Issue-Oriented Science: Using Socioscientific Issues to Engage Biology Students

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ABSTRACT

In today’s global society, with science and technology advancing at a rapid pace, issues about biological topics are common. A typical standards-based high school or general college-level biology classroom naturally lends itself to teaching issue-oriented science. In an issue-oriented classroom, students analyze and discuss personal, societal, and global issues that require an application of relevant scientific evidence. Learning in the context of issues can help engage students in higher-order thinking skills that will help them to become the scientifically literate citizens needed in the current global community.

Key Words: Inquiry, issue-oriented science, sustainability, trade-offs, scientific evidence.

What Is Issue-Oriented Science?

Socioscientific issues are at the core of an issue-oriented approach to teaching science. Studies suggest that students learn the concepts in a discipline when they are presented in a context that provides meaning for those concepts, such as a social or cultural context (Bransford et al., 1999). A socioscientific issue is a complex social issue with links to science concepts. One important aspect of issue-oriented pedagogy is that scientific evidence is used to draw a conclusion or make a decision about a socioscientific issue. The issue is examined from the perspective of multiple stakeholders, and the trade-offs associated with a decision or perspective are identified. Throughout an issue-oriented science course, students learn what it means to evaluate scientific evidence, how to base an argument on scientific evidence, and how science and society interact. Many of the socioscientific issues that lend themselves to teaching students methods for evaluating evidence and making evidence-based decisions have no obvious “correct” answer. Instead the use of complex issues allows students to examine the pros and cons of the issue and identify the trade-offs involved.

An Issue-Oriented Model

Figure 1 shows the iterative process of an issue-oriented instructional model. This model was developed by the Science Education for Public Understanding Program (SEPUP) at the Lawrence Hall of Science at the University of California at Berkeley. SEPUP specializes in developing issue-oriented curricula and created this model from extensive work with schools across the country teaching issue-oriented science. The model of issue-oriented science described here is a form of inquiry science. In fact, inquiry and issues go hand-in-hand in an issue-oriented classroom. In an issue-oriented classroom, students can be introduced to a complex issue at the beginning of the unit or series of activities to elicit their ideas and provide a context for the science learning. Then they explore a series of challenge questions by gathering and evaluating evidence through a variety of activities, including investigations, modeling, discussions, and readings. With each new inquiry...
experience, students connect the learning to previous ideas. In a culminating activity, students apply the evidence that was gathered over the course of the unit or series of activities to make a decision or recommendation about the original issue (Figure 1).

Through work with teachers and students using issue-oriented science, SEPUP has identified five criteria that are essential components in an issue-oriented classroom that uses the model described above: discussion, student collaboration, application of evidence, identification of trade-offs, and assessment. Table 1 describes variation in the emphasis a teacher places on the five key components of the instruction and learning environment in an issue-oriented classroom.

The following is an example of a classroom environment in which more emphasis is placed on the essential components described in Table 1. Over the course of a cell biology unit focused on the issue of what to do about an emerging infectious disease, students

- work together to observe cells and microbes under the microscope,
- independently complete readings about leprosy and other microbial infections,
- work in groups to use models to learn about the structure and function of cells, and
- collaborate in a simulation of a bacterial infection that illustrates why it is important to take an antibiotic as prescribed.

**Table 1. Essentials of an issue-oriented science continuum.**

<table>
<thead>
<tr>
<th></th>
<th>Less Emphasis</th>
<th>More Emphasis</th>
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</thead>
<tbody>
<tr>
<td><strong>Science Discussion</strong></td>
<td>Discussion of scientific facts in isolation from personal, societal, and global issues</td>
<td>Discussion with occasional reference to personal, societal, and global issues</td>
</tr>
<tr>
<td><strong>Student Collaboration</strong></td>
<td>Students work alone</td>
<td>Students work in groups with assigned roles</td>
</tr>
<tr>
<td><strong>Application of Scientific Evidence</strong></td>
<td>Students acquire scientific information</td>
<td>Students support a position about a personal, societal, or global issue with reasons that are subjective or unscientific</td>
</tr>
<tr>
<td><strong>Identification of Trade-offs</strong></td>
<td>Students take a position on an issue without identifying the trade-offs</td>
<td>Students take a position on an issue and recognize the trade-offs associated with personal, societal, or global issues</td>
</tr>
<tr>
<td><strong>Assessment</strong></td>
<td>Assessments address only science content</td>
<td>Assessments address science content and occasionally reference personal, societal, or global issues</td>
</tr>
</tbody>
</table>

Note: Students and/or a classroom may be at different points on the continuum for the various criteria.
At the end of the unit, students work through an epidemiological scenario of an emerging disease in a village. Students collaborate together to gather and discuss data as they work through the scenario, make a hypothesis about how the disease is spreading, and modify their hypothesis as more evidence is gathered. Once they have a model of transmission, students use evidence to make recommendations about what public health measures to take and identify the trade-offs of their decision. A trade-off is giving up something that is a benefit or advantage, in exchange for something that may be more desirable. For example, students might determine that mice are spreading the disease and recommend that a poison be used to kill all the mice in the village. The trade-offs in this case are that people’s safety is potentially compromised if they are exposed to the poison and that the targeted mouse population may have an important role in the ecosystem.

In order to foster discussion and collaboration, students could use a graphic organizer to summarize and discuss their ideas, and then participate in a walking debate to discuss various recommendations and trade-offs from their own or others’ perspectives. During and/or at the end of the walking debate, students could be asked whether the discussion changed their mind about their recommendation and why. Discussion and collaboration such as this can minimize the potential controversy that could arise with complex issues, and maximize the focus on using evidence to support a decision. The graphic organizers could serve as an assessment of students’ use of evidence to make a recommendation about an issue and identify the trade-offs.

**Advantages to Issue-Oriented Science**

There are many advantages to using an issue-oriented approach to teaching. One of the strengths of issue-oriented science is that it is engaging for all students in that it helps to make real-world connections and illustrates how science applies to everyday life (Zeidler et al., 2005; Tal & Kedmi, 2006). Sadler and Fowler (2006) and Bransford et al. (1999) advocate that issue-oriented science contextualize the content, which serves as an effective vehicle for learning and understanding the science. In particular, Zohar and Dori (2003) found that low-achieving students showed greater improvement in learning when taught using science that incorporated societal, cultural, environmental, political, and ethical issues.

When properly implemented, an issue-oriented curriculum teaches science content while simultaneously improving students’ reasoning and use of evidence to support a particular position or conclusion about socioscientific issues. Tal and Kedmi (2006) found that students studying an issue-based curriculum “improved their argumentation abilities, developed more complex patterns of reasoning based on scientific evidence, and even challenged the traditional perception of science as neutral.”

In SEPUP’s studies of the issue-based biology course Science and Global Issues: Biology, pre- and post-tests administered for each unit (Ecology, Cell Biology, Genetics, and Evolution) showed large and statistically significant educational gains for a variety of items, including multiple choice and constructed response. SEPUP’s evaluation also found that underrepresented STEM students showed the same large educational gains that other groups showed. In addition, teachers reported increased student engagement, consistent with the research described earlier.

**Choosing an Issue**

In order to incorporate an issue into a biology class, the first and perhaps most challenging step is to choose an effective issue that works well with the content being taught. To do this, it is helpful to first determine the specific content needs of the course and then choose an issue that integrates well with that content.

Socioscientific issues can range from personal to societal. Personal issues affect a person’s everyday life. For example, should you choose to drink bottled water or tap water? Societal issues can be focused at the community and/or the global level. An example of an issue at the community level is how would the closing of a portion of a wildlife reserve to hunting affect the biodiversity of the reserve and surrounding areas? At the global level, the issue could be “How should research funds be distributed among groups studying infectious and noninfectious diseases?” Other examples are described in Table 2.

**Table 2. The issue of sustainability in a biology course.**

<table>
<thead>
<tr>
<th>Biology Content Focus</th>
<th>Sustainability Focus</th>
<th>Personal Issue</th>
<th>Societal Issue</th>
<th>Global Issue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ecology</td>
<td>Human influence on ecosystems</td>
<td>Should you buy farmed fish? Is it healthy and sustainable?</td>
<td>What should be done about an invasive species in an ecosystem?</td>
<td>How can countries work together to make the ocean’s fisheries sustainable?</td>
</tr>
<tr>
<td>Cell Biology</td>
<td>Global health issues</td>
<td>How do you decide whether a new medicine is safe to use?</td>
<td>What should be done about antibiotic resistance?</td>
<td>Which infectious disease should be given global funding priority?</td>
</tr>
<tr>
<td>Genetics</td>
<td>Use of genetically modified organisms</td>
<td>Would you eat a genetically modified food?</td>
<td>Should labeling be mandatory for foods that are genetically modified?</td>
<td>Should the world’s governments approve the planting of genetically modified foods?</td>
</tr>
<tr>
<td>Evolution</td>
<td>Changes in and threats to biodiversity</td>
<td>Would you be in favor of using genetic engineering to recreate an extinct species, such as the woolly mammoth?</td>
<td>Should a local wetland be conserved or developed?</td>
<td>Where should global conservation priorities be set in order to maintain diversity?</td>
</tr>
</tbody>
</table>
Issues are distinct from topics. Tuberculosis is a topic. Some issues that could be derived from it include “How should limited funding be allocated to address tuberculosis worldwide?” and “How should we deal with the developing drug resistance of the bacteria that cause tuberculosis?”

Issues can range from broad and overarching to more specific. For example, the issue of how to live in ways that will sustain our planet’s systems and resources is a broad overarching issue with a number of more specific sub-issues. Table 2 outlines one way that the broad, overarching issue of sustainability and sub-issues of sustainability could be embedded across a 1-year high school or general college-level biology course. Other examples of overarching issues with many sub-issues include “How can we balance human needs and environmental protection?” and “What is the best way to use limited resources?” By choosing a broad issue with a number of content-specific and complex angles, there is more flexibility in how the issue relates to the content in each unit, while maintaining the overarching issue throughout the course.

A well-chosen issue will fit the following criteria:

- It will require an understanding of important scientific concepts and processes appropriate for the grade level and subject area being taught. Many issues address a number of content standards, and some cover content from multiple subject areas, which can provide a bridge between curricular units or courses.
- It will require an application of relevant, appropriate scientific evidence. Sometimes an issue that initially seems like a good fit with the topic is not the best choice because the science required to understand the issue is not at an appropriate level for the students or because it does not align well with the content standards being taught. Briefly mapping the content that is going to be taught alongside the science associated with an issue will help determine whether the level of scientific evidence is appropriate for the level of the course.
- It will engage a diverse group of learners in the science instruction.
- It will be complex enough to foster student debate and discussion frequently throughout the lessons or activities.

○ Integrating the Chosen Issue

Thoughtful and thorough integration of the issue is important. If the issue is incorporated only at the culmination of a long series of lessons, students will likely not fully understand the connections between the issue and the content being taught. Students will also be unable to identify and incorporate a variety of evidence for and the trade-offs of a decision. Incorporating an issue into a full biology course can provide an excellent framework for deepening student interest and understanding, and allow for more critical discussion and in-depth debate about the issue. It is important that the issue provides the context and the incentive for learning the content that informs the conclusion or decision about the issue. It is ideal but not always possible for the issue to be embedded throughout the lessons, unit, or course, instead of being added on as an infrequent, more superficial point of interest or timely news reference. At the very least, students should be given frequent opportunities to develop strong connections between the content and the issue. When students are given the opportunity to revisit socioscientific issues, this often increases their interest and engagement.

○ Techniques for Incorporating Issues in the Classroom

- Begin and end the unit with an activity related to the issue.
- Include case studies to connect the issue to biological concepts.
- Use a current and/or local news article.
- Incorporate the issue into the introduction of the activity or lesson.
- Integrate the issue throughout the activity or lesson.
- Use end-of-activity questions and discussion to reinforce connections between the issue and content.

○ Techniques for Blending an Issue into a Unit

The issue-oriented instructional model detailed in Figure 1 naturally lends itself to embedding an issue throughout the lessons in a variety of ways. To fully incorporate an issue, several techniques can be used within a single unit. Although the individual techniques are applied to particular lessons, it is important in the overall planning of the unit or course to base decisions primarily on how the issue is integrated into the larger framework of the curriculum. Many times, a typical lesson can be modified into an issue-based lesson by incorporating an issue-based scenario or practical problem into a hands-on activity, in which the scenario serves as the core of the activity. For example, in an ecology unit, the topics of population dynamics, food webs, ecosystems, and invasive species might be covered. The unit could be taught through the issue of ecosystem management and change. Lessons on population dynamics could incorporate fisheries management into the traditional predator–prey model, examining the effect of changes in birth, death, and migration rates on population levels, but use fishers as the predator, adding the concept of varying levels of fishing and its effect on population levels. This allows for the issue to be well incorporated while the required content is being taught. Another lesson in the same unit that teaches students about food webs might incorporate invasive species and their effect on an ecosystem that includes a commercially fished species. Both of these examples (fisheries and invasive species effects on population dynamics and food webs) could then be used in discussions about biodiversity, conservation, and other ecology topics throughout the unit. There are many techniques that can be used for blending an issue into a unit. Five are described below.

1. Book-end a unit with a strong introductory and concluding activity related to an issue. Beginning and ending, or book-ending, a unit with activities that focus specifically on an issue can create a context for students to make connections between the issue and the content. Students are presented with an issue or a problem, and then, after a series of activities in which they gather and evaluate evidence, they apply the evidence to address the issue or problem. For example, a unit on evolution that focuses on biodiversity and conservation might begin with an activity examining various human effects on biodiversity. Next, students could learn about evolutionary concepts in a series of activities. Then, in a culminating activity, students could use the evolutionary science they learned as part of the evidence in making a conservation decision about areas that have a certain level of biodiversity and contain resources used by humans. While book-ending can provide the overall framework of incorporating the issue into the content, it is important that the issue still be woven wherever possible throughout the activities being taught.
Tips for Incorporating Issues in the Classroom

- Elicit students’ ideas about the issue and/or the type of evidence that could inform their decision about the issue.
- Have students make a decision or recommendation about the issue.
- Whenever possible, connect the issue to current events and local problems or concerns. Use local newspapers, experts, speakers, and organizations for additional local connections to the issue.
- Make connections between the scientific principles and evidence related to the issue. The relevant science concepts may be more numerous than those investigated in the specific unit being studied.
- As students investigate the science content related to the issue, revisit the issue regularly to discuss new evidence that has been gathered and questions that have arisen.
- Be sure that students explain how scientific principles and evidence were used to help them understand the options and reach a decision about the issue.

(2) Include case studies to connect issues to biological concepts. Case studies can be a powerful way to make the issue relevant for students and can be used to make specific connections between content and an issue. For example, a lesson on dominant and recessive genes could include a case study on sickle cell anemia and malaria resistance. They can also be used to allow for a broader study of a topic (e.g., when studying population dynamics, case studies on the spread of several invasive species could be used to emphasize how environmental conditions affect population growth). Another strategy for using case studies is to include multiple case studies in a unit in order to follow an issue throughout, such as multiple case studies on diseases in a cell biology unit focused on global pandemics. A case study can be written for use with a specific activity or unit. This allows for relevant content connections, for adaptation to students’ reading abilities, and for bridging the content and issue between activities within a unit. If multiple case studies are used, they can be written with parallel structures so that the information the students are tracking can be compared. For example, in a genetics unit, each case study might include information on the benefits, risks, and concerns of the use of a genetically modified organism, the current status of research and development on that organism, and alternative solutions to the problem that the organism is supposed to address.

(3) Contextualize each activity. Incorporating an overarching issue into the introduction of an activity can help students make the connection between the content and the issue being studied. This can be done with a warm-up activity that brings out background knowledge about the issue. Such warm-ups could include a brief class discussion or brainstorming about a particular aspect of the issue or a short film clip, cartoon, news article, or reading about the issue. For example, when teaching about gene expression and how genes are turned on and off in cells, a connection can be made to the issue of genetically modified organisms. Genetically modified organisms have a gene or genes inserted or deleted. Usually the gene being inserted is from another species. In some genetically modified organisms, the inserted gene is turned on by various conditions, such as the addition of a specific chemical. A short reading on a genetically modified crop of this type that is being reviewed by the FDA for commercial use ties the content of gene expression to the issue of genetic modification and can be used to elicit students’ background knowledge on the topic of genetic modification.

(4) Integrate the issue throughout the activity or lesson. If the chosen issue works well with the content being taught, the issue can be incorporated into the body of the lesson(s), within the procedure of an activity, or throughout a reading. For example, the procedure for a typical non-issue-oriented activity about population dynamics might walk students through a predator–prey model in which students can model predators hunting “prey” by trying to find colored objects against a particular background. This activity conveys several aspects of population dynamics and can be easily modified to include concepts such as natural selection, birth and death rates, and the effects of disease on populations.

In order to incorporate the issue of how to make the ocean’s fisheries sustainable into the population dynamics activity, the model could be set up to mimic a fish population. The same procedures described above could be followed in order for students to learn about basic population dynamics. Once students are comfortable with these concepts, the model can be modified to add the pressure of fishing. Students can be given particular roles (e.g., trawl-net fisher, subsistence fisher, etc.) with different fishing limits, fishing seasons can be implemented in the activity, and the students can examine how the various pressures of fishing affect the population of fish. This provides students with a deeper understanding of the content being taught, as well as a context that is more meaningful than the typical wolves-and-hares model.

(5) Use end-of-activity questions and discussion to reinforce connections between the issue and content. The end of a typical lesson will often include questions that require recall or content understanding. Adding issue-oriented questions can elicit student discussion and debate about the issue. For example, in the gene expression lesson described above, an analysis question that focuses on a genetically modified crop expressing a specific trait would link the issue to the content being studied. Students could also debate the pros and cons of using a crop that has been genetically modified to express a specific trait. This strategy can also be helpful in drawing out links among several lessons that address various aspects of an issue.

Conclusion

Teaching issue-oriented science takes careful planning and designing of lessons or activities. When implemented properly, it can result in significant benefits to student learning. The relevance and engagement provided by issue-oriented science also helps students understand the nature of science and develop the skills of scientific literacy that will prepare them to think critically about the issues that face society now and in the future. Teachers with whom we have worked have reported that using issues engages students previously not interested in science, and it provides not only the students but also the teachers themselves with an improved experience in the classroom.

References


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