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Lesson

Real World Scenarios in Non-Majors Biology

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Abstract

Students in non-majors' biology courses may not choose careers that require biology content knowledge; however, all will encounter science in their lives. We redesigned a non-majors introductory biology course to support students in considering the importance of biology in their own lives. Our intent was to provide students with skills to engage in scientific reasoning, apply biological concepts, and increase their interest in the subject. One of the components we created to achieve these goals was a series of three Real World Scenarios (RWS). These RWSs consisted of existing case studies to which we added structured group discussion and individual reflection papers. These elements allowed students to grapple with a complex topic with peers, be exposed to viewpoints different from their own, and then have time to reflect and consider their own thoughts before they made an individual decision. We implemented these RWSs in both the face-to-face (F2F) and online sections. Students in both sections reported finding the assignments useful to help them connect the science to their own lives and appreciated the opportunity to interact with their peers and be exposed to differing viewpoints. We provide information on how we set up the assignment and provide suggestions for additional improvements.

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Learning Goals

◊ From the Genetics Society of America Core Competencies:
- » Students will identify and critique scientific issues relating to society or ethics

◊ From the American Society for Biochemistry and Molecular Biology Scientific Skills:

Students should be able to:
- » when provided with appropriate background information, identify consistencies and inconsistencies.
- » use visual and verbal tools to explain concepts and data.
- » translate science into everyday examples.
- » given a case study, identify both scientific and societal ethical aspects.
- » give and take directions to be an effective team member.

◊ Additional Learning Goals:

Students will:
- » explain how biological concepts connect to real life situations.
- » value the importance of using scientific knowledge to make decisions.
- » recognize how biology concepts relate to students' own lives
- » gain biological knowledge necessary to make informed decisions as citizens.

Learning Objectives

Students will be able to:

◊ make connections between various biological concepts and ideas.

◊ evaluate claims based on scientific reasoning, process, and legitimacy.

◊ engage with real world scenarios and their connection to biology both in group and individual settings.

◊ make informed decisions based on scientific content and group discussions.

INTRODUCTION

Most students in non-majors' biology courses will choose careers that are not focused on biology; however, some will utilize aspects of biology in their careers, and all will encounter science in their lives. Therefore, all students in biology courses need a foundation of scientific thinking that will ultimately help them make informed decisions (1). Unfortunately, many non-science majors are intimidated by science classes, believing in some cases that they are "just not good at it," or that it is not relevant to their lives. To counter this, instructors should consider focusing on students' self-efficacy and self-reflection as important components of a non-majors' course. Self-efficacy is "the strength of one's belief in one's ability to perform a given task or achieve a certain outcome" (2, 3). Self-reflection involves "a conscious exploration of one's own experiences" (4). By engaging in reflection as a part of self-regulated learning, students can begin to better understand their own learning by considering the work they have done and how they can adjust their strategies to improve it (5, 6). By addressing self-efficacy, we can help support the students who believe they are "just not good" at science. By incorporating self-reflection, we can support the students to see how the science is relevant and important to their own lives while they identify the academic strategies they need to adjust moving forward. While self-efficacy and self-reflection are considered separate constructs, there is existing evidence that engaging in reflection also improves self-efficacy. Several studies exist documenting the impact of teachers' self-efficacy (*e.g.,* 7). Use of reflection to enhance self-efficacy in undergraduate science students is less prevalent in the literature . However, one study found that student reflections in an introductory geology laboratory significantly increased their science self-efficacy (8).

We redesigned a non-majors introductory biology course to address these needs and support students in considering the importance of biology in their own lives. Our intent was to provide students will skills to engage in scientific reasoning, apply biological concepts, and increase their interest in the subject. Our focus was on students achieving science literacy which we have defined in earlier work as "an enhanced capacity, both at the individual and collective levels, to make effective decisions grounded in STEM-informed analyses of complex, real-world challenges" (9). In a science-literacy-focused course, students must learn how to use and apply knowledge in various contexts.

One of the components we created to achieve these goals was a series of three Real World Scenarios (RWS). These RWSs utilized existing case studies to which we added structured group discussion and individual reflection papers. Two of the case studies we chose also included an ethical element, so some of the questions did not have true "right" or "wrong" solutions. These elements allowed students to explore the full complexity of the topic with peers, be exposed to viewpoints different from their own, and then have time to reflect and consider their own thoughts before they made an individual decision. We chose the case studies to align with content the students were learning in class so that they could connect the content to an actual scenario in the real world.

Others have used case studies to engage biology students with success and many examples of case studies and their utilization exist in the literature (10–13). What makes this lesson different is the addition of individual reflection papers following the group discussions of the case studies. These papers asked students to comment on the science content but also to reflect on their own thoughts on the topic. This practice allowed the students to voice their own opinion, particularly if it differed from their group, and gave them the opportunity to consider how the content they were learning in class applied to real scenarios they might encounter in their own lives.

Intended Audience

The lesson described here was taught in an introductory biology course for nonmajors at a large university in both a face-to-face (F2F) (119 students) and an online section (80 students). Students ranged from first-year students to seniors. However, the same methods could be used in any science course. Instructors would simply need to choose different case studies that aligned with their topic of interest and adjust the questions on the individual paper instructions accordingly.

Required Learning Time

One 85-minute F2F class period for each case study. Online students were expected to allocate 60–120 minutes spread over 3 days for each case study. See additional details in Tables 1 and 2.

Prerequisite Student Knowledge

The prior knowledge students will need will depend on whether their instructor uses the same case studies we used, or if they choose different case studies. Instructors will need to determine the prerequisite knowledge students need depending on the case studies they use and their goals for student learning. For the case studies we used, students would need introduction to interpreting data (all three RWS assignments), the process of scientific inquiry and linking claims to evidence (RWS, #1), viruses and vaccines (RWS #2), and genetically inherited diseases (RWS #3). We addressed the topics of interpreting data and linking claims to evidence throughout the semester. Students were presented with data and graphs that were related to the content were we discussing at the time. Students would analyze and interpret these data with instructor support. The content was primarily linked to the textbook we used, *Scientific American Biology for a Changing World* (14). We discussed the process of scientific inquiry throughout the course but most specifically during the first week of introduction to the course and biology as a field of scientific inquiry (Chapter 1 in [14]), viruses and vaccines as part of the class period dedicated to the immune system (Chapter 32 in [14]), and genetically inherited diseases as part of two class periods dedicated to inheritance, simple genetics, and complex genetics (Chapters 11–12 in [14]).

Prerequisite Teacher Knowledge

The prior knowledge instructors will need to enact this lesson will depend on whether they use the same case studies we used, or if they choose different case studies. For the case studies we used, instructors would need an introductory biology understanding of interpreting data and linking claims to evidence, the process of scientific inquiry, viruses and

vaccines, and genetically inherited diseases. However, these same methods of adding individual reflection papers following the group discussions of the case studies could be applied to any course with any scientific topic. Instructors would need to choose case studies that aligned with the content they hoped to help students consider.

SCIENTIFIC TEACHING THEMES

Active Learning

For the F2F section, students engaged in clicker questions and group discussion on the content they needed for understanding the case study in the classes leading up to the RWS. During the RWS activity, students engaged in group discussion of the questions posed in the case study itself. Following the RWS activity, students reflected and wrote individual papers on the topic, their group's discussion, and their own thoughts on the scenario. The details of these activities for both the F2F and the online section will be described in more depth below.

For the online section, students engaged with the content via online notes, animations, and lectures on the content that would be needed for understanding the case study in the days leading up to the RWS. During the RWS activity, students engaged in group discussion of the questions posed in the case study itself. Following the RWS activity, students reflected and wrote individual papers on the topic, their group's discussion, and their own thoughts on the scenario.

Assessment

For the F2F section, the instructor measured student learning through clicker questions spread throughout the classes and by student answers to questions posed to the entire class after group discussion. After participating in the RWS group discussions, each group turned in answers to the questions posed in the case studies. Finally, students turned in individual papers which allowed the instructor to see how well each student understood the topic. Students self-evaluated their learning by completing the clicker questions during class and by reflecting on the topics and their own ideas as they wrote the individual papers. Please see Supporting File S4 for a breakdown of how each question on the RWS paper instructions aligns with the lesson learning objective it was meant to assess.

For the online section, the instructor measured student learning through their individual posts and their responses to classmate posts in the group discussion. After participating in the RWS group discussions, each student turned in answers to the questions posed in the case studies and individual papers which allowed the instructor to see how well each student understood the topic. Students self-evaluated by reflecting on the topics and their own ideas as they responded to classmate posts and wrote their individual papers.

Inclusive Teaching

This lesson uses small group discussions to engage students in connecting biology concepts they have learned to actual scenarios in the world around them. We assigned groups for the students so that they could engage in conversation with students they may not otherwise work with. This format allowed for more equitable groups so that everyone entered with the same level of familiarity with the other students, rather than a single student in a group where everyone else already knew each other. We included three Real World Scenarios so that students would have variation in the topics and would have more of an opportunity to interact with their peers to develop understanding of topics. Finally, the product of each of these lessons was an individual paper that each student wrote. This structure allowed them to hear other viewpoints during the group discussion but express their own ideas and decisions in the individual paper. We presented guidelines for productive and respectful group discussion and, in the F2F section, walked around to each group throughout the class period to identify any problems in the group discussion or questions they had about the assignment. In the online section, the instructor monitored the discussions to make sure they remained productive. Having both a group discussion and a written paper also provided students with two different platforms for showing the instructor what they had learned. Students received participation points for engaging in the group discussions and the paper was graded on their engagement with the topic rather than on the correctness of their responses. Therefore, students were able to earn points in the course simply by explaining their own understanding of the concepts and scenarios.

LESSON PLAN

We created a series of three Real World Scenarios (RWS) for students to help them see how the science they were learning connected to situations in real life. We used case studies from the National Center for Case Study Teaching in Science as the foundation for these scenarios and built additional structure around them. We did not modify the actual case studies and so have not provided them here for copyright reasons. They are available by subscription through the NSTA website. While these methods could certainly be used exactly as we did them (with the case studies we used), instructors could also use our process to develop structure about whatever case studies would be of best use in their own courses. Each of the three RWSs occurred at the end of each of the three units and aligned with the content of that unit. Unit 1 focused on the scientific process, chemistry, cell structure and function, and evolution. The case study we used was *Butterflies in the Stomach: Is Genetically Modified Corn Harming Monarch Butterflies?* (15). This case study connected to the content and discussion in class on the scientific process and linking claims and evidence. Students had to consider the scientific evidence presented to determine whether or not Bt corn was the cause of declining monarch butterfly populations. Unit 2 focused on cellular respiration, photosynthesis, bacteria and protists, the immune system, viruses, and vaccines. The case study we used was *What Should the Victor Do with the Vanquished: Deciding the Fate of Smallpox* (16). This case study connected to the discussion on the immune system, viruses, and vaccines and included a consideration of the ethics of keeping smallpox samples available for research purposes. Unit 3 focused on mitosis, meiosis, genetics, and stem cell technology. The case study we used was *Living with Her Genes: Early Onset Familiar Alzheimer's Disease* (17). This case study follows a woman whose sisters have been diagnosed with Early Onset Familiar Alzheimer's Disease, the biology and genetics of the disease,

and a consideration of the decisions the woman must make regarding her own future and whether or not to have children who may inherit the disease. This study connected to our discussions in class of inheritance and diseases with genetic components. The NSTA website has NCCSTS case studies for a plethora of topics which makes it easy to adapt this activity for any course or unit.

Face-to-face section

In classes before each of the RWS assignments, we discussed the content necessary for students to understand the topics in the upcoming case study. The clicker questions used in class are provided in Supporting File S5. The slides that we created as supplements to the text to support students in thinking about experimental design are provided in Supporting File S6. Finally, early in the semester, as a class we went through a case study that walked students through the process of designing an experiment, collecting data, and analyzing and interpreting those data. This case study is available at the same location as those used for the Real World Scenarios and is called *Winning By a Neck* (18).

Each RWS was given an entire class period (85 minutes) in a traditional lecture hall with 119 students. Students participated in the RWS after they had engaged in all of the material from the unit and before the exam for that unit. Students were divided into groups of 4–5 students. We assigned students to groups to ensure that they worked with different students each time. The instructor generally discussed the purpose of case studies and how students should approach them and then provided instructions on ground rules for discussion and introduced the structure of the case studies (Supporting File S1). Students were instructed to answer all questions within the case study as a group. Because of the nature of the room, they were allowed to spread out and sit on the floor or go to a nearby room with tables to facilitate discussion. Students turned in one sheet with all group members' names and the answers to the questions at the end of the class period. When they turned in the group work, they were given instructions for an individual paper. The instructions included questions for students to answer that pertained to the particular case study and also asked them to reflect on how their own thoughts and decisions were different (or not) from their classmates' (Supporting Files S2, S3). In this way students made decisions as a group and also had the opportunity to further consider the topic on their own and express their own ideas and decisions. The individual paper was due one week after the group discussion. Students completed both group work and individual papers for RWS 1 and 2. Because the last RWS was on the last day of classes, students only completed the group work for RWS 3 and did not submit an individual paper.

Online section

Each assigned RWS was spread over several days in the online section with 80 students. Students participated in the RWS after they had engaged in all of the material from the unit and before the exam for that unit. Students were divided into 8–10 groups of 10–12 students (groups were larger online to maximize interaction and, unfortunately, due to inconsistent participation). We assigned students to groups to ensure they worked with different students each time. The instructor provided instructions on ground rules for discussion and introduced the structure of the case studies. Students were instructed to discuss the questions within the case study as a group. Online discussion was facilitated by requiring students to make an initial post within a 48-hour period and then going back over the next 48 hours and commenting (meaningfully) on at least two other classmates' posts and replying to responses on their initial post. For their papers, students included answers to the case study questions and reflected on how their own thoughts and decisions were different (or not) from their classmates' (Supporting Files S2, S3). In this way students interacted as a group and had the opportunity to further consider the topic on their own and express their own ideas and decisions. The individual paper was due 3–4 days after the group discussion closed.

TEACHING DISCUSSION

In class in the F2F section, a few of the students rushed through the activity and left, but most stayed the entire class period, wrote thoughtful answers to the group answers, asked questions in class, and were clearly engaged in discussions. In addition, the individual papers that students wrote after the group discussions were thoughtful and indicated that students had engaged in productive discussion. They also provided evidence that most students achieved the lesson learning objectives.

At the end of the semester, students were asked to rate each of the elements of the course on a four-point scale from "not at all helpful" to "very helpful" (surveys collected as part of University of Memphis IRB # PRO-FY2017-145, online students did not complete this end-of-term survey). Elements included: in class activities, online discussions, LearningCurves (Macmillan Learning), Science in the News papers, reflection papers, RWS discussions and papers, and exams. Students were asked to rate these elements on the following criteria: (A) how helpful the elements were to helping them learn biology, (B) how helpful the elements were to helping them see how the concepts they learned in class applied to the real world, and (C) how helpful the elements were to helping them see how the concepts they learned in class applied to their own lives. On a scale of 1 (not at all helpful) to 4 (very helpful), students rated the RWS with an average of 3.3. This ranking was one of the highest rankings only lower than the Science in the News papers (3.4) and tied with the in-class activities (3.3). For the first question about how helpful the elements were in helping them learn biology, students ranked the RWS with an average of 3.1, a median of 3, and a mode of 4. For the second question about how helpful the elements were to helping them see how the concepts they learned in class applied to the real world, students ranked the RWS with an average of 3.5, a median of 4, and a mode of 4. For the third question about how helpful the elements were to helping them see how the concepts they learned in class applied to their own lives, students ranked the Real World Scenarios with an average of 3.3, a median of 4, and a mode of 4. Overall, students found these assignments to be helpful to very helpful in multiple ways. See Figure 1 for a summary of the average rankings per question.

When asked what they liked most and least about the course, 22 out of 95 responses specifically mentioned they liked the RWS and only 5 said they disliked them. Representative examples of comments from students who liked them include: "*The real world scenarios were a good way for me to connect the subject to the real world*", "*I enjoyed discussing real,*

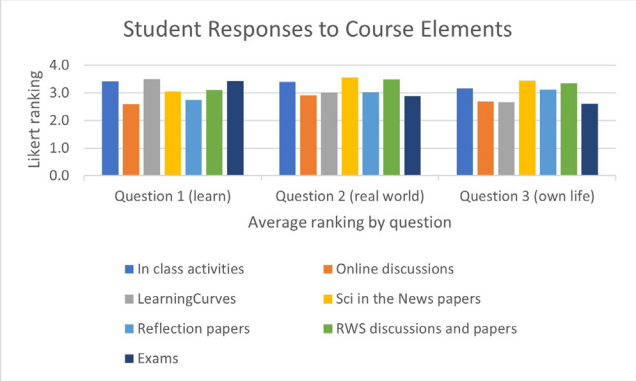

Figure 1. Student responses to course elements

valid, and relevant topics with my classmates and seeing how different people can think", "*What I liked about this class was the reflection and Real World Scenario assignments. They helped me reflect what I learned and how it applies to my own life*", and "*I actually really enjoyed the Real World Scenario assignments because it really helped me apply biology to the real world*". In contrast, most students who said they did not like them just listed the assignment and did not provide an explanation. Those who did provide an explanation indicated they did not like the group work they required. One student commented, "*The in-class group activities. There's just too many people in here for all that craziness.*" Another said, "*When the teacher picked out groups for the Real World Scenario discussion.*" Therefore, some consideration may need to be made to reduce the chaotic nature of having multiple groups working in the same large lecture room. Allowing groups to break out into other nearby classrooms may be an option. Further, some students may be able to engage better in the process if they are allowed to work with other students with whom they have already developed relationships.

This lesson worked well in a lecture-style auditorium with 119 students. A space where students could more easily work in groups would be preferential, but our students were still able to have productive discussions. Therefore, this activity could work in any size of class or classroom. We recommend the utilization of teaching assistants (TAs) or learning assistants (LAs) in large class sizes. In the F2F section, only the instructor was present which limited the interaction with each group. This lack of interaction meant that some groups were more engaged than others and some rushed through the activity so that they could leave earlier. We recommend having TAs/LAs move around the room along with the instructor and interact with each of the groups. In addition to TA/LA support, we recommend a full group discussion at the end of the class period. Having a full class wrap-up discussion would prevent students from rushing through the small group discussions and leaving early. TAs/LAs circulating and working with groups and listening for alternative conceptions that arise would help by allowing the TA/LA to address those issues immediately. They could also report back to the instructor who could make sure to address the issues in the final discussion.

While the online section did not officially have students rate elements of the course, they did provide feedback in the end of term course reflection. Consistently, students wrote they appreciated having a mechanism for interacting with classmates in an online section. Students reported they were impacted by the diverse range of opinions presented in discussions which influenced their own opinions and gave them new insight into the topics discussed. It is noteworthy that the RWS activities not only provided students the opportunity to consider how the content they were learning in class applied to real scenarios they might encounter in their own lives, but also how the content might apply to their classmates with potentially very different life situations.

Despite being fully asynchronous, by structuring when and how students made discussion posts, including having requirements for both their own initial opinion post and commenting on classmates' posts, the online section was able to facilitate student interaction and the exchange of ideas. These same methods could be implemented in any online course, adjusted as needed to accommodate the timing and participation requirements as fits the institution's online instruction expectations (*i.e.,* fully asynchronous, hybrid, or synchronous). Regardless of the online instruction type, because students are assigned to smaller discussion groups, these RWS activities could be implemented in online sections of any size. The need to check and monitor student posts, both for content and respectful interaction, is labor intensive and we recommend that TA/LAs are available to assist the instructor in large online courses.

In addition to the Real World Scenarios, both sections of the course also included Science in the News papers and Reflection papers. The Science in the News papers required students to choose a Scientific American article from a selection curated by the instructor and write about the science behind the article as it connected to their understanding from class, provide a summary of the article, and discuss their own thoughts on the topic and why they chose the article. Students completed two Science in the News papers during the semester (one between RWS 1 and 2 and a second between RWS 2 and 3). The Reflection papers asked students to consider their own understanding in the course and discuss in what ways they see biology as relevant to their own lives. One reflection paper was due at midterm and the second was due at the end of the semester. All three of these components together helped the students reach our goal of seeing the relevance of biology to their own lives.

SUPPORTING MATERIALS

- S1. Real World Scenarios – Instruction Slides for RWS Group Discussions
- S2. Real World Scenarios – RWS1 Paper Instructions
- S3. Real World Scenarios – RWS2 Paper Instructions
- S4. Real World Scenarios – Lesson Objectives Linked to RWS Individual Paper Questions
- S5. Real World Scenarios – Clicker Questions
- S6. Real World Scenarios – Experimental Design Slides

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Table 1. Face-to-face section details.

Activity	Description	Estimated Time	Notes
Preparation for Class			
Introduce students to the process of science and experimental design (Slides in Supporting File S6) Introduce students to content needed to understand the science of the case study in the class(es) before the Real World Scenario takes place. Make copies of case studies and paper instructions. Assign students to groups. Create the slide with group discussion expectations and instructions	1. Create teaching materials to introduce students to the needed content. 2. Make one copy of Case Study for each student (or provide in online LMS). 3. Make one copy of Paper Instructions for each student (or provide in online LMS). 4. Randomly assign students to groups of 4-5. 5. Create slide to show each group and its members 6. Create slide for expectations/ instructions	About 1 hour of creating content materials for slides and at least one class period for needed background content. About 20 minutes of copying and 20 minutes of assigning groups and making the slides	• Case Studies used here are all available on the NCCSTS Case Collection website • The paper instructions for the case studies we used are available in Supporting Files S2 and S3 • An example of the slide with group expectations and instructions is included in Supporting File S1
Class Session 1			
Give students instructions and pass out case study handouts Allow students to break into groups Walk around and offer support as needed Give students handout with paper instructions when they turn in the group work.		5 minutes for introduction 80 minutes for group work in which students alternate between reading and answering questions at the end of each section.	

Table 2. Online section details.

Activity	Description	Estimated Time	Notes
Preparation for Class			
Introduce students to content needed to understand the science of the case study in the class(es) before the Real World Scenario takes place. Post links with case studies and paper instructions. Assign students to groups. Post document with group discussion expectations Post document with paper instructions	1. Create and post teaching materials to introduce students to the needed content. 2. Provide a clear link to the case study and to discussion and paper instruction in the course calendar / on appropriate page 3. Randomly assign students to groups 4. Send reminder messages about discussion format, expectations, and due dates. 5. Send reminder messages about paper format and due date	About 1 hour of creating content materials for slides. About 30 minutes of formatting links, opening assignment, and assigning groups	• Case Studies used here are all available on the NCCSTS Case Collection website • The paper instructions for the case studies we used are available in Supporting Files S2 and S3
Class Session 1			
Open discussion on set date / time for students to access Monitor posts as they are made over the days the discussion is open		2-5 minutes opening assignment /confirming access Monitoring time will vary based on class size	