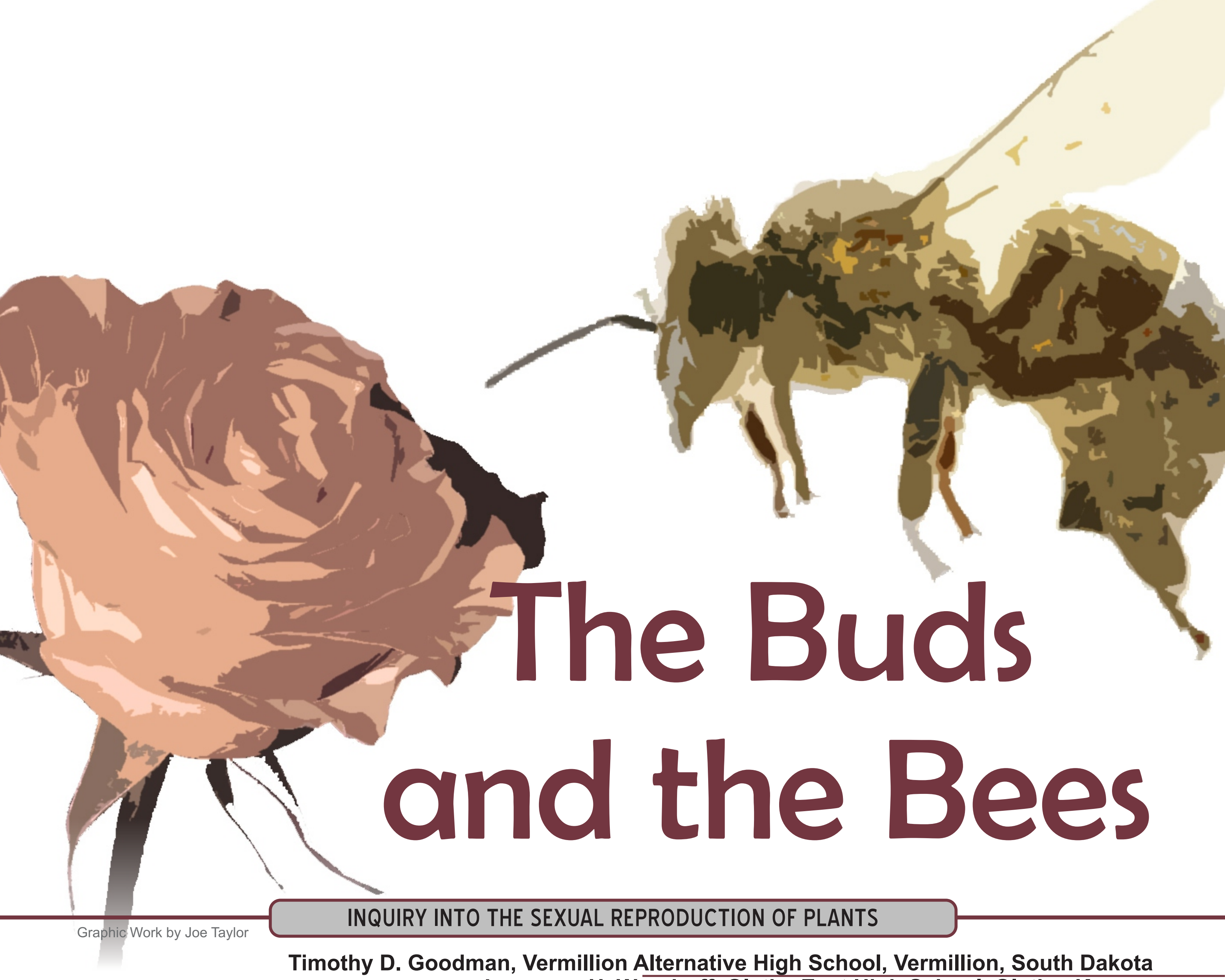

The Buds and the Bees

Graphic Work by Joe Taylor

INQUIRY INTO THE SEXUAL REPRODUCTION OF PLANTS

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ABSTRACT: Many students have few significant experiences investigating flower structure and function, yet are expected to understand sexual reproduction in angiosperms. We present here an inquiry-based hands-on activity where middle school students compare plant reproduction to more commonly understood animal reproduction. This provides a foundation to more deeply understand topics related to plant reproduction. This activity also provides many opportunities to explicitly address the nature of science and how science works. *This article addresses National Science Education Content Standards A, C, and G, and Iowa Teaching Standards 1, 2, 3, 4, and 5.*

This activity provides an introduction to the structure and function of flowers. Through concrete experience students confront the common misconception that plants do not reproduce sexually. We situate this activity at a point in the school year after students have a basic understanding of animal sexual reproduction. While not absolutely necessary for this activity, we have students carefully observe the behavior of bees, particularly how they interact with flowers to provide students with additional background on which they can draw during this activity. We designed this activity for middle school students, but it may be modified for use in high school introductory biology.

Because most students have likely viewed flowers only in passing, this activity provides a concrete experience in which we encourage students to closely observe the structure of flowers. Through these observations, students create a general model of flower structure and the function of key parts. Importantly, students do not "discover" the structure of flowers. We, as teachers, play an important role in helping students make meaning of their observations. Our questions, wait-time, and introduction of new information are carefully considered to ensure students remain actively mentally engaged.

Exploring Flowers

When choosing what flowers to present to our students, we considered flowers that possess easily identifiable male and female parts (Figure 1). We initiate this activity by providing pairs of students one flower from our pool. We then have students carefully observe and record their observations of the flower they received. As students make and record their observations, we wander among the students observing what they are doing and writing as well as listening to what they say. If students are struggling to make and record key aspects of the flower, we ask questions such as

- "How does your flower differ from your neighbors' flowers?"
- "What do you notice about the color patterns of your flower?"

The purpose of these questions is to direct student attention to particular elements of their flower they have yet to describe. While we could simply tell students what to look for, we want students to be curious. Furthermore, having students make observations rather than be told what to look for more accurately models how scientists do their work. Yet, students do need guidance in order to focus their observations. Our guidance, as detailed below, ensures that we also meet curricular expectations.

Students often have difficulties making distinctions between some aspects of flower parts. If students are struggling to note particular structures, we don't simply provide them magnifying glasses because this communicates that we will solve their problems for them. Instead, we ask

- "What would you need to get a better look?"

Once any group asks for and receives permission to use a magnifying glass or dissecting scope, other groups see what they are doing and seek the same assistance. Thus, students learn to think about how to solve problems and seek their classmates' assistance rather than always relying on the teacher.

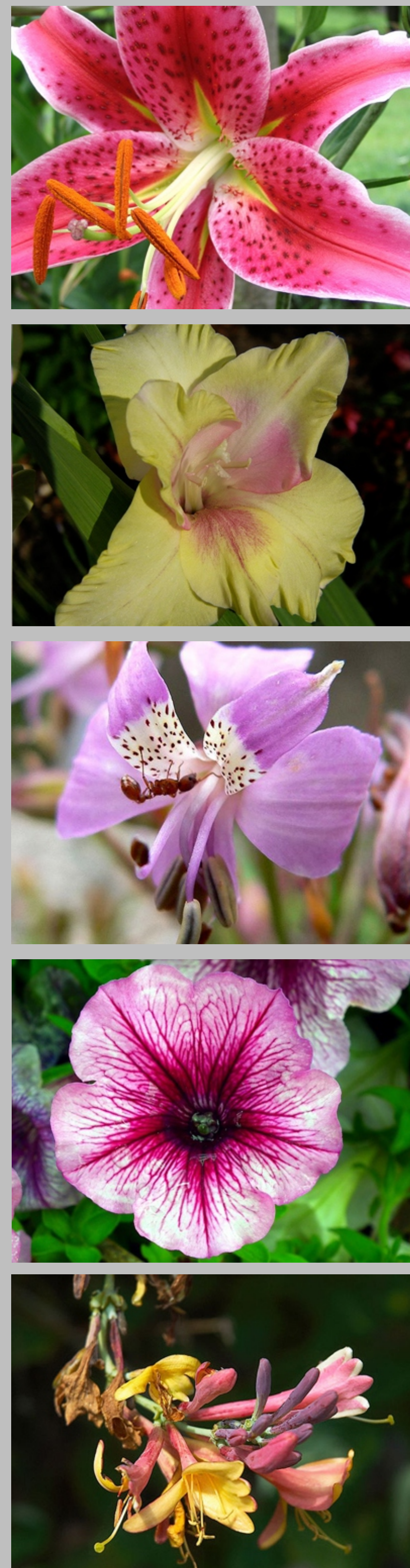
After students have recorded detailed observations in their notebooks, we have each group of two students create accurate diagrams of their flower on whiteboards. To ensure that students understand the value of creating diagrams along with their written notes, we ask the following questions:

- "What is the value of expressing your observations in words?"
- "What is the value of expressing your observations with diagrams?"
- "What would be lost if either of these expressions were missing?"

After students have finished creating their diagrams and descriptions, we have each group of students present their

FIGURE 1

Suggested flower varieties for students to observe.



Stargazer Lily

Gladiola

Alstroemeria

Petunia

Honeysuckle

All images used by permission (see copyright information at end of article) boards to the class. As each group presents, the same basic flower structures are presented, but with differing language or descriptions rather than names for structures.

Concept Development

To help students make connections among the various flowers, we ask

- "What are some of the ways in which all of the flowers the class presented are similar?"
- "What are the differences among the flowers?"

As additional groups present, we ask students

- "How does this flower change/add to our thinking about flowers?"

Students typically note that the petals might be different, but the "inside" of the flower seems to be similar. Some classes of students might even claim that the stems inside the flower all have the same pattern – one large stem in the middle and several around the outside.

Once students have begun noting important similarities, we use the opportunity to address the value of establishing a common language for flower parts. This approach is crucial for helping students come to understand that naming structures is not supposed to be an act of memorization, but rather a means to promote common language that will promote more effective communication about flowers. We use this same approach in most language intensive instruction. At this stage in the lesson, we are not yet worried about scientific names. For example, students may agree to refer to stamen as "long, puffy stalks".

After all groups have presented their work, we ask students to consolidate what they have learned from the collection of diagrams. While we (the teacher) typically create a drawing on the front board, students tell us what to draw and how to label the drawing. When completed, this class generated general illustration of flowers becomes the model-in-progress for the class. While we were initially tempted to simply find an "accurate" drawing of the parts of a flower here, we know that having the class consolidate their thinking into a common student-created drawing keeps students actively mentally engaged and wrestling with the content. This approach also provides us with important insight into student thinking.

As this drawing is being created, we work to keep the thinking and decision-making in the students' minds rather than ours. If we notice a problematic aspect of the class drawing, we might ask

- "Why might the kind of petals we put on our drawing not be important?"

When disagreements arise, we ask

- "How can we use our original drawings of the flowers to come to agreement?"

When students are discussing their ideas and linking their thinking to observations, we are sure to draw students' attention to how they are acting like scientists by asking

- "How might scientists use their observations to settle disagreements?"
- "How is the creation of our drawing like what scientists might do?"

Once our class drawing includes all student ideas, we are typically done with one 50-minute class period. In the next class session we want to further students' thinking regarding flower structure and function as well as introduce more formal vocabulary. We do not expect students to suddenly figure out that sperm and egg cells combine to produce an embryo, that pollen grains carry sperm, and that pollination is the transportation of pollen from the male flower parts to the female flower parts. Though there are many ways to provide students with this information, we found a short video that plainly describes these relationships without technical jargon (How Stuff Works, 1996). Yet, the video alone is not enough to promote active mental engagement or encourage students to make connections between their exploration, model development, and the video.

To create interest and prepare students for what will be presented in the video, we ask questions such as

- "What do you think is the purpose of the flower?"
- "What do you think is the function of each different flower part?"
- "How do you think bees interact with flowers?"

Students provide a wide variety of responses to these questions and rarely provide the accurate scientific understanding at this time. However, now having a vested interest in the answer to the questions, they are more attentive to the video.

To further ensure students' attention during this short video, we stop the video frequently to ask open-ended questions. Typically, we stop the video when connections might be made to previous discussions. For example, when the video uses the word stamen or pistil, we stop the video and ask

- "How does this relate to our model we created yesterday?"

When discussing these ideas we encourage students to modify models they might have in their notebooks by adding the more formal vocabulary. We also stop the video when new information or key concepts are introduced. For example, when the video notes that pollen grains carry sperm cells, we stop the video and ask

- "So flowers make use of sperm cells. In what other ways might plant reproduction be similar to animal reproduction?"
- "Given that flowers make use of sperm cells carried by pollen, what predictions might you have about other parts of the flower?"

These open-ended questions serve to encourage students to make connections among activities and remain actively mentally engaged during the video. Encouraging students to discuss what they see rather than fill out a worksheet better encourages student to make sense of information rather than seek factoids and trivia. Importantly, open-ended questions are not enough. To encourage more student participation we are sure to provide ample wait time to encourage student response (Rowe, 1986). Furthermore, we use encouraging non-verbal behaviors, such as smiling, raising our eyebrows, and open-hand gestures to further promote student communication (Clough, 2007).

Although we encourage students to make modifications to their drawings during the video, we return to the class model of the flower to re-label particular structures using information learned in the video, revisit the importance of agreed upon naming, and address in more detail flower structure and function. This consolidation serves as formative assessment of student learning and provides an opportunity for students to hear their peers explain the modifications to the class drawing. We also revisit the question, "What is the purpose of a flower?" However, greater care is taken to have students refer to the class model of the flower as we ask further questions that have them link function of flower parts to the structures appearing in their model flower. Some questions to explore these connections include

- "What role do the different flower parts play?"
- "How is that role related to the part's structure?"
- "How do the structures help the sperm and egg cells interact?"
- "Where does pollen originate?"
- "Where must pollen go for fertilization to occur?"

We then move to helping students understand the role of pollinators in plant reproduction by scaffolding student thinking when asking questions such as

- "What is a pollinator?"
- "How do bees and other pollinators interact with the flower?"
- "How does the structure of most flowers ensure that bees will carry with them pollen as they move from flower to flower?"
- "How do the bees benefit from this interaction?"
- "How does the plant benefit from this interaction?"

When students appear to have grasped these key ideas, we then encourage students to expand their thinking about how plant and animal reproduction compare. We ask

- "In what ways is plant reproduction similar to animal reproduction?"
- "In what ways is it different?"

We want students to make the connection between the role of sperm and egg cells in both animal and plant reproduction. Students typically come to this conclusion quite well. Inevitably, one student notes that flowers have both male and female organs so plants can reproduce with themselves. In a high school biology course this notion could lead to a discussion about the role of genetic variation.

How Science Works

Although we previously addressed some ideas regarding how science works or the nature of science, we revisit and expand on these ideas toward the end of the lesson. In particular, this lesson lends itself to helping students understand the use of models in science. We ask a series of questions to encourage students to consider the relationship between what we have done as a class and what scientists do. For instance, students are provided a scientific diagram of the flower parts, complete with vocabulary, for the purpose of comparison with our class-generated model. We ask students

- "How is our class model similar to this model?"

To push student thinking further we ask,

- "If I had simply handed you this diagram at the beginning of this investigation, how would that have misrepresented the way science works?"

Students may point out that our model, or the textbook model for that matter, does not exactly portray the parts of all the flowers we examined. We ask

- "Why would scientists use a general representation of flowers that is not precisely like any one flower?"

We can use this question to lead a discussion regarding the use of models to communicate relationships, the idealized nature of models, and the role of consensus in creating models. Some questions we might use to guide such a discussion include:

- "What is a model?"
- "In what ways are your drawings models?"
- "What is the value of a generic model?"
- "We have real flowers to view, so why create a model?"
- "How well does the generic model represent any of your specific flowers?"
- "How do you suppose scientists decided on a model?"

Conclusion

This exploratory activity and the following concept development typically require two 50-minute class periods to complete. While simply providing students with a labeled picture of plant parts would require less time, it does not promote the mental engagement and deep and robust understanding of plant sexual reproduction that we want. Plant sexual reproduction is a fundamental biology concept that will be revisited during later topics such as Mendelian genetics and plant evolution. The inquiry approach presented here reflects how students learn (Bransford, Brown & Cocking, 2000), increases students' interest in studying flowers, and more effectively advances all the goals we have for students.

References

Bransford, J.D., Brown, A.L. & Cocking, R.R. (Eds.). (2000). How people learn: Brain, mind, experience, and school. Washington, D.C.: National Academy Press.

Clough, Michael P. (2007). Synergistic Relationships: Why Effective Teaching is Complex. *Iowa Science Teachers Journal*, Editorial, 34(3), pp 2-3.

How Stuff Works, (Producer). (1996). Assignment discovery: plant reproduction. [Web]. Retrieved from: http://videos.howstuffworks.com/discovery/30702-assignment-discovery-plant-reproduction-video.htm

Rowe, M. B. (1986). Wait-Time: Slowing Down may be a Way of Speeding Up. *Journal of Teacher Education*, 37(1), 43-50.

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Petunia photo courtesy of Ramesh Ng.
Honeysuckle photo courtesy of Wouter Hagens.

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