



PCK Tools

Populations and Communities: Student Misconceptions and Strategies for Teaching

When we use the terms “populations” and “communities,” we generally are referring to everyday usage rather than their scientific definitions (Adeniyi, 1985). Community often is used to mean a “group of people living together with similar ideas,” and we do not distinguish between the terms population and community (Driver, et al., 1994). Krebs (1999) wrote that in popular culture people conceive of a community and population as “a group of similar living things.” However, the scientific definitions of these two terms are in fact quite distinct; moreover, they include not only people, but other organisms. A *community* is a naturally occurring assemblage of living organisms that inhabit a certain environment and interact with each other. A community consists of a variety of different species¹ interacting within a defined area (e.g. grass, flowers, trees, rabbits, squirrels, and foxes in a forest). A *population*, on the other hand, refers to a group of individuals of the same species living within a defined area. An example of a population would be all of a particular species of rabbits living within a forest. Finally, an *individual* refers to a specific organism within a population—for example, Bambi, the famous animated character, would be considered an individual within a deer population. Individuals within a population may vary slightly in some characteristics (e.g., some may be taller, shorter, thicker, or thinner than others). Some of these terms will be addressed in the section on student misconceptions.

It is important to understand that each living organism is part of an ecosystem, including humans. An *ecosystem*—a contraction of *ecological* and *system*—refers to the collection of biotic and abiotic components, processes, and interactions that function together as a unit. *Biotic* factors refer to organisms such as plant, animals, and lower-life forms such as bacteria and fungi that interact with other organisms or species within an environment. Predators such as eagles that feed on mice would count as a biotic factor, for instance. However, *biotic* factors also include the organic products of organisms within an ecosystem such as the carbohydrates produced by plants. In addition, biotic factors also include those that were once living, such as a dead leaf. *Abiotic* factors, on the other hand, relate to the nonliving factors that affect the ability of living organisms to survive in an environment, such as water, pH, oxygen, minerals, sunlight, and temperature. Introduction of new elements into an ecosystem, whether abiotic or biotic, tend to have a disruptive effect.

¹ Scientifically speaking, organisms are classified as different *species* if they are incapable of interbreeding to produce fertile offspring.

In an ecosystem, food chains and food webs describe the feeding relationships between species in a community. A *food chain* represents passage of energy through organisms in a community. The *trophic level* is the position, or feeding level, of one or more populations in a food chain. Those organisms in an ecosystem that are the same number of food-chain steps from the energy input into the system are considered to be within the same trophic level. These different trophic levels include

- third trophic level—all the secondary consumers, or heterotrophs
- second trophic level—all the primary consumers, or heterotrophs
- first trophic level—primary producers, or autotrophs

A *food web* extends the food-chain concept from a simple linear pathway to a complex network of interactions. A food web illustrates how a series of food chains are linked or interconnected and how a population can be at one trophic level in one food chain and a different trophic level in a different food chain.

The biotic components of an ecosystem include autotrophs and heterotrophs. *Autotrophs* are organisms that use light energy or chemical energy to produce all of their own organic compounds such as sugars, fats, and proteins required for their energy needs. Therefore, autotrophs are also called *producers* and are at the beginning, or bottom, of a food chain. In land-based ecosystems, producers are mostly plants, and in aquatic ecosystems, dominant producers are algae; both utilize sunlight to generate their own

State Standards

In looking at state standards at the middle-school level that address populations and communities, the following student expectations are included:

The **New Jersey Core Curriculum Content Standards** specify that by the end of 6th grade, students should be able describe and give examples of the major categories of organisms and of the characteristics shared by organisms. By the end of 8th grade, students should be able to compare and contrast kinds of organisms using their internal and external characteristics and discuss how changing environmental conditions can result in evolution or extinction of a species.

The **Texas Essential Knowledge and Skills (TEKS)** specify that during middle school, students should know the relationship between the structure and function in living systems and are expected to

- describe energy flow in living systems including food chains and food webs;
- identify how structure complements function at different levels of organization including organs, organ systems, organisms, and populations;
- identify components of an ecosystem;
- describe how systems may reach an equilibrium;
- observe and describe the role of ecological succession in maintaining an equilibrium in an ecosystem;
- observe and describe how organisms including producers, consumers, and decomposers live together in an environment and use existing resources;
- describe how different environments support different varieties of organisms;
- observe and describe the role of ecological succession in ecosystems; and
- describe interactions within ecosystems and analyze how natural or human events may have contributed to the extinction of some species.

organic compounds from carbon dioxide via photosynthesis. *Heterotrophic* organisms are considered *consumers* and need a source of organic compounds for their nutrition and energy needs, which they obtain by consuming other organisms, or their waste products. Heterotrophs include herbivores (i.e., caterpillars), carnivores (i.e., lions), omnivores (i.e., humans) and detritivores (i.e., earthworms). A *predator* is an animal that hunts and kills other organisms, called *prey*. The food chain is as follows: Tertiary consumers feed on secondary carnivores; secondary consumers (carnivores) eat the herbivores; and primary consumers are herbivores.

If there were unlimited resources and no other competing or predatory organisms, theoretically a population would increase in size exponentially indefinitely. However, in reality there are indeed many biotic and abiotic factors that limit population growth and eventually population size levels off at an average level. In fact, populations exist in a state of *dynamic equilibrium*, fluctuating in numbers around an average population size, regardless of the type of organism. When the size of a population changes, the change affects other species in an ecosystem to varying degrees. All species in an ecosystem are connected through a variety of different interactions (e.g., food webs) and relationships with abiotic factors (e.g., use of water). Each species has unique needs from and effects on the ecosystem. *Carrying capacity* is the population level that can be supported for a species given the quantity of food, habitat, water, and other life infrastructure present.

What Common Misconceptions Do Students Have Around Populations and Communities?

Most misconception research has focused on the physical sciences, with much less focused on the biological sciences and even less specifically on ecology (Munson, 1994). However, a number of misconceptions regarding populations and communities have been identified. The first task may be simply to help students understand the concepts under study. Marek (1986) investigated the impact of instruction on students' understanding of the concept of "ecosystem" and found 31% of the students had some understanding, 33% had a specific misunderstanding, and 36% provided no response, despite recent instruction (McComas, 2002). Thus, it does appear that a significant number of students, even after instruction, fail to understand the concept of ecosystem. It may also be helpful to refer to the PCK tool "Food, Food Chains, and Food Webs" to explore concepts related to ecosystems and the misconceptions associated with learning these concept.

Progression in Reasoning about Ecosystems

Driver, et al., (1994) note that students' thinking about ecosystems changes over time. Very young children have a tendency to think about ecosystems through a self-centered framework (e.g., things exist for me). This thinking can change to a more human-centered framework (e.g., things exist for humans) and then to a more expansive view that includes a wide range of factors (e.g., there can be reasons things exist not exclusive to human needs). With regard to populations, Leach, et al., (1992) found that young children tend to think in terms of individual organisms that people keep as pets (in this thinking, animals are seen as dependent on humans), while older children in middle school tend to develop

thinking about populations that includes wild animals, although some may still see a need for human care (e.g., as observed in a zoo). Finally, older children can think of populations, but tend to have a shallow understanding of the relationships between and among organisms without an underlying reason for their relationship (e.g., they may say sharks eat fish, but without an understanding that the fish provide necessary nutrition for the shark to survive). Older children are more likely to develop thinking of communities that include organisms competing for scarce resources.

Secondary students do not come with an understanding of the concepts involved in ecology. In his work on misconceptions in ecology, Adeniyi (1985) surmised that students ages 13 to 15 in Nigeria found four concepts difficult to define or describe: ecosystems, habitat, population, and community. Only 15% of students could define what community meant, while even fewer (8%) understood population in a scientific way. Students also confuse the meanings of these different concepts and conflate them with everyday meanings. Fifteen percent equated habitat with population. Twenty-seven percent equated biotic community with population. Further, the students confused the meaning of human population with the meaning of biological population or biotic community. Twenty-seven percent of students described biotic community and population in the same way as they described human community and population.

Adeniyi (1985) identified the following alternative conceptions for population and community held by students:

- An ecosystem is the relationship between living things.
- An ecosystem is the same as a population or a community.
- Populations are things in the community (e.g., population of people in community).
- Population is an area where living things occur.
- Population is the number of people/organisms in a certain area at the time (e.g., population of a country).
- Community is the biotic and abiotic components.
- Communities have the same ideas and reason together.
- Communities are the same as population.

Few students understand interdependency and use teleological reasoning. Leach, et al., (1992) found that nearly half of children between the ages of 5 and 16 could select pictures of organisms to construct a balanced community that contained a producer and primary and secondary consumers. However, few students at any age used the idea of “interdependence” to explain their selections. Most students based their choices on descriptions of their prior conceptions of nature or used teleological reasoning.

Teleological reasoning implies that form follows function—e.g., a person has ears because they have the need of hearing. Teleological reasoning therefore suggests that nature has a design or purpose. Teleological reasoning is often contrasted with *naturalism*, which implies that function follows form—e.g., a person can hear because they have ears. Naturalism therefore views nature as lacking purpose, a more scientifically accepted view point (e.g., things do not evolve towards a specific predetermined outcome, but rather as a result of random variation within a population combined with selective environmental pressures). In the case of a balanced community, students used teleological reasoning to

state that the organisms were there because one needed the other, which is like saying grass exists so that cows can eat it.

When asked which population of organisms would be the largest, most students at all ages chose producers. However, a significant number of students also chose secondary and primary consumers. Again, students were generally just describing what they saw in nature or using a teleological basis for their answer. There was little evidence of reasoning about interdependence or energy flow, although there was some progression of reasoning with age (Leach, et al., 1992).

As alluded to in the previous section, many students are egocentric and anthropocentric. Children can be self-centered by nature, especially at very early ages, so it should not be a surprise that children see the food chain as all about their needs as consumers. The species that are lower on the food chain are simply seen as there to feed the next level up (Hogan, 2000); in other words, some students think that organisms that are low on the food chain (like plants) exist simply to nourish the organisms (like animals) that feed on them.

Students are unclear about the relationship between predator and prey. Griffiths and Grant (1985) found the following misconceptions to be common to students' understanding of the relationship between predator and prey:

- A population higher on a food chain within a food web is a predator on all the organisms below it. In fact, organisms higher on the food chain feed on only some of the organisms lower on the food chain. However, almost 20% of 15-year-old students studied believed that predators feed on all below them in the food chain. As a result, these students could not solve problems involving populations that were not directly related as predator and prey.
- A change in the population of one species affects only those species related to it directly as predator or prey. Even after instruction, 16% of students still believed this to be true. This means that a significant percentage of students did not understand a basic principle of the food web concept as stated by Griffiths and Grant (1985): “[P]opulations which are not directly related as predator and prey can still influence each other because they are a part of the common food web.” Students tend to focus on direct relationships and do not consider indirect relationships.
- A change in the size of the prey population has no effect on the predator population. Students holding this belief appear to be unaware that food supply, in the form of prey population, is an important factor in determining the size of the predator population. While this misconception was found in just 6% of the sample, it was found in all of the age categories included, even by students as advanced as the 10th grade.
- If the size of one population in a food web is altered, all other populations in the web will be altered in the same way. The following response was offered by

Griffiths and Grant (1985) as representative of this misconception: “Population L will decrease because if one part of the food web decreases, this will cause populations throughout the food web to decrease because there is less food.”

More broadly stated, Griffiths and Grant (1985) and Barman, et al., (1995) along with Hogan (2000) found the following misconceptions to be common at the high-school level: “1) students tend to interpret food webs in terms of individual rather than interconnected food chains, and 2) students focus on direct rather than indirect effects of perturbations, which limits the number of steps they trace within food webs.” They focus on linear food chains, specifically the *predator-prey* relationship, in an isolated way. They only make single-step relationships between species and fail to see the wider food web. Therefore, students do not often consider broader conceptual frameworks such as cycles of matter, interdependency, or systems when making sense of ecosystems (Webb & Boltt, 1990; Driver, et al., 1994; Magntorn & Hellden, 2007).

Students do not understand the concept of producer. Similarly, Gallegos, Jerezano and Flores (1994) found that students see animals as carnivorous if they are “big and ferocious” and herbivorous if they are “passive or smaller.” Food chains are therefore determined by a student’s knowledge of feeding habits and the above mentioned preconceptions. As found with Griffiths and Grant, students simply see food chains as predator-prey relationships. Further, this means that students have not developed the concept of the *producer*. Students simply seeing a plant as the food eaten by an animal instead of understanding that a plant as the transformer of solar energy into the chemicals that the plant produces, and as the beginner of the food chain.

Students believe that ecosystems are limitless and that populations are either in growth or decline. Some students do not perceive populations as fluctuating around certain population sizes that are dependent on environmental variables. Instead, they see populations as in a state of either constant growth or decline, depending on their position in the food chain (Munson, 1991). Some students believe growth to be unlimited and can grow unlimited forever. Other students who do see ecosystems as limited in terms of resources project unlimited growth until the limits are reached, and then a population crash occurs that results in the extinction of the species. Although total population crashes do occur in natural systems, they are not the norm (Munson, 1994).

Students do not realize the impact of pollution on populations and communities. Hogan (2000) used students’ knowledge of pollution as an indicator of their ability to apply what they know about food webs. She found that students did not realize that chemical pollutants are changed in form as they move through the food chains and webs. Also, students tended to overstate the importance of the initial contact with pollutants while failing to appreciate the cumulative or concentration effect of pollution. Students in her study also were found to poorly understand eutrophication as a consequence of pollution. *Eutrophication* is the process where an ecosystem becomes enriched with dissolved nutrients, typically compounds containing nitrogen or phosphorus. Although this can occur with land or water bodies, it is most frequently discussed in terms of aquatic ecosystems.

This process generally promotes excessive plant growth and decay, favors certain weedy species over others, and is likely to cause severe reductions in water quality.

Students do not understand “what” is cycled. Magntorn and Hellden (2007) found that while students often describe the process in the ecosystem as “something is cycled,” they cannot explain what it is. Again, they make only single-step relationships between species and fail to see the wider food web. Further, students often see no cyclic relationship between producers and consumers. For example, students may not appreciate the cyclic nature of the carbon cycling between different organisms within an ecosystem— e.g., they may not appreciate that carbon-based foods such as sugars produced by plants are consumed by animals and oxidized so that waste products such as carbon dioxide can be released back into the environment, where plants can use this carbon dioxide to generate their own food.

Students do not grasp the spatial dimension of feeding relations. Eilam (2002) identified four interrelated “dimensions of understanding” ecosystems:

1. *Macrolevel dimension of feeding relations:* specific roles and order in the chain.
2. *Microlevel dimension of feeding relations:* the principle that molecules travel in and through the organisms as part of the world’s matter cycle; transfer of matter and energy in ecosystems in general and food chains in particular.
3. *Spatial dimension of feeding relations:* a dynamic view of the simultaneous occurrence of many activities in space and of organisms’ capacity to hold several roles at any point in time.
4. *Time dimension of feeding relations:* evolutionary forces that select webs rather than chains; an organism’s inability to feed on just any other organism due to its biological structure as selected in the course of evolution.” (p. 665)

Eilam argues the spatial dimension speaks most directly to populations and communities because such understanding is necessary for predicting events and developments within ecosystems, such as changes to a population’s equilibrium. Eilam found that three main difficulties characterized students’ perspectives regarding this dimension:

- The inability to grasp multiple occurrences as simultaneous (e.g., realizing that a loss of one population in an ecosystem could affect several other organisms at the same time);
- A difficulty in considering each element in the chain as occupying more than one role (e.g., realizing that bacteria could be both consumers and decomposers, or realizing that an animal may be a first-line consumer in one food chain or a second-line consumer in another food chain);
- A unidirectional perception of feeding relations (e.g., an organism might be seen as feeding on other organisms, but not be seen as being food for several other organisms). (p. 665)

These difficulties constrained students’ understanding of the web configuration.

Summary of Student Misconceptions

- Secondary students do not come with an understanding of the concepts of population and community as understood by biologists, as well as other important terms used in ecology.
- Few students understand interdependency and use teleological reasoning.
- The following misconceptions are common to student understanding about the relationship between predator and prey:
 - A population higher on a food chain within a food web is a predator on all the organisms below it.
 - A change in the population of one species would affect only those species related to it directly as predator or prey.
 - A change in the size of the prey population has no effect on the predator population.
- If the size of one population in a food web is altered, all other populations in the web will be altered in the same way.
- Students do not understand the concept of producer.
- Students believe that ecosystems are limitless and that populations are either in growth or decline.
- Students do not realize the impact of pollution on populations and communities.
- Students do not understand “what” is cycled.
- Students do not grasp the spatial dimension of feeding relations (e.g., the ability to recognize that multiple events could happen at the same time or place, that one organism could have more than one role in a food web and that that an organism could both be eating food and be food for other organisms).

What Are Some Strategies to Address Student Misconceptions About Populations and Communities?

Such ideas in ecology provide a much wider view of the world than many students are used to. Listed below are some suggestions from the research on how to reach students and help them to understand these ideas regarding populations and communities. Again, it may be helpful to refer to the PCK tool “Human Nutrition, Plant Nutrition, and the Food Chain” for further strategies.

Emphasize the scientific definitions of the concepts being studied.

Adeniyi (1985) identified population and community as two of the concepts that students find hard to define scientifically. Only 15% of students could define what community meant, while even fewer understood population (8%) in a scientific way. Make sure to start

with clear definitions of the concepts under study and address the fact that these terms are used differently in our common language outside the science classroom.

Understand and address student misconceptions.

As in other areas of science, teachers need to understand what their students believe and address the nonscientific viewpoints. Students create new knowledge and understanding based on what they already know and believe (Bransford, Brown, & Cocking, 2000). Consequently, it is important to ask students about their prior conceptions and to consider these when designing instruction. Teachers must create “a sense of ‘dissatisfaction’ with existing explanations by providing other explanations that are more powerful than the misconceptions” (Mintzes, 1984). This can be done through classroom experiences and experimentation, (e.g., germinating seeds and growing mature plants kept in the dark) along with discussion and debate about the differing notions. Such debates must take place in a “nonjudgmental atmosphere so that students feel comfortable asking questions and expressing their confusion so that they can come to understand the scientific viewpoint” (Mintzes, 1984).

Use concept mapping as a way to help students understand ecosystems.

Magntorn and Hellden (2007) used concept mapping extensively in their research to help illustrate how students understood ecosystems. The graphical structure of concept mapping has been “recognized as a powerful tool for helping students understand the notion of complex models such as ecosystems” (Kinchin, 2000). Research has shown the importance of getting familiar with concept mapping in order to make it a useful tool for students and teachers (Novak, 1993).

Teach about food chains as an interactive population.

According to Gallegos, Jerezano, and Flores (1994), food chains must be taught “not as a simple set of isolated organisms, but as an interactive population embedded in an ecological context.” As mentioned previously, the plant must be seen as a producer of chemical compounds so that in this way the flow of energy through the food chain members will be understood. It is also important to describe the various trophic levels (the position that an organism occupies in a food chain) of consumers and their relationships in their communities, and point out that organisms live in many communities in which many food webs and food chains exist.

Require students to apply knowledge in the study of ecosystems.

According to Eilam (2002), “students must personally and actively use and apply knowledge in order to:

- (a) make sense of ecology theories studied in the classroom,
- (b) construct their own relevant, interrelated bodies of knowledge about ecology, and
- (c) bring about a gradual conceptual change of ecological processes.”

Students should be able to alter their mechanical representations of food-relation concepts in order to develop “a deeper understanding of complex, dynamic, energy-and-matter-based concepts,” thereby integrating knowledge of ecology and physics.

Focus on causality to address misconceptions in ecology.

Some researchers contend that the root of many misconceptions about systems in ecology and other scientific disciplines stem from a limited understanding of the nature of causality. Use activities and or discussions that make different forms of relational causality (e.g., extended linear, two-way, and cyclic relations) explicit for the students (Hogan, 2000).

Encourage reflection.

Another strategy is to help students understand concepts in ecology is for teachers to encourage students to reflect on how their concepts have changed. For example, if students write an explanation about a phenomena or create a concept map at the beginning of the unit, have them return to it at the end of the unit to reflect on how their understandings have changed. This will enable students to check their own understanding and develop an awareness of their own progress towards understanding a given concept.

Bringing Our Population to the Scientific Viewpoint

Populations exist in a state of dynamic equilibrium, fluctuating in numbers around an average population size, regardless of the type of organism. Variations in any organism in a community can impact others. Similarly, variations in current instruction are needed to address these ecological misconceptions and bring students to the scientific viewpoint. Start by making sure that students understand the scientific definitions of the terms and concepts under study, identifying student misconceptions, and remembering that as people we tend to be egocentric and use teleological reasoning in understanding populations and communities.

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