Seamless Assessment in Science

A Guide for Elementary and Middle School Teachers

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T

earchers of science face the incredibly complex task of combining what we know about how students learn, science content that in itself is complicated and often difficult to understand, and scientific inquiry. Then, as if this were not enough, they have to assess the results of their teaching—student understanding. Reasons for avoiding science in the elementary school are not hard to come by. It would be nice if elementary—and for that matter, middle school—teachers had some helpful assistance through this educational maze. Well, they do. This little book, *Seamless Assessment in Science*, provides practical suggestions that will help all elementary and middle school teachers, both preservice and inservice. Let me say more about some of the book’s features, especially the 5E instructional model.

In the late 1980s my colleagues and I at Biological Sciences Curriculum Study (BSCS) received funding to develop a new program for elementary school science. As we began working, we confronted a fundamental problem—how could we incorporate research on learning in a way that was helpful for teachers? In particular, we had to balance what researchers described as a constructivist model of learning and the classroom constraints that elementary and middle school teachers face. Further, we had to create a program that teachers could comprehend and apply in order to achieve positive results in student learning. In short, the model had to be understandable, manageable, and practical. We adapted a model originally developed by Bob Karplus and colleagues and used it in the new BSCS program. We realized the model worked, so we also used it in BSCS programs for middle and high school. That said, I could not have imagined the widespread use of the BSCS 5E model two decades later. The
model has been used in state frameworks, other science programs, and now in this guidebook for elementary and middle school teachers.

At the time of our original work, I maintained that the 5E instructional model was a necessary but not sufficient condition to bring about conceptual change within the structure of school science programs. The model provided adequate time and appropriate opportunities for conceptual change. But there remained the critical interaction between teacher and student. The burden of student learning is too heavy to place exclusively on an instructional model. The teacher remains the essential link between instructional materials and student learning. All of this said, Sandra Abell and Mark Volkmann have provided a wonderful extension to the 5E model. They have added an assessment component that complements each phase of the model and helps teachers identify their students’ current science ideas (engage), determine how students are building understanding (explore), review students’ new understanding (explain), demonstrate their ability to apply new understandings (elaborate), and determine what students have learned from lessons (evaluate). This seamless use of assessment definitely enhances the 5E model. As for the criteria stated earlier, the model is still understandable, manageable, and practical. But now it is better!

In addition to practical assessment strategies, Seamless Assessment in Science incorporates recent research on how students learn. The book provides an excellent bridge between research and practice. Further, it also does this for the important area of scientific inquiry, as described in the National Science Education Standards.

In this era of assessment, all of us have learned that assessment is more than a test. Seamless Assessment in Science is a sophisticated and practical resource for all elementary and middle school teachers. It is the kind of book one reads and thinks, “I wish I would have done that.” Well, Sandra Abell and Mark Volkmann did, and both elementary and middle school teachers and their students will be better because they did.

Rodger W. Bybee
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This book grew out of our experiences as science teachers and science teacher educators. While teaching science, we have struggled with knowing how our students are thinking and how to help them understand science better. The idea of seamless assessment took seed as we worked through these struggles alone in our classrooms. A few years ago the seed sprouted when we together recognized the potential of linking science assessment with science teaching through an instructional sequence called the 5E model. This link helped us see assessment in a new light and helped us build assessment purposefully into our instruction.

As the seed, firmly rooted in a well-accepted instructional model, started to grow, we thought about how to communicate our ideas beyond our own classrooms. In 2003, we presented our ideas about seamless assessment at the National Science Teachers Association (NSTA) national conference in Philadelphia. The participants in that session responded enthusiastically and prompted us to disseminate our ideas. Our seedling idea of seamless assessment was taking on more leaves and becoming sturdier. Thanks to encouragement from Chris Ohana, editor of NSTA’s *Science and Children* journal, who attended our NSTA session, we translated our conference paper into a published article (Volkmann and Abell 2003).

Not long after the article appeared in press, Robin Najar from Heinemann contacted us about the possibility of turning our ideas into a book. We thank Robin for having the vision to grow our seedling into a tree. Her confidence in us provided the motivation that led our tree to bear fruit.
However, it is not easy to nurture a growing plant. We realized that input from classroom teachers would be essential enrichment. Thus, we found a group of local teachers who were willing to cultivate seamless assessment in their own classrooms. We collaborated with them, listened to their stories of science teaching, learning, and assessment, and integrated their stories into this book. We cannot begin to express our admiration and appreciation of these teachers. Their most important job is helping students learn, and they spend countless hours in the pursuit of excellence in science education. Yet they took time to write their stories, from which others can learn.

Our goal in writing this book is to help preservice and practicing elementary and middle school teachers of science think about science teaching, learning, and assessment as a seamless act. Chapter 1 sets the stage by outlining what counts as learning and what the standards say about assessment. In Chapter 2, we describe the 5E model of science instruction and introduce our notion of seamless assessment, which is linked to that model. We also share a variety of strategies for enacting seamless assessment. In Chapters 3, 4, and 5 we present examples of classrooms engaged in inquiry-based science instruction and seamless assessment. We have organized these chapters by science discipline. Chapter 3 focuses on life science examples, Chapter 4 on the physical sciences, and Chapter 5 on earth and space science. In each chapter, we include vignettes of science classrooms at the primary (K–3), intermediate (4–5), and middle school (6–8) levels. These vignettes, written by us and by our elementary and middle school teacher collaborators, tell stories of teaching, learning, and assessment in science classrooms. We believe that these examples, grounded in the real world of classroom teaching, will help others plan, enact, and learn from seamless assessment in science education. In the final chapter of the book, we present a summary of the seamless assessment model and what we learned by both employing it in our science teaching and using it to organize writing about our experiences. We conclude with a challenge to all teachers to incorporate inquiry-based instruction and seamless assessment into elementary and middle school science classrooms.

Our greatest hope is that readers of this volume will find the seeds of seamless assessment taking root in their own science instruction. Our ultimate goal is to grow a sustainable forest in which all students learn science.

Sandra Abell and Mark Volkmann
Columbia, Missouri
3 Seamless Assessment in Life Science

■ Introduction

The vignettes in this chapter are based on 5E units of instruction carried out with primary (grades 1–3), intermediate (grades 4–5), and middle-level (grades 6–8) science students. In these units, teachers aimed to develop students’ conceptual understanding about organisms, life cycles and reproduction, and ecosystems. Each vignette illustrates how teachers used seamless assessment to plan and inform their instruction. Table 3-1 describes the grade levels, topics, and assessment strategies used in the vignettes.

Life science topics are commonly taught in elementary and middle school classrooms. Many teachers enjoy teaching life science topics, perhaps because they have confidence in their own understanding or have a close personal connection to nature. In our classrooms, studying the life sciences should take students beyond knowing the names of plants or the classification of the animal kingdom, beyond planting bean seeds or observing classroom animals. Studying the life sciences should address important big ideas about the living world. That is what the units in this chapter attempt to do.

In the first vignette, Sandra Abell observes a first-grade teacher who asks her students, “How is a plant different from an animal?” Students grow plants with a purpose—to understand how some plants start as seeds, whereas some animals start as eggs. This age-appropriate investigation of a basic biological idea helps students build a foundation for learning other life science concepts.

In the next vignette, Michele Lee works with a group of fourth graders to help them recognize the link between plants and animals. Most of the inquiry that her students engage in is minds-on, rather than hands-on. With the
Seamless Assessment in Life Science

In the guidance of an expert teacher, the students use their thinking skills to make sense of an important life science idea that all animals depend on plants for food. Michele’s vignette illustrates the care that teachers must take when helping intermediate-age students connect several ideas into a coordinated whole.

In the third vignette, Marsha Tyson and Kelly Turnbough report on their collective experience with teaching reproduction at the middle level. Although the topic is personally relevant for middle-level students, it is often taught as a

Table 3-1 Life Science Vignettes by Grade Level, Topic, and Assessment Strategy

<table>
<thead>
<tr>
<th>Vignette</th>
<th>Grade Level</th>
<th>Topic</th>
<th>Assessment Strategies</th>
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<tbody>
<tr>
<td>Seeds and Eggs</td>
<td>1</td>
<td>Plants versus animals</td>
<td>Engage: sorting sheet; scientists’ meeting</td>
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<td></td>
<td>Explore: individual science notebook drawings; group alike/different chart; scientists’ meeting</td>
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<td></td>
<td></td>
<td></td>
<td>Explain: whole-class plant/animal chart</td>
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<td></td>
<td>Elaborate/Evaluate: group plant/animal identification game; constructed-response answering sheet</td>
</tr>
<tr>
<td>It All Goes Back</td>
<td>4</td>
<td>Importance of plants</td>
<td>Engage: group discussion with teacher-directed questions</td>
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<tr>
<td>to Plants</td>
<td></td>
<td></td>
<td>Explore: collaborative chart</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Explain: exit ticket</td>
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<td></td>
<td></td>
<td></td>
<td>Elaborate: team report</td>
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<td></td>
<td></td>
<td></td>
<td>Evaluate: scenario exam</td>
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<tr>
<td>What’s the Anther?</td>
<td>6</td>
<td>Plant reproduction</td>
<td>Engage: field trip notebook; discussion</td>
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<td></td>
<td></td>
<td></td>
<td>Explore: Fast Plant drawings; poster</td>
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<td>Explain: diagram labeling</td>
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<td>Elaborate: think, pair, share; Venn diagram intersection</td>
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<td></td>
<td>Evaluate: cycle diagram; student-generated Venn diagrams</td>
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<tr>
<td>Water You Know</td>
<td>7</td>
<td>Water ecosystem</td>
<td>Engage: water meter</td>
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<td></td>
<td>Explore: water quality survey</td>
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<td></td>
<td>Explain: water quality table and class booklet</td>
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<td></td>
<td>Elaborate: eco-mystery</td>
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<td></td>
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<td></td>
<td>Evaluate: conference presentation</td>
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set of terms to be memorized. Marsha and Kelly use a structure-function approach instead, which engages students in the type of thinking of many biologists. Furthermore, the teachers help students draw comparisons between plant and animal reproduction, returning to some of the basic ideas introduced in the first vignette.

As students mature in their knowledge of life sciences and their reasoning skills, they are ready to tackle more complicated relationships involving both living things (biotic factors) and the nonliving world (abiotic factors). In the final vignette of this section, Sara Torres provides a window into a yearlong investigation of water quality, using the local community as a site for data collection. Sara’s story illustrates how teachers can help middle-level students compare their evidence with regional databases and national water quality standards to better understand their local environment.

Each life science unit described in the vignettes was designed and carried out at a particular grade level. However, the National Science Education Standards, upon which each unit was built, address grade ranges, not specific grades. We hope you will find ways to adapt these units to your local context and grade level, where age appropriate. We also encourage you to develop new units about other important life science concepts for elementary and middle-level students, as detailed in the standards within the broad categories of life cycles, organisms and their environments, heredity, diversity and adaptation, and regulation and behavior (see National Research Council 1996).
Unit Notes

Grade: 4

Learning Goals: Students will understand that some animals eat plants and some animals eat animals, but almost all animal food can be traced back to plants.

National Science Education Standard: Content Standard: K–4, Life Science: All animals depend on plants. Some animals eat plants for food. Other animals eat animals that eat the plants. (National Research Council 1996, 129)

Assessment Strategies:

Engage: group discussion with teacher-directed questions

Explore: collaborative chart

Explain: exit ticket

Elaborate: team report

Evaluate: scenario exam

Vignette

Engage

“What are those for?”

“Are we having a party?”

“Why are there plants on the tables?”
I was greeted with these questions as my fourth graders traipsed into the science classroom and settled into a circle on the floor. Prior to their arrival, I had placed living plants, hay, and sticks in the center of the demonstration table. The students’ curiosity led naturally into my first assessment question: “Why do you think animals need plants?”

The discussion was lively as students suggested examples of animals eating plants or using them for their homes. Sarah said, “My guinea pig loves carrots.” Emilio pointed toward the plants on the table as he said, “Cows eat grass and hay.”

Billy volunteered, “Birds live in trees.”

“We feed Ms. Mitchell’s rabbit lettuce sometimes. He loves it!” offered Shalini.

“Pandas eat bamboo,” Kelly said.

Piggybacking on this idea, Jerry said, “I saw the giraffes at the zoo eating leaves off trees.”

Darnetta claimed, “Squirrels make nests with leaves.”

Matthew excitedly pointed out, “Izod eats kale.” (Izod was the class iguana.)

From their answers, I gauged students’ prior understanding, which predominantly focused on knowledge about pets, farm animals, or animals at the local zoo or in the local environment.

Students did not mention humans in their discussion of plant-animal relations. This did not surprise me because elementary students often do not think of humans as animals (Driver et al. 1994). Thus, I probed further. “Why do you think we—people—need plants?” There was a pause until the student who thought we might be having a party mentioned “decoration.” I nodded but looked around expectantly for other responses. I pulled an apple out of my pocket and set it on the demonstration table without saying anything. Picking up on this silent cue, students brainstormed various plants (mostly fruits and vegetables) that people eat.

Now that we had a lot of ideas and examples, I asked the students to vote: “How many of you think that animals need plants? How many of you think people need plants?” The entire class raised their hands for both questions. When I asked why, the explanations included “Animals need to eat them” and “People use plants for food.” I intentionally pressed further, asking students to consider animals such as fish, worms, insects, and spiders. A debate arose regarding whether fish flakes were made of plants or not as well as whether an earthworm that eats soil really needed plants. Students were unclear about what ants might eat and seemed puzzled when flies were the only food source that they could suggest for spiders. I asked, “Suppose all of the plants in the environment died and disappeared. Would all animals be able to survive?” Some responded with a definitive yes or no, while others were ambivalent. I told the students
that we were going to consider the importance of plants. “Our main question to explore further is: Do all animals, including humans, rely on plants?”

**Explore**

From the discussion, it was clear that students realized that people eat plants. Whether they realized that “almost all kinds of animals’ food can be traced back to plants” (American Association for the Advancement of Science 1993, 119) was less obvious. I invented an activity to help them explore this idea. Students went to their team tables, where I had placed a bag of common food items (pictures, toys, or real) derived from plants, animals, or both (e.g., french fries, steak, salad, orange, hot dog, fried chicken, taco, pizza, rice, green beans). Working in groups, students discussed if the food came from a plant or not. Each group recorded responses for two items on a collaborative chart on the whiteboard at the front of the classroom. Once the groups finished, I reconvened the class to examine the collaborative chart and discuss whether people, as animals, eat plants. Everyone agreed. Students were quick to clarify that humans also eat animals. Matthew pointed out that not all humans eat animals. “My neighbor is a vegetarian.” I asked him what he meant in case other students did not know that a vegetarian is a person whose food source is predominantly, if not solely, plants. Some students nodded in understanding, while others looked surprised.

After establishing a general consensus that humans use both plants and animals for food, I asked, “What if you decided to eat animals only? Let’s say you eat only chickens and cows. Would it be OK if there were no plants?” Ashley piped up immediately, “No, because plants give us oxygen.”

I replied, “That is an excellent point. Plants do produce oxygen that animals need to breathe and live. Let’s assume that somehow we are able to get the oxygen we need without plants. Do you think we still would be able to survive without plants as a food source?” I asked students to commit to an answer—yes, no, or maybe/unsure—with a show of thumbs-up, thumbs-down, or thumbs-sideways. The response was mixed. Students who said yes thought that people could survive just by eating meat. The reasons given for no were that “people have to eat plants” or “chickens and cows wouldn’t be able to survive without plants.” I asked students who gave the latter response to explain.

Wayne said, “Without plants, the animals would have nothing to eat and would die, so people would die because they would have nothing to eat.”

**Explain**

During the *Explain* phase, I wanted to help students understand two important concepts: (1) “some animals eat plants for food” (National Research Council 1996,
129) and (2) some “animals eat animals that eat the plants” (National Research Council 1996, 129). To help students visualize these relations, I made signs that could be worn as necklaces, such as animal (picture of human), animal (picture of a cow and a steak), plant (picture of grass), and plant (picture of corn).

I asked the cow and the corn to come to the front of the class. “How are cows and corn related?” I asked. Students explained that cows eat corn. I drew this relation on the board, linking the animal and the plant with lines. (I drew lines to show the relationship instead of using arrows, which I had read could confuse students [Driver et al. 1994]). We also considered the cow and its relation to other plants such as grass and soy beans, and I added these to the model on the board.

Next I invited the student wearing the “human” label to join the group. Audience members noted that the human ate the cow, which ate the grass and the corn; the performing students held hands to demonstrate how they were connected. I added to our model on the board. “What would happen if the plants died?” I wondered aloud. The corn and the grass dramatically released their hands and fell over “dead”; the human and the cow did the same. I asked another student, representing a chicken, to join the group. She held hands with the human and the corn, but not with the cow, and I added these relationships to our growing model. One by one I invited students to join the group and find plants and/or animals to which they were connected.

It was at this point that I revisited the notion expressed earlier—that people can survive just by eating meat. “What do you think now? Could we really survive if there were no plants to eat?” I asked students to write down one thing that they ate for dinner the night before and link it back to plants. At the conclusion of this lesson, I passed out an exit ticket that asked students to respond to the following prompt: “Almost all kinds of animals’ food can be traced back to plants. Do you agree or disagree? Why do you think so? Draw an example to support your answer.” All students could draw the relationship between plant eaters and plants, and many included meat eaters in their drawings. Luke’s response (see Figure 3-3) demonstrated that he was able to explain the links between both meat-eating and plant-eating animals and plants.

Elaborate

It seemed that students understood the importance of plants in relation to humans and many other animals and could trace relations of some animals back to plants. However, we had not addressed the idea that most other animals’ food linked to plants as well. Students initially had been confused about whether the food that animals such as fish, worms, insects, and spiders ate
Almost all kinds of animals’ food can be traced back to plants.
Do you agree ✓ or disagree ❌?
Why do you think so?

1) Some animal food is just plants so that was easy.
2) If the animal eats on animal that animal would’ve eaten a plant or an animal that ate a plant or so on.

Draw an example to support your answer.

FIG. 3-3 Luke’s Exit Ticket
linked to plants, and I wanted to ensure that they understood animal-plant relations broadly, not just for farm animals.

I assigned each student team to research a group of animals and the foods the group might eat:

- pets (fish, dogs, cats, birds)
- sea animals (fish, whales, clams)
- forest animals (lizards, deer, coyotes)
- river/pond animals (fish, mussels, snails)
- soil animals (earthworms, beetles, termites)
- other common insects and spiders

Students used library and Internet resources to investigate their animal group’s food sources. Teams discussed how the food sources could link to plants and drew models of the relations. When the whole class reconvened, each team reported their conclusions about how their particular animal group’s foods linked to plants, and they supported their conclusions with at least two examples. After each team reported, the class decided where to place each researched animal into a Venn diagram on the whiteboard: animals that eat plants, animals that eat animals, and in the middle, animals that eat plants and animals. At the end of the reporting, we examined the circles. “Are there any animals that did not fall into the circles?” I asked.

Students unanimously responded, “No!”

“What does that tell us about plants and animals?” I asked students to discuss this question with their groups. As I interacted with small groups, I probed students about the “animals that eat animals” circle. Each group was able to articulate how even the animals in this circle depended on plants to survive.

**Evaluate**

I wanted students to go beyond giving examples to using their ideas about plant-animal relations to solve some problems. I developed two scenarios that I asked students to respond to individually as a written test.

- What would happen to an owl living in a forest if all of the mice could not find food? Why?
- What would happen to the bees in an area if all the flowering plants died? Why?
The test directed students to draw and label a diagram to support their written explanations.

After students completed the test, we discussed their answers. Because in previous lessons students had considered the food relationship between animals and plants, they were able to complete this final evaluation task easily. I asked the class if someone was willing to share what he or she had learned. Eric, one of the quieter students, probably summed it up best: “It all goes back to plants. Even if you don’t eat plants, we all still are connected to them because what we eat might eat plants.”
What’s the Anther?

Marsha Tyson and Kelly Turnbough

Unit Notes

Grade: 6

Learning Goals: Students will understand that plants and animals (1) reproduce sexually, (2) have comparable reproductive structures and functions, (3) produce egg and sperm cells (gametes), and (4) produce offspring (zygotes) when gametes unite.

National Science Education Standard: Content Standard: 5–8, Life Science: In many species, including humans, females produce eggs and males produce sperm. Plants also reproduce sexually—the egg and the sperm are produced in the flowers of flowering plants. An egg and a sperm unite to begin development of a new individual. That new individual receives genetic information from its mother (via the egg) and its father (via the sperm). Sexually produced offspring never are identical to either of their parents (National Research Council 1996, 157).

Assessment Strategies:

Engage: field trip notebook; discussion

Explore: Fast Plant drawings; poster

Explain: diagram labeling

Elaborate: think, pair, share; Venn diagram intersection

Evaluate: cycle diagram; student-generated Venn diagrams
**Vignette**

**Engage**

“Do you remember the focus question for today’s visit to the nature center?” It was late April and the weather had cooperated with sunny skies and cool temperatures. We had decided the best way to begin the study of reproduction was to organize a field trip to the local nature center to raise student interest in plant reproduction. Upon our arrival at the nature center, we repeated the field trip challenge: “How many different kinds of seeds can you find?”

The student teams were excited and responded enthusiastically, “We’ll find the most!” and “We’ll get more than you!” and “We’ll find enough to make a new nature center!”

To help students remember their roles as budding scientists, we asked, “How do scientists make observations?” This had the expected calming effect.

Pam said, “They look with these,” holding up a hand lens.

Steve remarked, “They write stuff down.”

Jenni added, “They might make drawings.” Armed with hand lenses, notebooks, and pencils, we headed for the woods.

The assignment was for students to find as many types of seeds as they could (at least three), draw each seed, draw the parent plant, and describe how they thought the plant produced its seeds. Adult chaperones monitored each small group of students, who searched for the bounty. Prior to the trip, we had instructed chaperones on how to help students by sharing tips on where and how to look for seeds. We suggested they look in areas with dried brush left over from last fall and look for plants that may be producing flowers and fruits at the same time, such as the Mayapple. We asked chaperones to allow for student discovery with minimal adult guidance.

Back in the classroom, students shared their drawings and their ideas about plant reproduction. We learned that students were aware that flowers played a role in reproduction and that insects (especially bees) were involved in the reproductive process. We also learned that students lacked the language to talk deeply about these concepts. Without appropriate terms, students had difficulty distinguishing structures. For example, students found Mayapples in various stages of reproduction (from early flowers to developing fruit) but were unable to distinguish various parts such as the filament, the anther, and pollen (in association with the stamen) or the style, the stigma, and the ovary (in association with the pistil). In an effort to perpetuate the excitement generated by the field trip, we decided it was time to explore firsthand how seeds are produced. We would explore the concept of sexual reproduction using Wisconsin Fast Plants.
**Explore**

Sixteen days prior to our study of reproduction, teams of students planted, watered, and recorded the growth and development of a set of Wisconsin Fast Plants. These unique plants complete an entire life cycle in thirty-five to forty-five days (seed → germination → growth → flowering → pollination → fruit → seed production). We had timed the Fast Plants to bloom subsequent to our field trip. We used these plants to help students identify which parts were male and which were female (we identified the stamen as the male part that produced the pollen and the pistil as the female part that produced the ovary and the eggs) and to teach associated terms. Students examined the Wisconsin Fast Plant flowers with their hand lenses and drew the structures in their science notebooks. Aided by black-line diagrams (supplied with the Fast Plants by Carolina Biological Supply Company), students were able to label the male and the female flower parts with little trouble.

To help students think about the roles that these parts played in the production of seeds, we initiated student-led investigations using the Fast Plants by doing a variables scan (Jelly 2001) of the parts they might be able to manipulate in their studies. This activity helped students decide what variable to change and what variable to observe as a result. For example, Nathan, Pam, and Jenni selected the pistil as the variable to change and seed production as the variable to observe. They claimed, “If the pistil is removed, seeds will not be produced.” In order to test this claim, they removed the pistils from five plants and left another five intact. They predicted that the plants without pistils would not produce seeds, while the intact plants would. Suzy, Pedro, and Ricky selected pollen as the variable to change and seed production as the variable to observe. They claimed that the pollen from the anther was necessary for seed production. In order to test this claim, they decided to help pollen move from one plant to another by touching cotton swabs to the anthers of five flowers and then touching the stigmas of five others and vice versa. Other groups made similar claims and devised interesting strategies to test them.

Three weeks later, students harvested the seeds. They were excited to find evidence to support or refute their claims. Each group shared their results on a poster listing their claim, evidence, and conclusion. For example, Nathan, Pam, and Jenni wrote:

*Claim:* No reproduction without pistils.
*Evidence:* 5 plants without pistils did not produce seeds and 4 out of 5 plants with pistils did produce seeds.
*Conclusion:* Pistils (females) are needed for seed production.
Suzy, Pedro, and Ricky learned that pollen can be transferred by touching. However, they had not used an experimental control, so it was difficult for them to be confident about the role of touch in pollination. Other students learned that pollen goes from anther to stigma and not from stigma to anther, that wind supports pollination, and that seeds develop below the blossom.

Based on the poster assessment, we realized that students understood that reproduction in these plants required male and female structures (goal 1) and that the male structures produced material that was transferred to the female parts (goal 2). We hoped that some of the students understood that the union of the male parts (cells) with the female parts (cells) was the basis of sexual reproduction (goal 3) and that a seed would be produced from that union (goal 4). However, we knew these concepts would need more direct attention. We decided that we could help students use the evidence from their plant investigations to understand scientific explanations of plant reproduction. We also decided that students were ready to compare plant and animal reproduction to better understand both.

**Explain**

We drew a Venn diagram on the board and told students we would use the diagram to record characteristics of plant reproduction, characteristics of animal reproduction, and characteristics common to both. We began with plants. “What do we know about plant reproduction from our investigations?” we asked. As students volunteered characteristics of plant reproduction, we summarized and recorded them in the left-hand circle. For example, we wrote, “Some plants have male parts, some have female parts, and some have both male and female flower parts.” We also wrote, “Female parts produce eggs and male parts produce pollen.” Finally, based on a comment from Ricky, we wrote, “The pollen must join with an egg to produce seeds.”

At this point we felt that students were ready to hear a formal summary of plant reproduction and to make the bridge to human reproduction. We commented, “All of these steps in plants are known as sexual reproduction, because there are male and female contributions to making the offspring. Many types of plants reproduce this way, but some do not.” We wrote the term *Sexual Reproduction* above the Venn diagram and continued. “Do you think plant and human reproduction is alike in any way?” Some students vehemently shook their heads in opposition to this idea, but a few had quizzical looks on their faces, as if seriously contemplating this rather odd idea.

To help students and ourselves prepare for a discussion of human reproduction, we asked students to write down one claim and one question about
human reproduction and turn their papers in without names. This opened the door for many students to share information they had learned from parents or older siblings and to raise questions about human reproduction based on our study of plant reproduction. The next day, we read what students had written aloud to the class, using our judgment to monitor language and content, and taking care to preserve anonymity. We provided black-line diagrams showing human male and female reproductive systems. As we read student questions and provided responses, students labeled their drawings and wrote explanations below each diagram while we added ideas to the right-hand circle on the board. After we had read all the students’ questions and claims, we were ready to tackle the intersecting space of the Venn diagram.

**Elaborate**

We introduced the *Elaborate* phase with a challenge. “Earlier we asked if you thought plant and human reproduction were alike in any way. Let’s see what you think now. Write one reproductive structure or function that plants and humans share.”

“Are you saying plants and humans have the same parts?” asked Pedro.

“I don’t have any seeds,” Nathan quipped.

Suzy quickly responded, “A seed is just a baby inside its mother plant, just like babies can grow inside of us.” Suzy’s comment motivated students to get to work.

After the students had some individual **think** time, we asked them to **pair** up with someone and **share** their ideas. As we circulated, we heard students make a number of statements comparing plant and human reproduction. For example, Nathan said, “Plants and animals have eggs.” Pedro claimed, “Plants have pollen and animals have sperm.” Suzy interjected, “Plants have both male and female parts and humans have one or the other.”

After the pairs met, we asked them to share their ideas with the entire class. In addition to the ideas we heard when we circulated, other claims emerged, for example, “Plants and humans both produce offspring” and “Offspring look kind of like their parents.” As students presented their ideas, we listed them in the intersecting space of the Venn diagram. Students were surprised to see that the intersecting space representing shared characteristics of plant and animal sexual reproduction contained so many features. This interchange also helped students feel free to ask questions, such as: “Why do plants depend on the wind to aid with fertilization and humans do not?” “Do
plants have sex?“ “Do plants get pregnant?” and “Do all animals depend on fertilization?”

**Evaluate**

To reach closure on this unit about reproduction, we directed students to complete an individual summative evaluation. “In your science notebook, draw the stages of plant reproduction in a circular diagram. (Think back to those we drew for the water cycle.) Outside that circle, write notes to describe where human reproduction is similar and different.” Most of our students were eager to demonstrate their knowledge and had little difficulty drawing the inner circle. Many could also draw the outer circle for humans. Their products demonstrated that we had achieved the goals of the unit and were ready to move on.

Our final activity of the plant reproduction unit would lead us into the subsequent unit, genetics. We asked students to observe the plants that had grown from the Fast Plant seeds and compare the characteristics of the offspring with characteristics of the parents using a three-circle Venn diagram. In one circle student teams described characteristics in common with the father (pollen provider), in another they described characteristics in common with the mother (ovary provider), and in the third they described characteristics of the offspring. They filled the intersection with characteristics shared by all three (mother, father, offspring).

Some students expressed an interest in making similar diagrams showing relationships within their families (with mothers, fathers, sisters, and brothers). This is a powerful activity that would meet the goals of this instructional sequence. However, instead of asking students to diagram their nuclear family characteristics, we provided a menu of options. Students could choose to diagram their nuclear family, a relationship with a relative, or a relationship with a significant other who was not related (a friend, a guardian, or a teacher). We gave these options because many of our students come from blended or nontraditional families where bloodline relationships are sometimes difficult to trace. We have found that all students enjoy investigating these relationships, in part because doing so accentuates a connection with someone who is close or with whom they hope to build closeness. These relational diagrams would become the basis of our genetics study.

Throughout the reproduction unit, seamless assessment had informed us about student understanding of plant reproduction. It had also helped students ask their own burning questions about human reproduction. Finally, seamless
assessment demonstrated to us student readiness to study new concepts that would be addressed in upcoming units.

**Notes**

1 Wisconsin Fast Plants and accompanying materials are available from Carolina Biological Supply Company.

2 Think, pair, share is a common strategy we use to generate ideas in class. More information on the strategy can be found in Victor and Kellough (2000) and in Chapter 2.
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