

Post-Harvest Physiology of Cut Flowers: A Problem-Based, Cooperative Learning Activity for the Biology Classroom

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ABSTRACT

This article describes a problem-based, cooperative learning activity, where students investigate the role of ethylene in flower senescence. The cooperative learning activity is contextualized in an authentic problem experienced in the cut flower industry: how can the shelf life of cut flowers be prolonged? We describe the procedure for conducting the experiment and show the effectiveness of contextualized science that includes indigenous knowledge—an approach that Gibbons calls “mode 2 knowledge production.” In addition we also give suggestions on how this type of problem-based, cooperative teaching-learning activity can be used in a school biology classroom.

Key Words: indigenous knowledge; problem-based learning; cooperative learning; inquiry; post-harvest physiology of flowers.

○ Introduction: Context-Sensitive Science

Biology teachers and curriculum developers should be reminded of Gibbons’ (2000) concept of mode 2 knowledge production. Mode 1 knowledge refers to traditional discipline-based knowledge, whereas the shift to mode 2 knowledge refers to an adoption of what Gibbons calls “context-sensitive science”—more contextualized, problem-based, and interdisciplinary knowledge. In this article we show how the biology teacher can plan an inquiry learning opportunity with such a mode 2 focus, and utilize problem-based and cooperative learning strategies.

Mode 2 knowledge also encompasses a focus on indigenous knowledge systems. Several scholars have recently argued for the inclusion of indigenous knowledge in the school biology curriculum,

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presenting two camps. Authors such as Onwu and Mosimege (2004) are of the opinion that it would be unwise to subject indigenous knowledge systems to the same verification procedures as those of modern science. On the other hand, authors such as de Beer and Van Wyk (2012) state that indigenous knowledge claims, when introduced in the science classroom, should be subjected to such verification, as students should be introduced to the tenets of science, and scientific processes and procedures.

The increased complexity of world problems urge schools to develop in students the capacity to solve problems in the society in which they live. To help students in this regard, teachers can use different teaching-learning strategies, of which problem-based learning and cooperative learning are two examples. This intervention applies both these teaching-learning strategies to foster the following skills in students: critical thinking, problem-solving, collaboration, creativity, self-direction, leadership, adaptability, responsibility, and global awareness (Barell, 2010).

In this article we show how indigenous knowledge can be introduced in a creative and scientifically rigorous way, and how it could highlight the role of science in our daily lives.

○ Problem-Based Learning in the Biology Classroom

Problem-based learning is a teaching-learning strategy in which the students’ learning processes are embedded in real-life problems (Hung, Jonassen, & Liu, 2007). During problem-based learning experiences students need to solve ill-structured problems, based on real-world problems, while they are actively

involved in the learning process. Barrows (2002) argues further that problem-based learning is a student-centered approach in which students need to determine their own learning needs,

what they need to learn, define their own gaps in their knowledge base, and plan and reflect how to acquire the missing knowledge. Although students are expected to come up with solutions to the problem, the process that they follow and the lessons learned during problem-solving is just as important as the solution itself.

○ Cooperative Learning in the Biology Classroom

In contrast to competitive and individualistic learning, cooperative learning requires students to work together toward achieving shared goals (Johnson, Johnson, & Smith, 1998). Johnson and Johnson (1999) and Smith (1996) identify a number of basic elements of cooperative learning:

- **Positive interdependence:** Students should engage in cooperative learning with the view that they succeed only if other students do, too. Every student's work should benefit the others, just as the others' work would benefit him/her. Positive interdependence can be regarded as the heart of cooperative learning.
- **Individual accountability:** Each student should be held individually accountable for his/ her tasks in the learning activity. Individual accountability should result in students learning together but performing better as individuals. Individual accountability could be achieved by asking each student to explain to the group the portion of the work that they studied.
- **Face-to-face promotive interaction:** Students should support their other group members by explaining to each other how to solve problems. Students should discuss among themselves the nature of the concepts and suitable learning strategies, and should teach and assist each other in achieving the outcomes of the learning activity, and provide social support.
- **Social skills:** Students should develop their leadership abilities and decision-making, trust-building, communication, and conflict management skills. These skills have to be taught purposefully in the same committed way as content knowledge is taught. If these social skills or teamwork skills are fostered within students, they will be in a better position to cope in the demanding 21st century working environment.
- **Group processing:** For the students to work effectively as a group, they will have to identify, define, and solve problems that they encounter along the way. Members should discuss how well they are achieving their goals and maintaining effective working relationships. The group of students should continuously reflect on their actions and make necessary adjustments as needed.

○ Introducing the Mode 2 Inquiry Activity

We suggest that students work in groups of four. Johnson and Johnson (1999) argue that groups larger than four will not optimize learning and that the effectiveness of the learning opportunity will be compromised. All students should be involved in researching, planning, and executing the experiment, and making the poster or writing the article (see below). Apart from the academic work that should be done, there is also an important component of learning

that all students should engage in, and that is the management of the cooperative teaching-learning activity. We suggest the following division of labor, which will address the elements of cooperative learning as mentioned above.

- **Student 1:** Overseeing the assignment, and ensuring that the poster or article is submitted on the due date. This student will have to draw up a time plan that should be negotiated with the group to ensure that they reach the common goal (goal interdependence).
- **Student 2:** Negotiating with the group members which tasks will be assigned to each student. One student could, for instance, research the indigenous knowledge related to the post-harvest physiology of cut flowers; another student could do research on ethylene, and the influence of ethephon (discussed below). A third student could research chemicals that could serve as inhibitors, blocking the effects of ethylene (e.g., 1-methylcyclopropene or silver thiosulfate [STS]). The fourth student could research the commercial applications of substances like STS in the food and flower industry. Each group member is responsible for learning a portion of the content and is accountable to teach it to the rest of the group.
- **Student 3:** Based on group members' inputs, this student should direct the discussion to design an experiment and to develop a blueprint for either a poster or a paper, in which the research findings (i.e., the solution to the problem) could be communicated. The experimental design or blueprint for a poster/paper should be discussed with the group, and all valid opinions should be consolidated in the plan. In this part of the teaching-learning experience, face-to-face promotive interaction and their social skills are developed as students talk and listen to each other.
- **Student 4:** This student will be responsible for the collection and organization of the data. Student 4 could also be asked to write a "Methods" document, which the other students should agree to, before the experiment starts.

All four students are collectively responsible to provide support to the other group members by, for example, assisting members with relevant resources or articles, or acting as a sounding board if an individual experiences any difficulties. During the deliberations they continually need to reflect and give feedback (group processing) to each other in producing the poster or paper.

We recommend the sequence described below for this inquiry.

Dutch Indigenous Knowledge: Keeping Cut Flowers Fresh

The Dutch have more than 400 years of experience as leaders in the cut flower industry. *The Chicago Tribune* published a delightful article in the May 3, 1959, edition in which Dutch experts shared their knowledge on keeping tulips fresh. One of the tips provided is to use a knife when cutting stems, rather than scissors, since the latter may damage the xylem. Let the students start their inquiry by doing desktop research on indigenous knowledge wisdom in keeping flowers fresh. There are many such tips available on the Internet. Whereas some of these suggestions to prolong the shelf life of cut flowers have scientific merit, others are simply old wives' tales. However, these tricks actually warrant a laboratory investigation. A few suggestions to prolong the shelf life of cut flowers: put a little bit of soda in the water, add a little apple cider vinegar, a little alcohol (vodka) in the water, or use aspirin, bleach, sugar, or

even dropping a copper penny in the flowers' water. The use of ethyl alcohol could place a teacher in an extremely tenuous situation in the United States, and therefore we would rather suggest the use of other biocides. Bleach should have the same effect as alcohol. It is theorized that the copper in a copper penny could act as a fungicide, and that aspirin would make the water more acidic.

Contextualizing the Problem: Ethylene and the Cut Flower Industry

The cut flower industry and prolonging the post-harvest shelf life of cut flowers. The *Royal FloraHolland* flower market in Aalsmeer, Netherlands, is the largest flower auction in the world. On average 20 million flowers are sold every day in Aalsmeer. The problem is that millions of flowers need to be distributed all over the world in the shortest time possible, to ensure that the end consumer can still enjoy fresh flowers for at least a week. From Aalsmeer flowers are transported to Schiphol airport in Amsterdam, and from there to Europe, Africa, South America, and the United States. Flowers are transported from Aalsmeer to New York on an 8-hour flight. When flowers arrive in New York, they go to the New York flower market, and from there to retailers. The flower industry strives to get flowers from the grower to the consumer in under 48 hours. However, the moment the flower is cut, it starts to deteriorate. Let the students do desktop research on the role of ethylene in the ageing process.

The role of ethylene in senescence. Ethylene reduces the post-harvest life of flowers (Reid & Wu, 1992), as it results in flower senescence. Senescence can be described as the process that leads to the death of cells, tissues, and organs. The role of ethylene in senescence was first explored by testing the effects of exogenous ethylene. Exposing flowers to ethylene gas resulted in abscission of petals and failure of flower buds to open (Reid & Wu, 1992). This has prompted researchers to experiment with inhibitors of ethylene action.

The use of ethephon (ethehl) in our experiment. Ethephon (commercially marketed as Ethrel) is a plant growth regulator, which is changed to ethylene in plant tissue. It is commercially used to enhance fruit ripening, flower initiation, and breaking apical dominance in plants such as apples, barley, wheat, blueberries, cotton, and pumpkin. In our experiment, we wanted to see if ethephon would enhance the rate of senescence.

Only a very tiny amount of ethephon (1 mg) powder mixed in 1 liter of distilled water is needed. Students can either spray the ethephon on the flowers, or the flowers can be soaked for a minute in the ethephon solution (see Figure 1b & c). After the ethephon soaking, the flower stalk is placed in a container with distilled water (like all the other treatments).

Inhibitors of Ethylene Action

Beyer (1976) has shown that silver (in the form of silver nitrate, AgNO_3) effectively blocks the ability of ethylene to induce senescence in flowers. In the literature students can read about the use of silver thiosulfate to block the action of ethylene in plants. Another chemical product that binds to the ethylene receptor in plants, delaying senescence, is 1-methylcyclopropene, or 1-MCP. In our experiment, we used silver thiosulfate (STS).

Preparing silver thiosulfate (STS).—Mix 40 ml 0.1 M silver nitrate (AgNO_3) slowly with 160 ml 0.1 M sodium thiosulfate

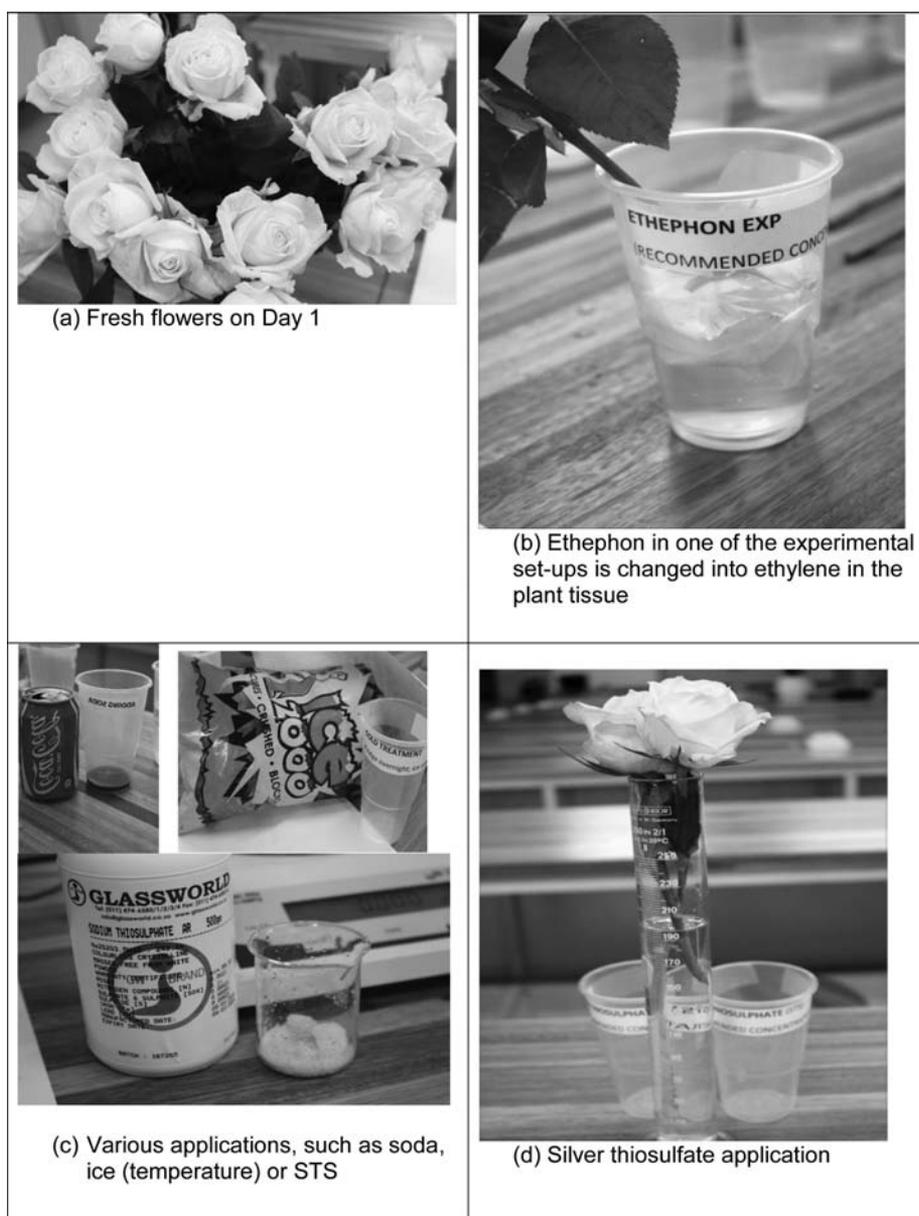


Figure 1. Preparing the experiment.

($\text{Na}_2\text{S}_2\text{O}_3$), while continuously stirring the solution. Dilute this to 1 liter with distilled water.

Using STS in the experiment to test its inhibitory influence of ethylene. Let the flower stalks stand, 3 cm deep, in the STS solution for 30 minutes (see Figure 1d).

Safety precautions. Students should use rubber gloves when working with silver nitrate. It causes burns and discoloration of the skin. If spilled, wash affected area with plenty of soap and water.

○ The Experiment

Let the students design their own experiments, based on a real-life, ill-structured problem presented to them. The paper/poster that the groups develop should depict the problem and its solution. Here we will describe our own experimental procedure:

- We bought fresh roses from the flower market, and decided to keep the flowers in a refrigerator while preparing the experimental set-up. Students should be made aware that some flowers are



Figure 2. All the treatments.



Figure 3. Results on Day 9: The recommended concentration of silver thiosulfate (middle) significantly slowed down senescence. Ethephon (on the right) again increased senescence in the flower.

not very sensitive to ethylene (such as tulips and daffodils), and other flowers are extremely sensitive. Ethylene-sensitive flowers include carnations, gladiolus, digitalis (foxglove), and Antirrhinum (snapdragons) (KES, n.d.). One of our variables in this investigation was temperature; one rose was exposed to low temperatures (kept in a refrigerator overnight, and placed in a glass with ice cubes during the day), and low temperature resulted in the same positive outcome (prolonged shelf life) as the use of STS (see Figure 5).

- The control constituted a rose placed in distilled water, and not exposed to any supplements in the water or to temperature treatments.
- Silver thiosulfate and ethephon were prepared, as described above. (Please take note of the safety precautions when working with silver nitrate).
- We decided to explore also applications advocated on the Internet (Reader's Digest, 2016) to see how the use of soda, alcohol, bleach, sugar, and copper pennies influence the post-harvest physiology of the flowers.
 - The flower stems were cut shorter under water, using a sharp knife, to prevent damage to the xylem or air bubbles in the vascular tissues.
 - Roses were placed in marked containers (Figure 2) and inspected daily. Where needed, the containers were topped off with distilled water.
 - Over a period of 13 days flowers were inspected, observations made, and photographs taken.

○ Results

In Figures 3 and 4 the results are shown. As expected, the ethephon application resulted in rather extreme senescence (much more than in the control). This is to be expected, as ethephon is converted into ethylene in the plant tissues. The STS resulted in a marked decrease in the rate of senescence. Our results clearly showed its effectiveness as an inhibitor that blocks the action of ethylene.

We decided to also experiment with a different concentration of STS. Whereas the recommended concentration of STS (as described above) resulted in a marked increase in the shelf life of the rose, a double concentration was less successful. Low temperatures (refrigeration and the use of ice cubes) had an effect similar to STS, resulting in a rose that was still in excellent condition on day 13. All the other experiments—use of bleach, sugar, alcohol, soda, and copper pennies—produced negative results, and from our findings there seem

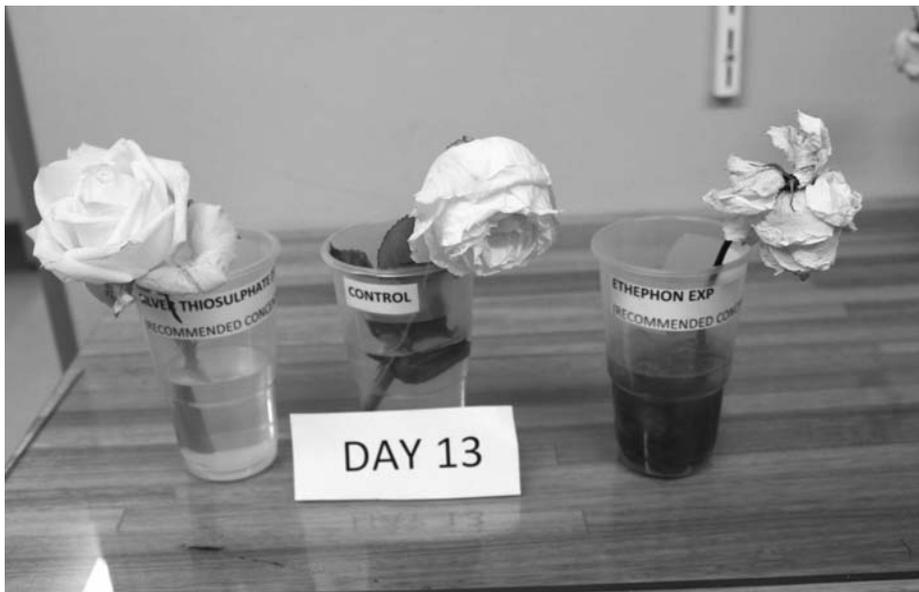


Figure 4. Results on Day 13: The rose exposed to silver thiosulfate (left) is still in a very good condition, compared to the control (middle). The rose exposed to ethephon (right) shows severe senescence.



Figure 5. Cold treatment and STS have a similar effect on senescence. From left to right: silver thiosulfate treatment; control; ethephon treatment; cold treatment.

to be little value in these applications. However, this offers a topic for discussion. Bleach and alcohol in the water would act as a fungicide, preventing the growth of bacteria or fungi in the water. Sugar and soda could theoretically nourish the flower. However, here the concentration of sugar or soda in the water is crucial. A too high sugar concentration in the container could lead to exosmosis, and wilting of the flower.

Communicating the Findings

Because the findings are visual, a poster is ideal for communicating them. Another option is a journal paper. Provide the students with

very little understanding of their application in society. Gibbons (2000) advocates for mode 2 knowledge production, in which science is better contextualized, and we focus on biology in a more interdisciplinary way. This investigation on the role of ethylene in plant senescence, portrayed as an ill-structured problem, requires the students to formulate a hypothesis, plan an experimental procedure to inhibit senescence through various interventions, make careful observations, and communicate their findings through either a poster or a journal article. However, it is contextualized in terms of a real-life problem: How can stakeholders in the cut flower industry retard senescence and thereby enhance the shelf life of cut flowers? This is an activity in which problem-based and cooperative learning

the guidelines of *The American Biology Teacher* and ask them to share their results in the form of a journal article. Students should be prompted to critically reflect on their findings: What could be the potential role of bleach in prolonging the life of cut flowers? How is STS utilized in the cut flower industry? A third option would be to have students deliver oral presentations. Each group can learn from listening to other groups discuss their experiment designs. Such oral presentations would also facilitate more discussion on how the experiments could be improved.

We also strongly suggest that a Claims-Evidence-Reasoning (CER) activity is scheduled for interpreting the results. CER would place a demand on students to explain the results they found.

- **Claim:** Students state their understanding of a phenomenon, or the results of the investigation (Activate Learning, n.d.).
- **Evidence:** Students are expected to use data to support the claim.
- **Reasoning:** Students illustrate why the particular evidence they offer is the right evidence to use in support of the claim (Active Learning, n.d.).

This CER activity could lead to rich discussions that can reveal either true understanding of the parameters of the investigation—ethylene pathways, climacteric physiology, and enzyme inhibition—or major misconceptions of these terms.

○ Discussion and Conclusion

So often we do not contextualize inquiry activities for the students, and the activities therefore remain abstract constructs in the laboratory, with students having

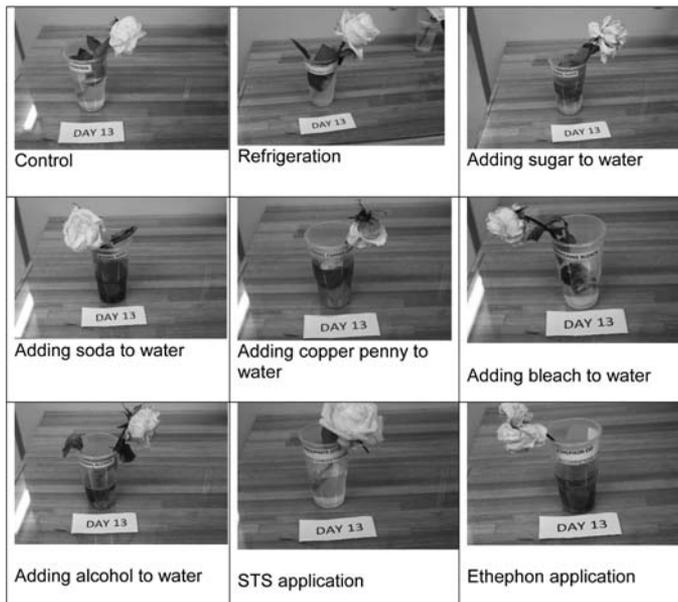


Figure 6. All treatments on Day 13.

could be very beneficial. We have not facilitated this activity with school learners, but we did introduce it in a professional development course for teachers. A strong emerging theme from our research was that teachers saw the affectiveness of such problem-based and cooperative approaches to teaching and learning. Such an activity not only stimulates student interest in the content, but also teaches other affective outcomes, such as respect for other people (by having to work in groups) and an appreciation for the role of science in our everyday lives. This activity also illustrates to students that *all* cultural groups possess indigenous knowledge. So often we tend to associate indigenous knowledge with Indian or African tribes, forgetting that European cultures also possess such cultural knowledge.

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