INQUIRY & INVESTIGATION

RECOMMENDATION

Explore Your Local Biodiversity
– How School Grounds Evoke Visions of Sustainability

SONJA T. FIEDLER, THOMAS HEYNE, AND FRANZ X. BOGNER

ABSTRACT

Biodiversity and sustainability are key words of modern nature-of-science teaching. While most studies use rather abstract examples for biodiversity loss, we focused on habitats that students are familiar with. Our module was developed to deepen the understanding of domestic botanical ecosystems by having students work with and on designated pasture areas. The economic implications of sustainability were addressed by contrasting intensive and extensive agriculture, as well as by touching upon topics such as organic labels and modern agriculture. By focusing on domestic ecosystems within everyday contexts, combined with digital teaching methods, we successfully increased individual knowledge levels when taking before-and-after participation scores into account. Based on these results, we conclude that our approach to using different forms of pasture on the school grounds is a promising way to improve students’ understanding of the economic and ecological implications of sustainability.

Key Words: biodiversity; sustainability; sustainable agriculture; school garden; digital teaching methods.

Introduction

Environmentally friendly products, ecological footprints, and pollution of the environment are currently subjects of lively public discussion. Visions of sustainability in an environmental as well as social and educational context have long been integrated in school syllabi. Students have recently shown, in a worldwide movement, that they are interested in sustainability despite heavy criticism regarding their lack of knowledge in this field, especially in evaluating human impacts on earth systems (Wahlstro¨m et al., 2019).

Botany might not be students’ favorite subject; however, plants and their role in ecosystems offer a smooth transition to the core ideas of “human impacts on earth systems.” A school garden, for example, can demonstrate the relationships between abiotic factors (like water supply or light intensity) and biotic factors (such as plant growth or interspecies relations). Several studies have focused on students tending a school yard or investigating a wild backyard area (e.g., Cobb et al., 2003; Passy, 2014). Some have used different approaches, like contrasting experimental and traditional instruction styles (Poga´nrik et al., 2014) or socioeconomic influences (Moon & Spinelli, 2013). Despite employing various designs, all these studies concluded that teaching in school gardens has positive effects on emotional and cognitive scores (Nyberg, 2014; Ampuero et al., 2015; Wistoft & Dyg, 2017). There is a direct relation between students successfully gaining ecological knowledge and the proximity of the studied ecosystem to their own “natural” environment (Simonneaux & Simonneaux, 2009). This implies that subjects such as biodiversity are taught more effectively in the context of local ecosystems like pastures, instead of using extreme examples like the Amazon rainforest or the Sahara Desert. Hence, we decided to focus on the influence of human impacts on local ecosystems. The combination of plants and animals in their natural habitat and digital methods in our intervention design ensures an authentic yet pupil-based learning environment. We defined intensive agriculture as being focused on the highest yield possible by using fertilizers, insecticides, mechanization of labor, and so on. Extensive agriculture uses techniques in accordance with the natural fertility of the land, local climate, and other factors, which results in less yield per unit but is considered more environmentally friendly.

One main difference between natural habitats and those suffering under human influences is biodiversity, which includes genetic diversity, species diversity, and ecosystem diversity (Jeronen, 2019). Here, we do not focus on the latter, since we are looking at one specific ecosystem. In our latitudes, the typical pasture is manmade through thousands of years of people’s intervention.
years of cultivation and deforestation. The cultivation of plants, namely agriculture, was one of the main aspects of human evolution and has affected plant evolution as well. Maize, for example, cannot persist without humans because it is not able to spread its seeds on its own (Campbell et al., 2017). Plant breeding has been used for many generations, from long before people understood how genes and genetic transfer work. Since the latter discoveries, the impact of agriculture on plant biodiversity has been even greater. Widespread use of monocultures, for example, has influenced local biodiversity dramatically, and the cultivation of forage crops has heavily reduced species diversity (Rusch et al., 2017). Older students (ages 16–18) are already aware of ecological and economic aspects of biodiversity loss (Menzel & Bögeholz, 2009). Creating awareness of such complex issues in younger students needs something like a methodical wake-up call.

The first step is to be able to identify different species. We took into account what schools are able to provide in the way of living things that young students are able to work with and decided to use plants for taxonomy exercises. Learning scientific identification techniques and the respective scientific vocabulary is a prerequisite for understanding the important role of flowers in ecosystems. Most plants’ eye-catching appearance is a result of coevolution of plants and insects: attracting potential pollinators through nectar makes the insect touch stigma and carpel, hence spreading the pollen from one flower to the next (Occhipinti, 2013). The dependencies of insects and plants, and their implications for ecosystems, can only be fully grasped if we can identify similarities and differences between plant species. Despite its essential role in pollination and fertilization, most people cannot identify a flower’s basic structures (Menzel & Bögeholz, 2009). One reason might be the great variety of the outward appearance of the flower itself (Mader, 2009). Thus, we used a balanced combination of a theoretical framework – namely appropriate vocabulary and how to properly use an identification key – and working in the field with real flowers in their natural habitat.

Besides addressing biotic factors of ecosystems, we also focused on the abiotic ones. In intensive agriculture, farmers use fertilizer to reduce nutrient deficiencies in their plants. By doing so, they manipulate the whole surrounding natural habitat through nutrient enrichment (Hendricks et al., 2019). We want to support the idea of using organic fertilizers, naturally derived from a mix of different types of decomposed organic matter, which prevents overfertilization. Installing a compost maker at home and using its decomposed matter as a natural fertilizer can be one example for a more sustainable lifestyle on an individual level. Adding additional nutrients, such as nitrogen, not only affects the species diversity of the respective habitat but has far-reaching consequences, especially when it reaches the groundwater level. An influx of nutrients critically degrades the quality of aquatic ecosystems and adjoining terrestrial ecosystems (Barszczewski, 2017). This results in a noticeable loss of biodiversity, because plants that are specialized in certain nutrient deficiencies are overrun by less adapted and therefore fewer sensitive species, which would not be able to survive in a habitat without nutrient additions. The impact of diversity loss is not yet fully assessable, but many scientists predict heavy negative outcomes for humankind and for ecosystems in general (Cardinale, 2014; Dempsey, 2015; Roe, 2019; Rosenberg et al., 2019).

The overall aim of our learning module is to create visions of sustainability in the context of agriculture. Organic farmers use different (and sometimes more expensive) farming techniques in order to promote a healthier lifestyle for people and the land (Mader, 2009; Rusch et al., 2017). According to the U.S. Department of Agriculture (USDA), the main differences between organic and conventional farming techniques are that the latter rely on synthetically produced fertilizers, herbicides, and pesticides, whereas the former use “old” farming techniques, which rely on natural nutrition, crop rotation, and sufficient biodiversity to fight pests (see USDA, 2015). Our aim is to deepen students’ understanding of different farming techniques and their impact on local ecosystems.

**Student Learning Objectives**

After completing our learning module, students will have developed a certain sensitivity for flowers and their impact on ecosystems. They can use a taxonomic key for local flowers and are familiar with the importance of biodiversity in general. They can evaluate intensive and extensive agricultural methods in terms of profit, influence on natural habitats, and sustainability. They have rudimentary knowledge of sustainable and not-quite-as-sustainable everyday activities.

**Details of the Intervention**

Our intervention uses ecosystems that the students are familiar with as a tool to evoke visions of sustainability through connectedness to nature. It was designed to provide an authentic glimpse of different states of pasture, combined with digital teaching methods (Figure 1).

There were four separate plots of pasture, ~6 m² in size, simulating “normal” lawn, grazing land for intensive agriculture, grazing land for extensive agriculture, and insect-friendly pasture with a variety of different flowering plants (Figure 2). To create authentic plots, we sought out the help of a plant nursery that provides seed mixtures for local farmers. We gathered information about our soil (pH value, nutrition saturation, average soil moisture), and the plant nursery created seed mixtures, based on these values, of either agricultural crops or flowers (the latter mix is used in specific areas that are designed to help stabilize pollinator populations; in our setup, this seed mixture was labeled “natural”). The plots then, of course, had to be cultivated – thus introducing the students to garden work. Both intensive and extensive plots were created with the agricultural seed mix and were treated differently: the intensive area was mowed more frequently, which resulted in an overall reduced height of the plants and reduced diversity. The aim of having four plots in close proximity is that they appear to be different at first glance. Thus, when students approach the pasture area, they instantly notice significant differences between the four plots.

Our intervention covered two lessons, each lasting two hours. Teachers were required to ensure a certain level of pre-knowledge about flowers as reproductive organs. Each intervention day was designed for two student groups of about 25 pupils each, which completed the two different lessons in reversed order – that is, one group started on the pasture, while the other started in the...
so-called green classroom (Figure 3). The student groups were guided through the day by a researcher diary, which provided work assignments and space for taking notes and summarizing. The diary automatically divided students into “expert groups” with specific tasks for factor measurement on the pasture and the green classroom unit. An example diary is provided in the Supplemental Material available with the online version of this article.

Exploring the Pasture

This module was divided into two major phases: plant taxonomy and ecosystem. Students had to identify different types of plants on the basis of features like size and shape of the leaves. The identification key was provided on tablet computers with the iBlumen app (Figure 4). Students in “bring-your-own-device” classes could bring their own tablets, whereas schools that do not have access to such devices were provided with iPads on site. Although the app is intuitively designed, students were paired up during the identification part to make sure that students with little digital knowledge had peer support when facing technical difficulties.

The features shape of flower, type of inflorescence, margin of leaves, and arrangement of leaves were established beforehand. In the app, students had to choose one out of six possible values of these plant characteristics. The show button then revealed the possible solutions remaining (ideally only one). In the screenshot (Figure 4), no characteristic is marked, so show is left with all possible solutions – in this case, 1727. We ensured that all “unknown” plants used in our setup were determinable by the iBlumen app.

The students received pictures of two flowers. First, they had to find the respective flowers on the pasture. Second, they had to identify the features to find out their common names. There was a chart in the researcher diary that corresponds with the identification features of the app (Figure 5). Students had to tick the
Figure 4. Screenshots from iBlumen (English version).

Figure 5. Excerpt from the researcher diary (taxonomy).
appropriate boxes in the diary after they had determined their plants via the app. This design made it possible to also have non-tablet classes that identified their plants with a book that is commonly used in German schools. They used the same characteristics as in the app. The “unknown” species were chosen by the instructors on a day-to-day basis, because our intervention lasted longer than the flowering time of certain species. After a plenary phase in which students compared their findings with the help of the chart in the diary, they were given a third unknown flower. In this phase, the students had to establish the concept of plant families with similar features. Once again, students had to tick the correct boxes and their findings were discussed in plenary and, if necessary, corrected (Figure 5).

Parameters of an Ecosystem
The next part of the pasture module focused on the pasture ecosystem and its unique features. The pupils had to measure and record certain parameters of the ecosystem, like light intensity and soil humidity. Tablet users were able to work on a cloud-based document to save time during the summary phase. The collected data were then compared to given data from the nearby forest in order to emphasize the fact that ecosystems are defined by their abiotic and biotic features (Figure 6). To wrap up this lesson, the students completed a concept map (Figure 7).

Getting to Know the Experts
The second (or first) module of the intervention was set in the green classroom. (This part can be realized without practical work on the pasture plots beforehand, but we assume that it would not be as powerful.) In an introductory discussion, different images of the “Fridays For Future” movement were displayed (see https://fridaysforfuture.org). The pictures evoked student reactions related to sustainability and a sustainable lifestyle (e.g., “no plastic,” “global warming kills polar bears”). The instructor used these reactions to shift the focus to sustainability on a local level. Standardized questions – like “Is global warming only bad for the polar bears’ living space? How about the area where we live?” – in combination with the overall topic “pasture” were used to guide the students toward sustainability in agriculture. The pupils were divided by random selection into four groups. Each group was provided with material linked to the comparison of intensive and extensive agriculture from a certain “expert angle” (see Table 1).

Group 1 watched an interview with a “normal” farmer (using intensive methods). After watching the video, the students had to answer certain questions related to the information given in the interview. Group 3 had the same objective, but the farmer used extensive methods. Groups 2 and 4 were provided interactive presentations focused on a local politician and a member of an NGO. For details on the experts, see Table 1, which also provides suggestions for two additional experts (marked in gray) that were designed...
Table 1. Expert angles with core ideas.

| Expert                     | Core Ideas                                                                 |
|---------------------------|---------------------------------------------------------------------------|
| **Farmer**                | More fertilizing, more mowing → less biodiversity                        |
|                           | More return (fodder)                                                     |
|                           | Less environmentally friendly → no organic label                          |
|                           | “Normal” products are usually underpriced → struggle                     |
| **Organic Farmer**        | Less fertilizing, less mowing → more biodiversity                         |
|                           | Less return (fodder)                                                     |
|                           | More environmentally friendly → organic label                             |
|                           | Products with organic labels are, on average, more expensive              |
| **NGO-Member**            | What is an ecosystem?                                                    |
|                           | Why is biodiversity important?                                            |
|                           | How to preserve biodiversity                                              |
|                           | Visions of sustainability (environment)                                   |
| **Politician**            | Struggles of local farmers → subsidies                                    |
|                           | Strict regulations for organic farming                                    |
|                           | Strict regulations for environmental protection                           |
|                           | Visions of sustainability (society)                                       |
| **Engineer (Sewage Plant)**| Soil sealing problems in big cities                                       |
|                           | Nutrient input on groundwater level                                       |
|                           | Issues caused by heavy rain (drainage system)                            |
|                           | Climate change and its effect on cities                                   |
| **Organic Grocery Store Owner** | What is an organic label?                              |
|                           | Regulations for organic groceries                                        |
|                           | Organic farming techniques                                                |
|                           | Sustainable food                                                          |
for more urban areas, where farming might not be as present in the students’ perception. The script for the expert interviews as well as the instructions are available in the Supplemental Material.

The results of the group work were presented in the form of an expert discussion, in which two pupils from each group usually argued from the point of view of “their” expert. This setup illustrated the ongoing discussion in society.

**Visions of Sustainability**

In the second phase, the pupils went back into their core groups. They were given a selection of environmentally friendly measures related to agriculture. They were asked to select four out of 12 measures and to design a digital poster on a tablet with Adobe Spark Post (one tablet per group; see Figure 8). The measures that students could select from are available in the Supplemental Material. These posters were then presented to the class via wireless projection. Once again, the students had to argue and justify why they had selected these four measures. In a concluding class discussion, the importance of a sustainable lifestyle was highlighted. The pupils wrote down their “visions of sustainability” in their workbook or tablet.

**Alignment with NGSS**

The learning unit was designed to meet several elements of the *Next Generation Science Standards* (NGSS). It obviously contains Science and Engineering Practices, as the students perform standard taxonomic procedures and interpret data. Crosscutting Concepts are met in Systems and System Models (boundaries of the ecosystem “grassland”), Structure and Function (of reproductive organs of plants), Stability and Change (stability of abiotic and biotic factors of ecosystems determine their overall stability), as well as Cause and Effect (different methods of farming result in changes of the affected ecosystems). Biological Core Ideas are represented in ESS3.C (human impacts on earth systems), LS2.A (interdependent relationships in ecosystems), LS2.C (ecosystem dynamics, functioning, and resilience), and LS4.D (biodiversity and humans). Scientific Method Core Ideas are addressed as mentioned in MS-LS2-4 (“Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations”) and MS-LS2-5 (“Evaluate competing design solutions for maintaining biodiversity and ecosystem services”).

**Conclusion**

The learning unit is designed to expand to further issues, such as including digital working methods in “outdoor biology,” monitoring students’ attitudes toward and perception of environmental issues over a longer period, and fostering environmentally friendly thinking in young students. It succeeds in bringing a rather complex vision of a more sustainable lifestyle to the awareness of young students. Therefore, it fills a knowledge gap that has been left open by curricula until now. Young people call for information about biodiversity, ecosystems, ecology, and sustainable development, which we provide with this program. Botanical knowledge of form and function is also deepened. The contents align with NGSS in multiple dimensions and can be integrated into existing syllabi.

Establishing pasture plots according to our outline can also be easily achieved – and even provides more opportunities for biological hands-on learning.

**Acknowledgments**

We thank the Wild-Park Klaushof in Bad Kissingen for supporting us in the creation of different pasture areas. We also thank the...
Bavarian Ministry of Education for permitting our study. Financial support has been provided by both the University of Bayreuth and the University of Würzburg.

References

Ampuero, D., Miranda, C.E., Delgado, L.E., Goyen, S. & Weaver, S. (2015). Empathy and critical thinking: primary students solving local environmental problems through outdoor learning. *Journal of Adventure Education & Outdoor Learning*, 15(1), 64–78.

Barszczewski, J. (2017). Diversified fertilization and its effect on yields and the content of mineral nitrogen forms in soil and ground water. *Journal of Research and Applications in Agricultural Engineering*, 62(3), 13–20.

Campbell, N.A., Urry, L.A., Cain, M.L., Wasserman, S.A. & Minorsky, P.V. (2017). *Biology: A Global Approach*. London: Pearson Higher Ed.

Cardinale, B. (2014). Overlooked local biodiversity loss. *Science*, 344, 1098–1098.

Cobb, P., Confrey, J., diSessa, A.A., Lehrer, R. & Schauble, L. (2003). Design experiments in educational research. *Educational Researcher*, 32, 9.

Dempsey, J. (2015). Fixing biodiversity loss. *Environment and Planning A*, 47, 2555–2572.

Hendricks, G.S., Shukla, S., Roka, F.M., Sishodia, R.P., Obreza, T.A., Hochmuth, G.J. & Colee, J. (2019). Economic and environmental consequences of overfertilization under extreme weather conditions. *Journal of Soil and Water Conservation*, 74, 160–171.

Jeronen, E. (2019). Biodiversity: sustainability. In S. Idowu, R. Schmidpeter, N. Capaldi, L. Zhu, M. Del Baldo & R. Abreu (Eds.), *Encyclopedia of Sustainable Management*. Dordrecht, The Netherlands: Springer.

Mader, S.S. (2009). *Concepts of Biology*. Boston, MA: McGraw-Hill.

Menzel, S. & Bögeholz, S. (2009). The loss of biodiversity as a challenge for sustainable development: how do pupils in Chile and Germany perceive resource dilemmas? *Research in Science Education*, 39, 429–447.

Moon, C. & Spinelli, R. (2013). Elementary school gardens and the community. https://digitalcommons.calpoly.edu/cgi/viewcontent.cgi?article=1142&context=soessp.

National Research Council (1996). *National Science Education Standards*. Washington, DC: National Academies Press.

Nyberg, L. (2014). Seeding science in elementary schools. *Science and Children*, 51(7), 84.

Occhipinti, A. (2013). Plant coevolution: evidences and new challenges. *Journal of Plant Interactions*, 8(3), 188–196.

Passy, R. (2014). School gardens: teaching and learning outside the front door. *Education 3-13*, 42(1), 23–38.

Pogačnik, M., Žnidarčič, D. & Strgar, J. (2019). A school garden in biotechnical education. *Archives of Biological Sciences*, 66, 785–792.

Roe, D. (2019). Biodiversity loss – more than an environmental emergency. *Lancet Planetary Health*, 3(7), e287–e289.

Rosenberg, K.V., Dokter, A.M., Blancher, P.J., Sauer, J.R., Smith, A.C., Smith, P.A. & Marra, P.P. (2019). Decline of the North American avifauna. *Science*, 366, 120–124.

Rusch, A., Bommarco, R. & Ekblom, B. (2017). Conservation biological control in agricultural landscapes. *Advances in Botanical Research*, 81, 333–360.

Shiwakoti, S., Zheljazkov, V.D., Gollany, H.T., Kleber, M., Xing, B. & Astatkie, T. (2019). Micronutrients in the soil and wheat: impact of 84 years of organic or synthetic fertilization and crop residue management. *Agronomy*, 9, 646.

Simonneaux, L. & Simonneaux, J. (2009). Socio-scientific reasoning influenced by identities. *Cultural Studies of Science Education*, 4, 705–711.

USDA (2015). Organic practices fact sheet. https://www.ams.usda.gov/sites/default/files/media/Organic%20Practices%20Factsheet.pdf.

Wahlström, M., Kocycba, P., De Vyd, M. & de Moor (Eds.) (2019). Protest for a future: composition, mobilization and motives of the participants in Fridays For Future climate protests on 15 March, 2019 in 13 European cities. https://protestinstitut.eu/wp-content/uploads/2019/07/20190709_Protest-for-a-Future_GCS-Descriptive-Report.pdf.

Wistoft, K. & Dys, P.M. (2017). Wellbeing and social relations in school gardens: the case of the gardens for bellies food and environmental education program. *Environmental Education Research*, 24, 1177–1191.

SONJA T. FIEDLER is a Research Assistant in Didactics of Biology, University of Würzburg Biocenter, Würzburg, Germany; e-mail: sonja.fiedler@uni-wuerzburg.de. THOMAS HEYNE is a Project Manager in the Professional School of Education, University of Würzburg; e-mail: thomas.heyne@biozentrum.uni-wuerzburg.de.

FRANZ X. BÖGNER is a Professor of Didactics of Biology and Head of the Department of Biology Education, University of Bayreuth, Bayreuth, Germany; e-mail: franz.boegner@uni-bayreuth.de.