Child-led inquiry in stream ecosystems:

a lesson plan for a democratic school setting

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Abstract

This lesson plan aims to support a group of unschooling students between ages 7 and 13 in developing scientific skills. Because this learning setting gives children much greater agency than most schools, it is an ideal setting for child-directed inquiry, but it also requires that lessons be genuinely related to the children's experiences and passions to provoke successful participation. Stream ecosystems are compelling to children and engage their natural desires to investigate. This lesson expands the children's playful explorations of stream ecosystems into an inquiry process, by meeting and learning from professional stream ecologists, as well as by practicing reflection, gathering questions, and identifying actionable questions as a group. The goals are for students to 1) build skills in scientific inquiry, and recognize that they are capable of answering their own questions through direct investigation; and 2) recognize biotic and abiotic markers of stream quality, and distinguish between healthy and impaired streams.

Instructional Context

The participants in this water quality project are an unusual group: they are 12 homeschooled children who meet three mornings a week for "nature unschool," an egalitarian educational group based out of a parent's home. The children range in age from seven to 13, and have varied family approaches to homeschooling the rest of the week, including self-directed unschooling, online courses, Waldorf-based curriculum, and learning based around the family farm.

At the nature unschool, adult mentors (including myself) facilitate a combination of nature-centered activities, student-determined activities, and free time in nature. The goals of the group are two-fold: 1, to be a community in which homeschooled children can work as a group on projects and learning activities that they are empowered to choose and direct themselves, with support from thoughtful adults; and 2, to provide regular, consistent time in nature with mentors knowledgeable about the natural world and its stewardship. Influential philosophies on our day-to-day activities include unschooling, democratic schools (also called free or Sudbury schools), coyote mentoring (Young, Haas, and McGown, 2010), and forest kindergartens.

The mixed-age setting increases the need for differentiated instruction. It is also an asset to differentiation, as individual students can work on the task that is most appropriate for where they are, regardless of their age. For example, most of the 10- to 13-year-olds are displaying interest and ability to focus for a relatively long period of time on written or building projects. But one of the older children, D, has shorter bursts of attention for relatively sedentary projects, and much more focus for boisterous, physically active activities. In an inquiry, D might engage best with some of the shorter and/or more active tasks that I would invite the younger children to do, but I can give her opportunities to participate in either set of tasks, since both are available. This avoids both pigeonholing her, or pushing her into an area that she is just not ready for. Similarly, one of the more bookish nine-year-olds is ready for the older group's tasks.

Having mixed ages also provides opportunities for both younger and older children to deepen their learning experience in particular ways. Peter Gray (2004) observed that when adolescents interacted with younger children, the younger children were likely to be playing and working in their zone of proximal development. Conversely, the adolescents were placed in a leadership role, requiring them to explicitly communicate and teach knowledge that they may not have had to articulate before. At our unschool, we have noticed this gives children a chance to experience both being leaders and followers: the 7-year-old who dominates his peers may defer to the pre-teens, and a quiet pre-teen may direct younger children, even if she doesn't assert herself in the other pre-teens' decision-making. Ideally, the lesson plan will have features that encourage and take advantage of this dynamic. Instructional scaffolding is an educational technique in which teachers support and model skills and understandings that are just above a student's current capabilities, gradually removing that support until students are able to perform those skills and understandings independently. Gray (2004) points out that scaffolding can be provided by older children as well, as they are often just one or two stages ahead of younger children and can model their skills to other children. This lesson plan aims to scaffold inquiry skills so that children can implement their own inquiries; in its ideal implementation, it holds opportunities for other children to perform scaffolding for others in the group.

Sobel (2008) proposes that certain patterns of fascinations may occur in children at particular ages, and that addressing these topics at the right age is likely to synergize with the child's motivations and passions. Creek meandering is surely one of these. Few children can resist the pull to wade into the water, turn things over, and wander up the course of the creek. These activities aim to leverage that fascination into experiencing elements of scientific inquiry.

Instructional Input

Habitat degradation is a major concern for biodiversity preservation, as land use change and water pollution are among the top reasons for the current wave of extinctions (Schipper et al., 2008). Streams and rivers are not exempt from these injuries. In the Columbia, Missouri area, where the nature unschool meets, impacts from urbanization are top concerns for streams: underplanned land development is causing sedimentation, erosion of riparian corridors, and contamination from over-taxed sewage systems (Baumer, 2007; Stranko et al, 2011).

Nutrient overload, causing eutrophication, is another problem for freshwater quality. The US Environmental Protection Agency estimates that 40% of streams and rivers in the U.S. are impaired by nitrogen and phosphorus (USEPA, 1996). Missouri streams pass through prime glacial till farmland, accumulating ammonia, nitrogen and phosphorus from run-off of agricultural fertilizers. These nutrients can be toxic to aquatic animals and invertebrates. They can also cause algal blooms that change the competitiveness of the system's species, leading to changes in the community composition. These changes include increase in plant species tolerant of low light, and a decrease in Ephemeroptera, Plecoptera, and Trichoptera taxa (Baattrup-Pederson et al., 2015; Wang et al., 2007) . Because of the accumulative nature of stream system, downstream rivers and seas are directly determined by upstream health. Upstream eutrophication in the Missouri-Mississippi River watershed accumulates into the hypoxic "Dead Zone" in the Gulf of Mexico. The high nutrient concentration feeds enormous algal blooms, which cause dissolved oxygen to plummet, suffocating fish and other marine life (Dodds and Welch, 2000; Meyer et al., 2007).

Yet children growing up in degraded habitats may not recognize the difference between a healthy stream, a degraded stream, or a stream that has become something entirely novel, due to what Miller calls the “extinction of experience” (2005). Since children have not experienced streams in their original states, they do not realize that previous generations enjoyed streams of greater biodiversity, streams that flooded less, or streams posing fewer health threats to the children playing in them; the degraded state becomes their new baseline. Even depending on which streams are most accessible from their homes, children may grow up with varied baseline expectations for what is acceptable environmental quality. By understanding aquatic biodiversity, and the habitat features that support it, they will be able to distinguish between well-functioning and impaired streams, and consider actions to help.

Biological measures of water quality use the presence of pollution tolerant or intolerant species to evaluate the health of streams. Species using headwater streams and medium streams include various algaes, bacteria, benthic macroinvertebrate (including Ephemeroptera spp., Plecoptera spp., Trichoptera spp., and Odonata spp.), salamanders, and fishes, many of which are found only in headwaters (Meyer et al., 2007). Benthic macroinvertebrate richness has been found to decline in richness in response to sedimentation, and especially the specific indicator taxon of Trichoptera (Ramezani et al., 2014). Other studies have supported the use of macroinvertebrate indices as tools for assessing stream health impacted by a variety of stressors, and the “Biological Criteria for Wadeable Streams of Missouri” uses Taxa Richness (TR), Ephemeroptera/Plecoptera/Trichoptera Taxa Index (EPTT), the Biota Index (BI), and the Shannon Diversity Index (SDI) as official measures of stream health in Missouri (Sarver et al., 2002).

Diversity of aquatic species can be seen and measured by primary children gathering samples with nets. This makes these methods superior to chemical testing for water quality for young children, who have not yet developed the level of abstract thought to fully understand the meaning of invisible processes. In addition to sampling aquatic species, the children can learn to identify abiotic elements that support or impair aquatic species. Varied microhabitats within streams, including riffles, pools, leaf packs and log jams, and sandbars, may all be favored by different macroinvertebrates (Gregory, 2005). Sedimentation may be measured and visually understood with simple tools, such as the Secchi disk.

Lesson Plan

Goals

Education to create scientific and environmental literacy is one part of the response to declining stream biodiversity. The environmental literacy goal of this lesson is for students to recognize biotic and abiotic diversity in stream ecosystems and recognize differences between more and less healthy streams. The scientific literacy goal is for students to practice forming questions about the natural world, forming ways to answer those questions, and seeing themselves as co-creators of knowledge about their local environment.

Standards addressed

Standards are from the North American Association for Environmental Education's (NAAEE) Guidelines for Learning (K-12), which set guidelines for excellence in environmental education, rather than the Missouri state science standards. Because of the mixed ages of students, both the K-4th grade standards and the 6th-8th grade standards are used in parallel, with the 6th-8th grade standards deepening the same basic concepts used for the K-4th ages. Strands addressed include Strand 1: Questioning, Analysis and Interpretation Skills, Strand 2.2: The Living Environment, and Strand 2.4: Environment and Society. See Appendix 1 for complete standards.

Day 1: Engaging interest in investigating aquatic ecosystems

1. **Engaging interest at morning circle:** Share that we will be visiting several creeks repeatedly over the next few weeks, and will have the chance to meet professionals who work with creeks in various ways.

Ask students what living things and nonliving things they have seen in creeks, introducing the words "biotic" and "abiotic" for the older children. What do they see as evidence that a creek is healthy or unhealthy? On a large piece of poster paper titled "What we know about creeks," draw a diagram of a creek with the elements they mention.

2. **Engaging interest at creek A (Bonne Femme Creek):** Allow the students 1.5 to 2 hours for free exploration and play in the creek. Bring collection bins and simple nets for students interested in gathering creatures, and engage with the students as they make discoveries: Ask them questions about their fish and invertebrates, such as where they found them, what the creatures were doing, and what be supporting the fishes' needs.

3. **Practicing reflection at the creek A:** Save ten minutes before closing circle for private reflection. Explain that reflecting on what you experience in nature is an important step in understanding it. Students should choose a private sit spot along the creek, far enough away from

other students that they cannot speak to them. They have a choice of writing down some of the natural phenomena they observed, drawing them, or simply sitting and observing with all of their senses. Whatever they choose, ask that they keep these minutes silent to respect the students who are deeply involved in what they are doing.

Gather up for a closing circle. Ask the students to share some of what they wrote/drew in the journals, or thought about while sitting. Use the poster we made of the creek at morning circle to add any new observations. Questions to ask include: Based on what you saw in the creek today, what should we add to what we know about creeks? What different plants and animals did you discover, and where were they? The diagram of the creek should, by the end, include stream microhabitats, including riffles, pools, and leafpacks or logjams.

Add a section to the poster entitled "Questions." Some questions will naturally emerge as students share their observations, and write those down throughout the conversation. Towards the end of the conversation, ask directly what questions they thought of today. Also ask what questions they might have for the stream ecologists they will meet on days 2 and 3.

Days 2 and 3: Scaffolding skills in water quality assessment and scientific field methods

1. **Learning new skills (scientific field methods):** On Day 2, Corey Dunn, PhD student researcher at the Missouri Cooperative Fish and Wildlife Research Unit, will visit to share different methods for capturing fish, including kick nets, dip nets and traps. Students will assist in setting up the traps and using the nets. Corey will show techniques for basic fish ID and share some of the characteristics of the fish and their needs. After spending 1 -2 hours exploring what they have caught with Corey, students will be invited to ask Corey some of the questions they brainstormed.

Continue the end of day routine established on day 1: Students spend ten minutes writing, drawing, or quietly sitting to reflect on something they saw and learned today. Then, in circle, have students share those reflections. While sharing, write new additions on the “what we know” and “questions” sections of the poster. If any questions have been answered today, add the answers and the evidence that supports that answer to the poster.

2. **Learning new skills (water quality assessment):** We will have a visit from the Missouri Department of Conservation (MDC), either stream ecologist Seth Lanning or a representative from the Missouri Stream Team program. They will lead students through a biological water quality assessment, using the presence of pollution tolerant or intolerant macroinvertebrate and fish species to draw conclusions about the water quality. All students will likely be involved in sampling species, and interested students may do the calculations for objective scores of species richness. The MDC guest will also share about the research done by MDC, compare the stream we are visiting to other Missouri streams, and share how the MDC uses similar data collected by volunteers.

Continue the end of day routine of reflection, sharing, and recording new knowledge, new questions, and newly-found answers.

Day 4: Inviting inquiry and action

1. **Integrating at morning circle at Bonne Femme Creek (Creek A):** Return to the first creek we visited, Bonne Femme Creek. Review all the knowledge, answered questions, and unanswered questions we’ve gathered over the last three days at the creek. How have their perceptions of the creek changed? Discuss how agricultural and urban run-off and land use change are causes of the different conditions of the creeks we visited.

Share examples of how children have taken conservation action or conducted their own research, including from Missouri Stream Teams, the Leafpack Network (http://www.leafpacknetwork.org), and Dragonfly Magazine. Invite interested students to sign up for a "Young Scientists" group to conduct research or action projects.

2. Creating projects in the Young Scientists group: Those children who are uninterested in joining the Young Scientists group can continue having free exploration and play in the creek. With the Young Scientists group, however, it is time to support participants in planning a project and carrying it out.

Review the unanswered questions from days 1 - 3 as a group. This can be related to the scientific process: they have investigated a phenomenon and are now focusing on a question (Llewellyn, 2011). Determine the questions we are most interested in, and figure out if they are *answerable* questions. Arizona State University's question tree can be used as a tool for determining good, testable questions (SCENE). Alternatively or complementarily, action projects such as community service may be the most interesting to students, and the group can also narrow down a focus for that.

At this point, the adult mentor will need to evaluate and plan the next steps for the group based on the interests and intentions set by the children. The group may be ready to plan ways to test the question, or may need further learning experiences to be able to test it. They may need to meet other community members to carry out their project. There is opportunity for peer leadership: the leaders in the Young Scientist group could ask other children to assist in data collection (even if they did not participate in experiment design) or in tasks that need done to pull off the action component. If conducting research, be sure to follow through with the steps of drawing conclusions and evaluating how reliable those conclusions are. The routine of reflecting at the end of the day and sharing at circle is a good setting for those conversations.

Reflection

Planning content for a group of children who have true choice in how they want to learn can be challenging: to stay true to the principles of unschooling, the mentor must be willing to follow the children's initiatives and interests, rather than charting out their curriculum for them.

However, when we see a pursuit that sparks intrigue in the children -- such as exploring a creek -- we can plan both learning strategies and content knowledge to offer at the right moment. Unschooling is a model more concerned with *how* to learn than what to learn, and inquiry is one strategy of how to learn. By having a model of inquiry in our "lesson plans", we can respond to unschoolers' curiosity with a tool that helps them pursue it. In this lesson, I could plan for content area knowledge that lets me respond to the children's interests as they explore the creek, by developing my own background knowledge on stream ecology, and connecting to local professionals in stream ecology, provides me. In conjunction, holding a model of inquiry out to the unschoolers gives them a scaffold to deepen their own learning, while keeping it in their hands.

Connecting with community professionals is particularly important in this lesson, because the principles of unschooling hold that students can learn directly from the world. As such, learning by interacting with real-world professionals gives the students a better chance to engage with the material, be motivated, and gain relevant, applicable knowledge, compared to me bringing them a classroom-style lesson.

I also anticipate that the creek setting itself will be an important part of supporting a group so diverse in interests, ages, and attention. It provides many nooks and crannies for students to engage with the aspect of the “lesson” most appropriate to their interest and developmental stage -- some may stay continually in the “exploring and investigating” stage of day one, while others go on to designing investigations. Because of the outdoor setting, this can be accommodated without disrupting one another.

While this lesson provides much support to enable students to make sense of stream ecology, students may face challenges with designing an inquiry, as they might not have seen many examples of constructing experiments. Before or alongside this creek unit, it may be beneficial to have already established the Young Scientists group, and run several guided experiments of various kinds, unrelated to creeks. I believe this would be better as a complementary unit than part of the stream project, as students may struggle to follow their own questions about the creek if they have had teacher-guided creek experiments modeled for them first.

Creeks seem to be one of childhood’s passions:children are natural investigators and stewards of streams. Their playful explorations provide opportunity to invite them to further inquiry and action. We can extend that invitation by modeling practices of reflection on their experiences in nature, and by connecting them to adults doing work relevant to their passions.

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Appendix 1: Standards met by this lesson in the North American Association for Environmental Education's "Guidelines for Excellence (K-12)"

- Strand 1: Learners are able to...
  - in the K - 4th grade age range
    - A. develop questions that help them learn about the environment and do simple investigations.
    - B. design simple investigations
    - C. locate and collect information about the environment and environmental topics
    - E. describe data and organize information to search for relationships and patterns concerning the environment and environmental topics.
    - Develop simple explanations that address their questions about the environment
  - In the 6th-8th grade age range:
    - A. develop, focus and explain questions that help them learn about the environment and do environmental investigations
    - B. design environmental investigations to answer particular questions -- often their own questions.
    - C. locate and collect reliable information about the environment or environmental topics using a variety of methods and sources.
    - E. classify and order data, and organize and display information in ways that help analysis and interpretation
    - G. synthesize their observations and findings into coherent explanations
- Strand 2.2: Learners understand…
  - In the K-4th grade age range:
    - A. basic similarities and differences among similarities and differences among a wide variety of living organisms. They understand the concept of habitat.
    - C. basic ways in which organisms are related to their environment and other organisms.
  - In the 6th-8th grade range:
    - A. Biotic communities are made up of plants and animals that are adapted to live in particular environments.
    - C. Major kinds of interactions among organisms or populations of organisms.
- Strand 2.4: Learners understand…

- In the K-4th grade age range:
  - A. People depend on, change and are affected by the environment.
  - E. Learners are familiar with some local environmental issues and understand that people in other places experience environmental issues as well.
- In the 6th-8th grade age range:
  - A. Learners understand that human-caused changes have consequences for the immediate environment as well as for other places and future times.
  - Learners are familiar with a range of environmental issues at scales that range from local to national to global. They understand that people in other places around the world experience environmental issues similar to the ones they are concerned about locally.