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Lesson

# What's in this? Students Deliberate on Endocrine Disrupting Chemicals Found in Everyday Healthcare Items to Build Democratic Skills

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## Abstract

In helping our students become informed and active members of society, it is necessary that they develop certain skills that will empower them to improve their community and governance. These skills include communication, collaboration, and application of information. One way of helping students develop these important skills is through deliberative pedagogy. In this article, we present the curriculum for a small group activity called Deliberative Democracy (DD). Here we describe one DD activity that was iteratively developed over five years for an introductory biology course. In this DD activity, students were asked to develop a policy statement that addresses the question: "What kind of regulations should be placed on cosmetics that contain potential endocrine disrupting chemicals (EDCs)?" We incorporate multiple strategies in this activity, including readings, videos, worksheets, clicker questions, small group and individual work, and whole class discussions. This activity supports students in developing important democratic skills and provides an opportunity to apply course content to real-world issues.

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**Supporting Materials:** S1. Deliberative Democracy - Day 1, Media Reading Quiz (Option A); S2. Deliberative Democracy - Day 1, Lecture Slides; S3. Deliberative Democracy - Day 1, Student Worksheet; S4. Deliberative Democracy - Day 2, Scientific Reading Quiz; S5. Deliberative Democracy - Day 2, Lecture Slides; S6. Deliberative Democracy - Day 2, Student Worksheet; S7. Deliberative Democracy - Example 1-day DD Activity; S8. Deliberative Democracy - Day 1, Media Quiz (Option B); S9. Deliberative Democracy - Clicker Question Examples

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## Learning Goals

Students will:

◊ develop their "ability to understand the relationship between science and society," a *Vision and Change* competency (2009).

◊ explore how biological principles and other information can apply to real-world issues.

◊ improve their scientific literacy and learn to identify reliable information sources.

◊ practice collaborating and deliberating with peers to achieve a common goal.

◊ communicate scientific information with peers and instructors.

## Learning Objectives

Students will be able to:

◊ search and utilize published scientific data to construct an argument.

◊ discern between more-credible and less-credible resources available on the internet.

◊ describe several ways that endocrine signaling works.

◊ describe what could happen when endocrine disrupting chemicals are introduced into the body.

◊ deliberate with peers to write an informed consensus statement.

◊ assess multiple (sometimes conflicting) variables in addressing a problem, including scientific, social, economic, and equity issues.

◊ associate democratic skills (communication, collaboration, and applying information) with course content and everyday life.

## INTRODUCTION

As introductory biology instructors, we know that many of our students will not pursue academic careers in biology but will often continue in the health profession, a different science, technology, engineering, and mathematics (STEM) field, or will leave STEM altogether (1, 2). Regardless of where their careers take them, each of our students will make personal and political decisions on societal issues throughout their life, many of which will rely on a working understanding of aspects of science and the nature of science. Instructors have the opportunity—and arguably the responsibility—to teach our students to navigate the scientific and pseudoscientific information that circulates society. It is crucial to remember that we are educating members of society; thus one of the most essential things we can do is teach students to "understand the relationship between science and society," as cited in the *Vision and Change* report (3).

In helping our students become informed and active members of society, it is necessary that students develop certain skills that will empower them to help improve their government and community (4). One framework for cultivating undergraduates as actively informed members of society proposes three democratic skills of particular importance (5):

1. **Communication:** Students should develop effective communication skills (written and oral) in a variety of contexts and among diverse groups of people.
2. **Collaboration:** Students should develop effective dialogue, deliberation, public reasoning, and collaborative decision-making skills.
3. **Application of information:** Students should understand and critically analyze information (*e.g.*, research skills, evaluating the quality of arguments).

One approach to scaffold opportunities to develop these democratic skills in the undergraduate classroom is through deliberative pedagogies (DP), a group of teaching strategies relatively new to college classrooms (6). DP is a way of teaching students how to grapple with real-world problems through informed deliberations (6). DPs have been used and studied in college courses and K-12 alike. In K-12 classrooms, teachers report that using DP "changes how [students] think, write, and understand their roles in society" (7). DP has also been used at the college level to encourage students to critically discuss global climate change (8) and to facilitate conversations between non-majors chemistry undergraduates and the general public on the use of nanotechnology (9). Student participants in DP activities have reported an increased interest and knowledge of the associated topic (8, 9), that they valued deliberative discussions (9), and that the activity helped them cultivate communication skills and increased their critical thinking (9).

For several years, we have refined and assessed student outcomes from a specific structured DP strategy called "Deliberative Democracy" (DD), which was first developed for a non-majors biology course at our institution (10). In DD activities, students are presented with a topic that is relevant to the course content and has local, social, political, and/or environmental relevance. Through deliberation, each student group forms an initial stance based on limited information, which summarizes the group's initial opinion on how the problem should be addressed. Following this activity, the students independently conduct a literature search to learn more about key aspects of the problem. Students come back together to demonstrate how the evidence they found supports or refutes their initial stance and deliberate in small groups to arrive at a more informed consensus. Students then develop a final group consensus statement, constructed as a suggestion for policymakers.

Through this exercise, students develop the skills of **application of information**, **communication**, and **collaboration** as they deliberate in groups and come to a consensus. In 2016, Weasel and Finkel conducted an initial assessment of DD at our institution in a course that was redesigned to largely center around deliberative activities. Evidence from student surveys and exams indicated that deliberations in this class format increased student engagement and learning (10). They found that students increased their use of evidence to support their claims, collaboratively engaged with their peers, and performed higher on assessments at the end of the term than the start (10). The authors proposed that the course model has the potential to be expanded across other science disciplines with relative ease (10). The positive outcomes from this study led to a larger-scale institutional initiative to expand implementation of DD to several STEM courses, resulting in evidence that the DD activities left a lasting impact on biology and chemistry students alike (11).

Implementing DD helped us towards achieving national goals. We aimed to meet calls for undergraduate STEM reform by increasing structured, student-centered activities in our often lecture-based courses (3, 12, 13). We also wanted to offer students a platform to practice using evidence-based scientific information to inform their positions on real-life issues. Lastly, we aimed for students to develop key democratic skills as they deliberated relevant issues. Teams of graduate student teaching assistants (TAs) and faculty instructors worked together to develop DD activities centered around topics that both aligned with the course curriculum and were likely to be relevant and intriguing to students. DD topics have included electrolyte-supplemented drinks (introductory biology), the impacts of sunscreen chemicals on the environment (introductory chemistry), and the safety of bridges during earthquakes (introductory physics). Our research on the impacts of DD curricula at our institution found that students' perceptions of DD were generally positive and were salient to students over a year later, though students had some negative perceptions related to the use of class time and challenging group dynamics (11, 14, 15).

Here we describe one DD activity that was iteratively developed over five years in an introductory biology course for majors. In this DD, students were asked to develop an informed consensus statement that addressed the question: "What kind of regulations should be placed on cosmetics that contain potential endocrine disrupting chemicals (EDCs)?" We chose the topic of EDCs because 1) the endocrine system and mechanisms of hormone action can be a challenging topic for introductory biology students; 2) investigating EDCs in the context of cosmetics presents a personal, relevant application

of course content; and 3) scientific research and public views on the topic are ongoing and often contradictory, allowing for nuanced and lively deliberation.

*Intended Audience*

While we have used DD in a variety of contexts, including majors and non-majors courses across biology, physics, and chemistry, the DD activity we describe here (EDCs) was designed for a large-enrollment (~150-400 students) undergraduate introductory biology (for majors) course. Other audiences for this DD, or a modified version, could include courses in anatomy and physiology, bioethics, conservation biology, endocrinology, environmental studies, general biology, and health studies. Because students work in teams of 3-5, this DD activity can work for both small- and large-enrollment courses and has previously been adapted for online instruction (see Teaching Discussion).

*Required Learning Time*

The EDC DD activity can be completed in approximately two one-hour lecture periods, with additional out-of-class time for reading/homework. If time is constricted, it may be modified or condensed into a one-day activity (see Teaching Discussion).

*Prerequisite Student Knowledge*

We conduct this DD activity after students have had one or two one-hour class periods with lectures on the endocrine system and hormone signaling. We recommend that students have some exposure to several topics before engaging in the activity as designed:

- the endocrine system (*e.g.,* organs and glands, signal and signal reception)
- hormones and hormone action (*e.g.,* peptide/polypeptide, amino acid derivatives, and/or steroid hormones; their structures and how structure impacts how they affect a cell)
- hormone signaling mechanisms (*e.g.,* autocrine, paracrine, endocrine pathways)
- using search engines to find relevant scientific literature (*e.g.,* Google Scholar, Web of Science, PubMed)
- equitable group work norms and behaviors

Please note that the above topics were introduced at a high level, geared toward basic conceptual understanding, and the exercise could be modified for varying levels of content knowledge. We recommend the following supplemental videos about the endocrine system, in particular if the course does not include lessons on the above listed topics.

- Bozeman Science - The Endocrine System
- Crash Course - Endocrine System, Part 1 - Glands & Hormones: Crash Course Anatomy & Physiology #23

*Prerequisite Teacher Knowledge*

Instructors should be familiar with teaching basic endocrinology and working with students to emphasize the connections of biological content with real-world implications. The instructor's experience should include use of basic active learning techniques to promote critical thinking, dialogue, and collaboration; guiding students through navigating primary literature and data sources; and fostering an inclusive, safe environment for students to share their experiences and perspectives.

## SCIENTIFIC TEACHING THEMES

*Active Learning*

This DD activity provides structure for students to engage with the course topic in novel ways and increases student control over their own learning. Students complete assigned out-of-class readings, watch relevant videos, and conduct literature searches to learn about aspects of the topic that interest them the most. Students complete in-class group worksheets, which guide participation in both small-group and whole-class discussions. Students respond to intermittent clicker questions throughout class time, guided by think-pair-share prompting.

*Assessment*

We developed both formative and summative assessments to align with the DD activities. The assessments allow both students and instructors to evaluate comprehension of the topic and readings and are timed to motivate student participation. Specifically, we administer a closed-ended online reading quiz before students begin the DD activity to assess students' understanding of assigned background readings and/or videos. We also use clicker questions throughout the DD activity days as check-ins, allowing instructors to immediately assess students' understanding of relevant course content, figures, and tables from the reading assignments, enabling instructors to provide additional explanations to students if necessary. Clickers are used to periodically check group progress during the activity and to adjust timing of the lesson plan as needed. Group worksheets are primarily used to delineate student roles, guide students through both days of the activity, take attendance, and organize student-collected information. The worksheets are graded largely on student participation rather than content and offer an opportunity for formative assessment in that students obtain written feedback from teaching assistants (TAs) or learning assistants (LAs). Finally, midterm and final exams include close-ended questions related to the DD activities (biology content questions and DD topic and/or literature-based questions).

*Inclusive Teaching*

In our large-enrollment course, students are randomly assigned to small pre-determined groups of four students and to one LA who is positioned in a specific area of the classroom. Students work in the same small groups throughout the term and physically sit in their group's section of the room on group-work focused days. This design element allows students to develop camaraderie and familiarity with the same small group of students and their LA. In developing these structured seating arrangements, instructors should accommodate students who may need to sit in accessible areas of the classroom due to physical disabilities. We work in concert with LAs to ensure that all of the students in their groups are able to participate. Students may arrange with the instructor to opt out of group work and complete a modified DD activity on their own.

Group work is facilitated by LAs, a graduate TA, and a faculty instructor, allowing for a ~1:20 ratio of instructors (LA, TA, and Professor) to students. LAs are trained in promoting equitable group interactions, and the instructor maintains an identity-safe classroom environment through explicit articulated expectations and conversations. DD is predicated on a "consensus" model, and while there are no right or wrong answers, the activity concludes with students deliberating to form an agreed-upon policy recommendation related to the topic. Group roles are used to ensure each group member has a role in the activity, and each student additionally assigns themselves a specific piece of evidence that informs their group's consensus, allowing students to engage with the topic in accordance with their own individual interests. Instructors remind students to recognize that there may be sensitive social and/or politicized aspects to their deliberations and proposed solutions and to civilly consider such factors. We encourage students to respectfully voice their own opinions and experiences in these deliberations and to encourage equitable participation among their peers. LAs are asked to alert the instructor and TA if any complications or inappropriate behavior arises.

## LESSON PLAN

### *Pre-Class Preparation*

Prior to the activity, we introduce relevant course content to students, including the endocrine system, hormone types and structures, feedback loops, and mechanisms of hormone signaling and action. This course content may be conveyed to students through in-class lecture, assigned textbook chapters, and videos (see Prerequisite Student Knowledge). We recommend supplementing this content information with additional media that highlight the controversy of exposure to endocrine disruptors, such as the video "Our Chemical Lives" (0:00 – 1:30) and/or the online TedTalk video (entire video; Table 1) as supplemental in- or out-of-class assignments. We also recommend two resources for students to learn more about science, media, and policy:

- Science News and Information Today
- How to shape policy with your science

The instructor assigns preliminary media resources (Table 1) and the media quiz (Supporting Files S1, S8) to be completed before Day 1. Coming into Day 1, we encourage students to bring an item or take a picture of a cosmetic or personal-care item (*i.e.,* makeup, shampoo, soap) that they use regularly to check the label for EDCs during Day 1 of the activity.

### *In-class: Day 1 – Initial Stance*

By the time students arrive for Day 1 of the EDC DD, they should have some level of background knowledge about EDCs and understand that potential EDCs are components of many common products commercially available in stores, including soaps, creams, sunscreen, makeup, deodorant, plastics, and powders. Students also should have completed the media quiz before coming to class (S1. Day 1 - Media Reading Quiz [Option A]).

Instructors may use the Day 1 lecture slides provided (S2. Day 1 - Lecture Slides), create their own slides, or use publisher-provided slides (we use some slides provided by Biological Science – Freeman, 7e). We introduce the DD activity through clicker questions that prompt students to consider how this topic may impact their personal lives. Through clicker questions, we ask about the quantity of cosmetic products they use regularly and, thus, their potential exposure to EDCs. After the poll, the instructor introduces examples of purported EDCs, including parabens, phthalates, oxybenzone, resorcinol, and polytetrafluoroethylene. A second clicker poll asks students to look at the ingredients list on the cosmetic project they brought to class and to report whether their product contains one of the chemicals, which helps students gain an idea of the prevalence of these chemicals and increase personal investment. We then introduce the EDC DD question: "What kind of regulations (if any) should be placed on cosmetics that contain potential EDCs?"

Day 1 worksheets prompt students to select group roles (*e.g.,* leader, spokesperson, devil's advocate; S3. Day 1 - Student Worksheet). Descriptions of roles can be found on the Day 1 lecture slides and worksheet (Supporting Files S2, S3). Each student group chooses one of the listed EDCs on which to focus their literature review. The goal of the Day 1 worksheet is to help students develop their initial stance on the EDC question and consider what additional information would help them better understand the issue at hand. We let students know that their initial stance will likely evolve or change on Day 2, when they complete their literature reviews and develop an "informed consensus statement." Students assess gaps in their knowledge and identify what evidence would be needed to better inform their initial stance. Each student selects a topic on which to conduct an out-of-class literature search. After conferring with the LAs, we select a few small groups who wish to share their initial stance and/or knowledge gaps with the rest of the class. For this, we pass out a hand-held microphone, ask the student spokesperson to introduce themselves and to share their group's ideas with the class. We facilitate a supportive classroom culture while students share out, by encouraging students to applaud, asking any relevant follow-up questions, and thanking them for volunteering.

Students are expected to find additional sources/information to fill their knowledge gaps before Day 2 outside of class and come prepared to share the information that they learned with their group. Additionally, a supporting scientific article and associated reading quiz are assigned (S4. Day - 2 Scientific Reading Quiz) to be completed prior to EDC DD Day 2.

### *In-class: Day 2 – Informed Consensus Statement*

By the time students arrive for Day 2, students will have completed their literature reviews and the reading quiz (S4. Day 2 - Scientific Reading Quiz). During an introductory mini-lecture, the instructor reviews key points and figures from the assigned scientific article and provides logistical instructions for Day 2 discussions. Instructors may use the Day 2 lecture slides provided (S5. Day 2 - Lecture Slides) or create their own.

During the mini-lecture, we also discuss how to write a final consensus statement, which should build on the initial stance that the groups developed on Day 1. The refined statement should be backed by the scientific evidence that students found outside of class, and should be realistic with respect to logistics, society, and equity. We often encourage students to address these statements as an informed advisory suggestion

for policymakers and ask students to aim to produce a statement that will be meaningful to both experts and those who are unfamiliar with the issue.

Guided by the Day 2 worksheet (S6. Day 2 - Student Worksheet), students work in the same small groups. Each student selects a group role, different from the one that they held in Day 1, and shares the evidence that they gathered during their independent literature search with the rest of their group. The Day 2 worksheet guides students to craft their evidence-backed consensus statement. As in Day 1, at the end of class the instructor asks groups to volunteer to share their final informed consensus statement with the rest of the class.

### *Additional Follow-Up Activities*

At the end of the activity, most students realize that more data is likely still needed to further improve their final consensus statement. Depending on the time remaining, instructors may ask student groups to design a follow-up experiment to collect data that would improve, inform, or refine their policy recommendation. We allow student groups to describe their experiment in any way they prefer (*e.g.*, sketched out, flow chart, written).

Another optional activity is a "spokesperson swap." With this activity, each group's spokesperson (assigned role) joins a different group for about five minutes to share their group's findings and consensus statement. This swap allows for the exchange of ideas and information at a larger group level, similar to a "jigsaw" approach.

## TEACHING DISCUSSION

### *Student Experiences and Feedback*

We have found that students and instructors report that DD activities are effective in engaging students and giving them practice in democratic skills such as communicating science, collaborating with peers, and applying knowledge to the real world. We have conducted several studies to assess the impact that DD activities have on students (11, 14, 15). Through qualitative analyses of open-ended survey responses asking students about their experiences with DD, we found that working with peers, applying the scientific literature to real-world scenarios, and gaining new perspectives on the DD topics were positive aspects students reported with their DD experiences. Students reported that negative aspects of DD participation included challenges in group work, worksheet format, and time constraints (11).

In a longitudinal study of majors and nonmajors biology students, we found that one year after participating in DD activities, students described lasting impacts (*e.g.*, content knowledge, changed perspectives) from their DD experiences (11). Students reported that DD was a memorable experience, indicating that lessons learned from DD may be salient enough to persist over time. Table 2 includes a few student quotes on their DD experiences from an open-ended survey we distributed at the end of the term (IRB approval #153524 and #184471).

### *DD One-day Version*

When time is limited, we adapt DD activities to fit into one day of class. One-day DD activities are similar in that students are still deliberating on a content-related, relevant societal problem. However, while students can be encouraged to look for relevant online information during class, they do not have time to conduct thorough literature searches or fill out a typical DD worksheet. We recommend that instructors who are adapting a two-day activity into a one-day activity provide their students a worksheet that is more guided and based on the pre-activity readings (S7. Example 1-day DD Activity). When analyzing open-ended survey responses reflecting student perceptions of one- versus two-day DD activities, we did not identify any noteworthy differences (unpublished data).

### *DD Online Format*

In Spring 2020, we adapted our in-person DD activities to the remote format necessitated by the COVID-19 pandemic. Most aspects of the DD were kept the same and were conducted with ~200 students and ~10 LAs synchronously via online videoconference (Zoom) over a two-day period. We used Zoom's breakout room feature (or Google Meet for accommodating >200 students/50 rooms) to divide students into small working groups, which were consistent throughout the term to help students build community despite working remotely. Group roles were modified slightly as needed, and students used Google Docs and the classroom management system to collaborate on their worksheets in real time. Anecdotally, students reported particularly enjoying the opportunity to interact and collaborate with other students online—a brief reprieve from the social isolation of the pandemic. Students also had the opportunity to do a more thorough investigation of their household healthcare and cosmetic items, making the activity more personal and interactive. Drawbacks of the remote format included increased difficulty for the faculty instructor and TA to interact with small groups and engage in discussion to the same extent as in-person instruction, technical difficulties with students adjusting to remote learning, and the difficulty of reorganizing students into new groups on the spot when class absences were high. The LAs were immensely helpful in dealing with these issues, as they could help facilitate discussions and could quickly communicate with instructors on the success of the activity and any problems that arose. For full-class discussions at the end of each activity, we had LAs provide names of students who had indicated their willingness to share their conclusions with the class when we rejoined in the main Zoom room.

### *Conclusion*

This deliberation-based activity is an engaging and adaptable lesson that supports students in developing important democratic skills and applying biology to real-world issues. By incorporating multiple teaching strategies, including readings and videos, worksheets, clicker questions, small group work, and whole class discussions, students are given several opportunities to develop important skills over the two-day activity. This activity is a platform that allows for scientific communication, collaboration with peers, and increased scientific literacy, while also addressing the *Vision and Change* (3) competency of the "ability to understand the relationship between science and society."

## SUPPORTING MATERIALS

- S1. Deliberative Democracy - Day 1, Media Reading Quiz (Option A)
- S2. Deliberative Democracy - Day 1, Lecture Slides
- S3. Deliberative Democracy - Day 1, Student Worksheet
- S4. Deliberative Democracy - Day 2, Scientific Reading Quiz
- S5. Deliberative Democracy - Day 2, Lecture Slides
- S6. Deliberative Democracy - Day 2, Student Worksheet
- S7. Deliberative Democracy - Example 1-day DD Activity
- S8. Deliberative Democracy - Day 1, Media Quiz (Option B)
- S9. Deliberative Democracy - Clicker Question Examples

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**Table 1. Lesson Timeline.**

| Activity | Description | Estimated Time | Relevant Supporting Files |
|---|---|---|---|
| **Before DD Day 1** | | | |
| • Instructor lecture<br>• In class video Our Chemical Lives (0:00-1:30)<br>• Media article reading (Option A) or TED talk (Option B)<br>• Quiz (Option A or B)<br>• Find or take photo of student's everyday item | • Lecture includes overview of cell-cell signaling: chemical signaling diversity, how hormones act on target cells, what hormones do and how they are regulated (based on Freeman, *Biological Science*, Chemical Signals Chapter)<br>• Media reading and quiz are used to engage the student with the real-world problem | ~1-hour class period<br>~2-3 hours (outside of class) | S1. Day 1 - Media Reading Quiz (Option A)<br>S8. Day 1 - Media Quiz (Option B) |
| **DD Day 1 - Initial Stance Statement** | | | |
| • Group work<br>• Day 1 worksheet<br>• Clicker questions<br>• Class discussion | • Instructors and Learning Assistants facilitate while student groups are forming initial statements. | ~1-hour class period | S2. Day 1 - Lecture Slides<br>S3. Day 1 - Student Worksheet<br>S9. Clicker Question Examples |
| **Before DD Day 2 and Literature Search** | | | |
| • Peer-reviewed article reading and quiz<br>• Outside of class literature search on group chemical/topic | • Peer-review reading and quiz are used to engage the student with the real world problem.<br>• Students perform a literature search to fill in the gaps they found during the Day 1 worksheet. | ~1-3 hours (outside of class) | S4. Day 2 - Scientific Reading Quiz |
| **DD Day 2 - Informed Consensus Statement** | | | |
| • Group work<br>• Day 2 worksheet<br>• Clicker questions<br>• Class discussion | • Instructors and Learning Assistants facilitate while student groups are forming science advisory statements/consensus statements. | ~1-hour class period | S6. Day 2 - Student Worksheet<br>S7. Example 1-day DD Activity<br>S9. Clicker Question Examples |

**Table 2. Examples of Student Quotes.**

| Student Quotes |
|---|
| *"[DD] helped me learn the concepts more and understand how to use them in the future. Many people forget content once they have learned it, but [DD] uses real life problems to link science and the real world to reinforce learning."* |
| *"Doing the EDCs [DD] was exciting because we were learning about hormone signals, so having that real-world anchor to why we are learning this helps!"* |
| *"There's many variables to take into consideration when forming a consensus in your group. It opened my mind and changed my way of thinking. These aren't always black or white, or good or bad."* |
| *"The EDCs [DD] was an interesting addition to class and lecture."* |
| *"Although the actual in-class discussions can be at times tedious, this exercise would be ineffective without the community forum component."* |