packer (2002) suggest that students should be given the opportunity to apply the knowledge we provide them with to real life examples, which is likely to facilitate understanding. Dove et al (2012) suggest that this could be achieved by visiting attractions such as botanic gardens and zoos, particularly when studying rainforests as ecosystems, as this will allow students to appreciate the true scale of the rainforest plants. Prokop et al. (2007) identified that students had a greater understanding of ecological concepts such as ecosystems and food webs when field trips were involved. Genc et al. (2018) showed an improvement in students’ attitudes towards the environment and living organisms when they had been engaged in nature-based education. It is worthy of note however that students do not necessarily need to be taken on a school field trip to allow them to explore the natural environment; the school grounds should be utilised, and this certainly provides the perfect opportunity to explore a human-built or urban area as an ecosystem!

This Key concept relies upon an understanding of concepts developed in prior topics. If students struggle to distinguish between population and community, the role of decomposers, or in their understanding of food chains and food webs, it may be a good idea to revisit the items that address these areas in topics BOE1.1 and BOE1.2.

**References**

Adeniyi, E. O. (1985). Misconceptions of Selected Ecological Concepts Held by Some Nigerian Students. *Journal of Biological Education,* 19(4)**,** 311-316.

Alexander, S. K. (1982). Food web analysis: an ecosystem approach. *American Biology Teacher,* 44**,** 189-190.

Allen, M. (2014). *Misconceptions in Primary Science, 2nd* ednBerkshire, UK: Open University Press.

Ballantyne, R. and Packer, J. (2002). Nature-based excursions: School students' perceptions of learning in natural environments. *International Research in Geographical and Environmental Education,* 11**,** 218-236.

Barenholz, H. and Tamir, P. (1987). The design, implementation and evaluation of a microbiology course with special reference to misconceptions and concept maps. In Novak, J. D. (ed.) *Proceedings of the 2nd International Seminar: Misconceptions and Educational Strategies in Science and Mathematics, 26-29 July.* Ithaca, N.Y.: Cornell University.

Barman, C. R., Griffiths, A. K. and Okebukola, P. A. O. (1995). High school students' concepts regarding food chains and food webs: a multinational study. *International Journal of Science Education,* 17(6)**,** 775-782.

Brehm, S., et al. and Michigan State Univ, E. L. I. f. R. o. T. (1986). Ecology: A Teaching Module. Occasional Paper No. 94.

Brinkman, F. and Boschhuizen, R. (1989). Preinstructional ideas in biology: A survey in relation with different research methods on concepts of health and energy. In Voorbach, M. T. & Prick, K. G. M. (eds.) *Teacher Education 5: Research and Developments on Teacher Education in the Netherlands.* London, UK: Bloomsbury Paperbacks.

Brumby, M. N. (1982). Students' perceptions of the concept of life. *Science Education,* 66(4)**,** 613-622.

Casper, A. M. A. and Balgopal, M. M. (2018). Conceptual change in natural resource management students’ ecological literacy\*. *Environmental Education Research,* 24(8)**,** 1159-1176.

Dove, J. (2012). Tropical rainforests: a case study of UK, 13-year-olds' knowledge and understanding of these environments. 21**,** 59-70.

Genc, M., Genc, T. and Rasgele, P. G. (2018). Effects of nature-based environmental education on the attitudes of 7th grade students towards the environment and living organisms and affective tendency. *International Research in Geographical & Environmental Education,* 27(4)**,** 326-340.

Gotwals, A. W. and Songer, N. B. (2010). Reasoning up and down a food chain: using an assessment framework to investigate students' middle knowledge. *Science Education,* 94(2)**,** 259-281.

Griffiths, A. K. and Grant, B. A. C. (1985). High school student's understanding of food webs: identification of a learning hierarchy and related misconceptions. *Journal of Research in Science Teaching,* 22(5)**,** 421-436.

Grotzer, T. and Bell Basca, B. (2003). How does grasping the underlying causual structures of ecosystems impact students' understanding? *Journal of Biological Education,* 38(1)**,** 16-29.

Helden, G. (1992). Pupils' understanding of ecological processes. Kristianstad University College, Sweden: Learning in Science and Mathematics Group Working Paper.

Hogan, K. (2000). Assessing students' systems reasoning in ecology. *Journal of Biological Education,* 35(1)**,** 22-28.

Jin, H., et al. (2019). Secondary Students' Understanding of Ecosystems: A Learning Progression Approach. *International Journal of Science and Mathematics Education,* 17(2)**,** 217-235.

Jordan, R., et al. (2009). An Assessment of Students' Understanding of Ecosystem Concepts: Conflating Ecological Systems and Cycles. *Applied Environmental Education and Communication,* 8(1)**,** 40-48.

Leach, J., et al. (1992). Progression in conceptual understanding of ecological concepts by pupils aged 5-16. University of Leeds, UK: Centre for Studies in Science and Mathematics Education.

Munson, K. G. (1997). Barriers to Ecology and Sustainability Education in the U.S. Public Schools. *Contemporary Education,* 68(3)**,** 174-176.

Odum, E. P. (1977). The emergence of ecology as a new integrative discipline. *Science,* 195**,** 1289-1293.

Ozkan, O., Tekkaya, C. and Geban, O. (2004). Facilitating Conceptual Change in Students' Understanding of Ecological Concepts. Journal of Science Education and Technology.

Prokop, P., Tuncer, G. and Kvasnicak, R. (2007). Short-Term Effects of Field Programme on Students' Knowledge and Attitude toward Biology: A Slovak Experience. *Journal of Science Education and Technology,* 16(3)**,** 247-255.

Sander, E., Jelemenska, P. and Kattmann, U. (2006). Towards a Better Understanding of Ecology. *Journal of Biological Education,* 40(3)**,** 119-123.

Sequeira, M. F. and Freitas, M. (1986). Death and decomposition of living organisms: children's alternative frameworks. *11th Conference of the Association for Teacher Education in Europe.*

Smith, E. L. and Anderson, C. W. (1986). Alternative student conceptions of matter cycling in ecosystems. Paper presented to National Association of Research in Science Teaching.

Webb, P. and Boltt, G. (1990). Food chain to food web: a natural progression? *Journal of Biological Education,* 24**,** 187-190.

Yücel, E. Ö. and Özkan, M. (2015). Determination of Secondary School Students' Cognitive Structure, and Misconception in Ecological Concepts through Word Association Test. *Educational Research and Reviews,* 10(5)**,** 660-674.

Zak, K. M. and Munson, B. H. (2008). An Exploratory Study of Elementary Preservice Teachers' Understanding of Ecology Using Concept Maps. *Journal of Environmental Education,* 39(3)**,** 32-46.