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Supplemental Materials

for

Creating and Teaching Science Lessons in K–12 Schools Increases Undergraduate Students' Science Identity

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Table of Contents

(Total pages 19)

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Appendix 1: Elementary school service-learning lesson plan

Service-learning Activity Planning Sheet (15 pts.)

Names: Date:

Activity Topic:

Objectives: What do you want the students to know about your topic? No more than 1-2 concepts.

Introduction to the Activity (2-3 minutes) This should be an exciting introduction to your topic and hit upon the objectives you hope to achieve. You can give some physiology here, or you can wait to talk about it at the end when you do your assessment. A great visual aid will help with the introduction.

Questions to answer: How will you explain the activity to the students? Who will do this? What will be your visual aid?

Activity (5-7 minutes)

The activity should be planned so that a group of five to six K-12 students can do it and it is not too long and not too short. The activity should be attractive/interesting to young students.

Questions to answer: What activity will your group perform? What materials do you need? Who will lead the activity? Will you divide up the students into smaller groups to do the activity? Does the activity help you to get across your objectives?

Material List (include quantities)

Assessment of Objectives (2-3 minutes)

At this point, you can use this time to ask the students about what they have learned during their experiment, and record their answers. You want to make sure that your assessment aligns with your originally stated objectives. Your assessment is most easily achieved by having the students raise their hands to answer questions (and count them). You need to return from the activity with a quantifiable result of your activity. **Please attach to this sheet a copy of your assessment data recording sheet and the name of the person in your group who will be responsible for recording the data. You need these data for a brief final report.**

Questions to answer: What questions will you ask on your assessment? How will you execute your assessment? Who will lead this?

Overall Logistics to Consider:

1. Is each section properly timed out?
2. Does every person in your group have a specific role?

***We will need a Phys student from each lab to volunteer to give a 1 minute or so overall welcome, introduction, and instructions!**

Appendix 2: Elementary school service-learning dress rehearsal rubric

Topic:

Names:

	Rating
Objectives are appropriate for the age group. (2 pts.)	
Introduction catches student attention. (1 pts.)	
Introduction is physiologically informative. (1 pts.)	
Activity addresses objectives. (2 pts.)	
Timing is considered, flow of activity is smooth upon execution. (2 pts.)	
The assessment tests the stated objectives. (1 pts.)	
The assessment is quantifiable. (1 pt.)	
Each individual student in the group is well prepared and has a role. (2 pts.)	
Visual aids are well done and informative. (2 pts.)	
Total time is between 10-12 minutes. (1 pts.)	
Total Points (15 possible)	

Additional Comments:

Appendix 3: Elementary school service-learning example lesson plan

Service-learning Activity Planning Sheet (15 pts.)

Names: Date: *3/1*

Activity Topic: *Sense of Smell*

Objectives: What do you want the students to know about your topic? No more than 1-2 concepts.

1. *Why do certain smells evoke certain feelings and responses, and how does this help keep us safe?*
2. *How do we smell?*

Introduction to the Activity (2-3 minutes) This should be an exciting introduction to your topic and hit upon the objectives you hope to achieve. You can give some physiology here, or you can wait to talk about it at the end when you do your assessment. A great visual aid will help with the introduction.

Questions to answer: How will you explain the activity to the students? Who will do this? What will be your visual aid?

We all know some things smell good, and some things smell bad. For example: (have one blindfolded elementary student smell 1 good thing and 1 bad thing and observe their reaction). But why do we like the smell of some things and hate the smell of other things? And how do we smell in the first place?

Visual aid will be a 3-D posterboard cutout of a nose with different receptors drawn inside. "Smell particles" that fit into the receptors will be created to show how these molecules fit to different receptors, and then tell the brain what kind of smell it is.

Activity (5-7 minutes)

The activity should be planned so that a group of five to six K-12 students can do it and it is not too long and not too short. The activity should be attractive/interesting to young students.

Questions to answer: What activity will your group perform? What materials do you need? Who will lead the activity? Will you divide up the students into smaller groups to do the activity? Does the activity help you to get across your objectives?

Each student will be blindfolded and different smells will be presented for them to smell. We will have 2 bad smells (spoiled milk, dirty water from river) 2 good (chocolate, lilac), and 1 neutral (water). We will ask them what they think the smells are and record their answers. We will then reveal to them the answers, and ask them why they think the spoiled milk and dirty water smelled bad. We will explain that evolutionarily, we think these things smell badly so that we don't eat things that are bad for us.

Next we will use our visual aid to explain HOW we mell. We will talk about olfactory receptors bind to chemicals that enter our nose, and these receptors send signals to the brain that interpret that smell as good or bad.

Material List (include quantities)

Spoiled milk (1 cup)

Dirty water (1 cup)

1 chocolate bar

Lilac candle

Water (1 cup)

Poster cut out of nose and receptors

Assessment of Objectives (2-3 minutes)

At this point, you can use this time to ask the students about what they have learned during their experiment, and record their answers. You want to make sure that your assessment aligns with your originally stated objectives. Your assessment is most easily achieved by having the students raise their hands to answer questions (and count them). You need to return from the activity with a quantifiable result of your activity. Please attach to this sheet a copy of your assessment data recording sheet and the name of the person in your group who will be responsible for recording the data. You need these data for a brief final report.

Questions to answer: What questions will you ask on your assessment? How will you execute your assessment? Who will lead this?

Pick the right answer by a show of hands (students will cover their eyes so as not to be influenced by their neighbors):

1. *Why does rotten milk smell bad to us? Raise your hand if you think it is to keep us from drinking it. Raise your hand if it's because you see that it is past its expiration date.*
2. *How do you smell? Raise your hand if it's because your nose sends signals from receptors to your brain. Raise your hand if the chemicals go directly to your brain.*

Overall Logistics to Consider:

1. Is each section properly timed out? *Yes*

2. Does every person in your group have a specific role? *Yes*

	Correct Response	Incorrect Response
Question #1		
Question #2		

*We will need a Phys student from each lab to volunteer to give a 1 minute or so overall welcome, introduction, and instructions!

Appendix 4: High school service-learning lesson plan

Title of Lesson Here…. Be creative (10 points)

by: YOUR NAMES HERE

Student Learning Objectives:

Students will:

1. List here your measurable objectives. What do you want the students to walk out knowing or being able to do?
2. Make sure your objectives match the lesson/activities and are appropriate for high school. Two or three objectives will be enough.
3. Come up with your learning objectives BEFORE thinking of the activity.

<table>
<tr><td rowspan="3">Lesson Overview: 1-2 sentences here</td><td>Subject Area: Basic Molecular Biology</td></tr>
<tr><td>Topic: Nature-nurture</td></tr>
<tr><td>Audience: high school biology</td></tr>
<tr><td rowspan="2">Resources:

1. List any powerpoints/student worksheets that are to be developed and used in this lesson
2. List any websites that are required in executing this lesson
3. If you are using a published case study, what is the title, who are the authors, and where did you find it?</td><td>Suggested Time: 45 minutes

Elaborate here. How much time will each part take?</td></tr>
<tr><td>Materials:

1. List them here
2. And, here
3. And, more here
4. Do your students need their own computers or cell phones?</td></tr>
</table>

Background:

1. Include background information that the instructor (or you and your classmates) should know about the topic (be descriptive!).
2. Are there any chapters in your textbook, youtube videos, or websites that the instructor should visit for good information? List them here.
3. Your lesson should be related to findings from the scientific literature. List at least one relevant article here. Summarize the article.

Engage:

1. Include a few sentences describing the **e**ngagement activity you will use for your lesson. How will you capture their attention?
2. How will you assess what they already know? Or how will you review fundamental concepts that you think they should know already?

Explore:

1. Include a description of the **e**xploration activity you will use for your lesson. This part will probably be the heart of your lesson.
2. Again include links to any web resources and materials that are needed.
3. Will the students be working as a class, in groups, individually?

Explain:

1. How will you discuss the results of the activity with your class? This is a great place to bring in some case studies.
2. How will you further assess and correct misconceptions in content knowledge?
3. Will you use powerpoint? Worksheets? Small group discussion?

Elaborate/Extension(s):

1. Additional situations in which students can apply the concepts and skills they just learned. For example, a skit or game works great here.
2. Allow them time to re-evaluate their understanding of these concepts and fit them into their prior knowledge.

Evaluations/Assessment Strategy:

1. Provide an activity that assesses student understanding of the learning objectives.
2. If you plan to use a game, what kind of game will you play? Jeopardy, Kahoot, etc.? Will you split them into teams?
3. If you plan to have them free-write, how will you direct them? Will you collect?
4. If you give a quiz, will it be timed?
5. Will there be an award for the “winners”?

Appendix 5: High school service-learning lesson plan grading rubric

Lesson Plan Grading Rubric (1 point each; 10 points total)

The activities and learning objectives relate to epigenetic concepts.

Includes actual concepts/cases founded in the literature. (Uses cases based on empirical evidence.)

The learning objectives are clearly defined, match the activities, and are reasonable for this audience.

Relevant and descriptive background information is included.

Engagement activity is reasonable and incorporates assessment of prior knowledge.

Explore. The activity/lesson will be engaging for all high school students, not just high functioning students. Engages everyone in the room.

Plan for explaining and elaborating concepts seem effective.

The assessment plan is effective.

There is evidence that the authors contemplated the timeframe. The lesson could be done in 45 minutes. (Not too short or too long.)

The lesson plan is neat and organized. (It is easy to envision what the lesson will entail.)

Appendix 6: High school service-learning subway speech instructions

Subway speech on your choice of article related to epigenetics (10 points)

Instructions: Choose a **primary, peer-reviewed** article on epigenetics (published in the last 3 years). Recall the definition of epigenetics and find an article that *INTERESTS YOU*. Prepare a brief (3-5 minute) summary of the article in the language that you would use to discuss an article with an average person. Keep in mind that this speech is not so much a demonstration of the complex vocabulary and concepts that you know, but instead, your ability to distill those complex ideas into a form that a nonscientist can understand.

Your speech summarizing the article should include the following:

1. Pertinent background info. Assume that they have a high school education – they have been exposed to concepts such as cells, DNA, and genes, but might need some help. They *definitely* will not know what methylation and acetylation are. Background information should include why this topic is interesting to you (i.e. why you chose that particular article).

2. The high points of the article. Avoid getting into very fine detail that might lose the audience.

3. Why they, the average person, should care. Why should the findings in this paper matter to them? How does it affect their everyday lives?

<u>The speech is out of 10 points. This is the rubric I will use to grade you:</u>

Professionalism					Points earned
Correct grammar	0	1			
Clarity of speech	0	1			
not a lot of "umms", voice volume, etc.					
Enthusiasm and interest in the topic	0	1			
Makes eye contact, doesn't read off of paper, etc.					
Spoke at the average person's knowledge level	0	1	2	3	
Content					
Sufficient background to understand article	0	1			
Why the article interests you	0	1			
Summarized high points well	0	1			
Good explanation of why they should care	0	1			

Appendix 7: High school service-learning subway speech rubric

Presenter's name _____

Professionalism	Points earned				
Correct grammar	0	1			
Clarity of speech	0	1			
Enthusiasm and interest in the topic	0	1			
Spoke at the average person's knowledge level		0	1	2	3
Content					
Sufficient background to understand article	0	1			
Why the article interests them		0	1		
Summarized high points well		0	1		
Good explanation of why the audience should care	0	1			

Total points:_____

Appendix 8: High school service-learning reflection questions

Name: _____

1. Do you think the activity was successful? Why or why not?

2. What part of the activity do you think worked really well?

3. What part of the activity would you change?

4. In what way was this activity valuable you as an Augie student or in your future career? What skills did you get from the activity?

5. Describe your role in the activity. How much effort and enthusiasm did you put in? Did you see others putting in the same or more effort?

6. Is there anything else that you think is important for the instructor to know?

7. Out of a possible ten points, give yourself a grade: _____/10
8. Explain why you gave yourself the grade that you did.

9. Choose two other people with whom you worked closely during the development and execution of the activity. Give each of them a grade out of 10….

    a. Name of person #1: _____
        i. Grade out of 10 points: _____/10
        ii. Explanation:
    b. Name of person #2: _____
        i. Grade out of 10 points: _____/10
        ii. Explanation:

10. Besides the two people above, was there anyone else in your lab section who you think deserves a 10/10? Why?

Appendix 9: Common post-survey

The purpose of this study is to assess the effect of service learning projects on various aspects of student learning and persistence in science. Results of this survey may be reported in a future life sciences education journal. You will be benefitting the scientific community by contributing the best teaching practices in the life sciences. This survey is completely anonymous. If you do not wish to participate, do not answer the questions and turn in the survey blank. Your responses or refusal to participate will not affect your grade.

Instructions: Do not put your name on the survey or make marks that could identify you. Please rank each statement by placing an X in the appropriate box.

	Don't know	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I am confident with my knowledge of (the topic).						
I am confident explaining scientific concepts to the general public.						
I am confident in my ability to work with K-12 students.						
I see myself as a scientist.						
I am a member of the scientific community.						
In general, scientific outreach is important to the community.						
My participation in scientific outreach is important for the community.						
Understanding (the topic) is valuable knowledge for the general public.						
I am excited to help someone else discover a new concept in science.						
I believe that nonscientists have a realistic view of what current scientific discoveries are telling us about the world.						
My participation in the activity matters in the k-12 students' understanding of (the topic).						
My participation in the activity matters in those students' perception of science (excitement, understanding, value, etc.).						
I have strongly considered a career in teaching.						
The opportunity to do service as part of my coursework is valuable to me.						
Applying my scientific knowledge outside of the classroom is exciting to me.						
I have participated in a summer research experience						

Appendix 10: High school service-learning example lesson plan

Oh my goat!

by: Biol 358 section C

Student Learning Outcomes:

Students will:

1. Explain information flow in the cell (central dogma)
2. Define epigenetics
3. Describe how individuals with the same DNA may have different phenotypes
4. Describe how modification of DNA and DNA packing can change how a gene is expressed

<table>
<tr><td rowspan="3">Lesson Overview: Students will learn about epigenetics through a hands-on activity, comical skit about DNA packing, and fun games.</td><td>Subject Area: Basic Molecular Biology</td></tr>
<tr><td>Topic: Epigenetics/Nature-nurture</td></tr>
<tr><td>Audience: high school biology</td></tr>
<tr><td rowspan="2">Resources:

1. Powerpoint file to guide flow of activities (Smartboard or projector with screen is needed)
2. Kahoot! (Students will need cell phones or portable device to access Kahoot)
3. Goat scream Youtube video: https://www.youtube.com/watch?v=ZVCFcR1LOng (need access to projector and sound)</td><td>Suggested Time: 45 minutes

Engage 5 min, Explore and Explain 15 minutes, Extend 7-10 minutes, Evaluate 10 min, Conclusion if remaining time</td></tr>
<tr><td>Materials:

1. Tubing cut into long pieces and placed into three boxes (see explore)
2. Construction paper for signs
3. Yarn (elaborate)
4. Timers (explore)</td></tr>
</table>

Background:

1. Identical twins and clones can be different because their DNA, although identical in sequence, can be modified by chemical tags, such as methylation
2. These modifications can change the way genes along the DNA are expressed, such as during development
3. Heterochromatin is tightly packed and does not have expressed genes
4. Euchromatin is not tightly packed and genes are expressed

Engage:

1. Introduce selves
2. Play Taylor Swift/goat scream video. Screaming goat needs to be cloned. Ask the class, “Will the cloned goat have the same scream?” Whip around the room.
3. Assess prior knowledge: Kahoot questions range from genotype-phenotype relationship to epigenetics definition

Explore:

1. Present 3 boxes (nuclei) have been filled with rubber tubing (DNA) to the class.

    a. In one box, the rubber tubing represents euchromatin. The gene is marked by a red sharpie. The tubing is uncoiled with the gene easily found.
    b. Second box contains heterochromatin. The tubing is all coiled up with the gene in the middle of the packed DNA (tubing). It is hard/impossible to access the gene.
    c. Third box has methylated DNA. The tubing has tape (methylation) wrapped around it, including covering the sharpie (gene) so the gene cannot be found.
2. Choose HS student volunteers to work as teams. Two students per box. One student is labeled a 'transcription factor'.
3. HS student volunteers will be timed for how long it takes them to find the "gene" among the DNA and unravel that strand of DNA.

Explain:

1. Reinforce concepts from the box activity using a few illustrative examples of above concepts
2. Introduce the basic ideas of methylation and its role in epigenetics

Elaborate/Extension(s):

1. Present the idea that gene expression can change during development. Introduce other important major concepts
2. Perform a short comical skit about the action of DNA packing during puberty
3. Divide class into small groups with 1-2 MB students per group. Using yarn as DNA and HS students acting as histones, HS students model actively expressed versus silenced expression, with the guidance of MB students.

Evaluations/Assessment Strategy:

1. Summarize what was explored during lesson
2. Revisit "Will the cloned goat's scream sound the same?"
3. Kahoot questions will assess what the HS students actually learned

Appendix 11: Elementary school detailed faculty instructions

1. **Article Discussion**. We required the students to read "Skepticism of science is on the rise. . . what makes reasonable people doubt reason?" published in the March 2015 edition of National Geographic (8) as a good way to stimulate discussion on the importance of this topic. The article was posted on the course website and students wrote a one paragraph reaction piece to the article that was worth five points. Chairs were set in a circle, and the instructor led a discussion of the article by asking students to volunteer to read their reaction pieces out loud or to give a summary of their reaction to the piece. Other questions such as, "What are things scientists could do to help people increase their trust and understanding of science?" and, "At what age do you think people begin to be skeptical about science?" were asked of the group in order to foster discussion. The discussion was completed by the instructor suggesting that one small way to provide the public with a positive experience with science would be to visit an elementary school and explain physiological concepts to elementary students. The instructor then introduced the assignment. This discussion was normally done during lecture time, but could easily be done during lab as well.
2. **Lesson Design.** Students selected a topic, determined one or two learning outcomes, and thought of an activity to engage the elementary students that aligned with the learning outcomes (Appendix 1). They also had to consider how they would assess student learning. A good deal of guidance was needed by the faculty during this initial brainstorming and planning session. Although no specific instruction or handout on how to create learning objectives was given, faculty provided a great deal of guidance to each group by asking students think about whether the objective the students want to teach is appropriate for the age level, and whether the activity that they proposed fit into time constraints. Students often wanted to explain too many aspects of vision, for example, and they were encouraged to focus on only one. It was also important to question the students about how their activity aligned with their objective. Faculty emphasized the importance of the students creating a simple and useful visual aid for their presentation. In addition, it was helpful to provide the students ahead of time with the rubric that will be used to grade their dress rehearsal presentations.
3. **Dress Rehearsal.** During the dress rehearsal, each group presented their presentation to the class, who posed as elementary students. Faculty timed these presentations to be sure that they fit into the

time frame of 12 minutes/presentation. The students gave the presentation, feedback was elicited from peers first, then the faculty provided verbal feedback. The expectations of changes to make was written on the rubric (Appendix 2) which was tallied and given back to the students the next day.

4. **Presentation Day**. Faculty reminded students that each group is responsible for bringing their materials on the presentation day. It was most efficient to create a shared spreadsheet (such as in Google Docs) to facilitate ride-sharing to the schools. Beforehand, one student should be appointed to introduce the college students and let the elementary students know how to proceed through the stations. During the activities, faculty observed and took pictures of the students as the action unfolded. The wrap-up back in the classroom was an important component to the activity and should not be overlooked. Students were reminded again of the importance of science communication to the general public and congratulated on their efforts to this end. We asked students specific questions such as, "How does the activity we just did increase public scientific literacy?" and "How would you have viewed college students visiting your classroom when you were in elementary school?". We told students to reflect upon the example they provided by demonstrating an interest in science and in the elementary students themselves. We encouraged them to consider that their presence may have sparked an interest in science or a desire to attend college. We asked them to share when they first became interested in science, and pointed out that it was often a teacher, parent, or some other figure that they admired who encouraged them. Pointing out the challenges and joys of being an elementary teacher was also a helpful exercise, and we made a point to encourage students to consider teaching science as a career. We found that if one assumes that students understand the wider relevance of the activity without explicitly taking the time to discuss the implications of the activity, they often will not see it, and will wonder why such an elaborate activity was done just to learn sensory physiology. Therefore, it was necessary during the wrap-up to reiterate that the objectives of the activity go far beyond students merely learning content. These sessions do not need to be taught immediately after one another, but in actuality were taught throughout the semester. This adds some flexibility to planning the syllabus.

Appendix 12: High school detailed faculty instructions

1. **Lesson Design.** During the first meeting, the instructor described the service-learning activity and its learning outcomes for the students in the Molecular Biology class. Students were given plenty of in-class time to develop their learning outcomes for the high school students and lesson plan, but were also expected to work on the project outside of class. In general, the students were independent when designing activities, but needed guidance in developing concrete learning outcomes and with some of the more nuanced development, such as creating quiz questions. Holes in the students' knowledge were realized and filled during this stage of the activity. Students turned in two-page lesson plans (Appendix 3). A grading rubric was used to score the plans (Appendix 4). All students in the class voted for their favorite lesson that they wanted to teach in the high school classes. An award was given by the instructor for the selected lesson. Therefore, all lab sections taught the same material, with each lab section visiting one high school class.
2. **Subway Speech.** Before the second meeting, students prepared an oral summary of a primary journal article (Appendix 5, with grading rubric in Appendix 6). This 'subway speech' activity, so named because it was slightly longer than a traditional elevator speech, was intended to allow the students to practice speaking at the level of the general public. Students were tasked with evaluating each other to keep them engaged, but also to ensure students observe a range of science communication abilities. Using a common rubric, each student was graded by the instructor based on accuracy of content, professionalism, and their ability to describe complex ideas to someone who is not a scientist (Appendix 6). Providing too much technical detail and scientific jargon were common mistakes, which were often realized as the student is speaking. Students were then allowed time to work on development of the selected lesson as a whole lab section. Students in their small groups took ownership of a specific part of the lesson, for example, the opening game, a skit, or the final assessment, however, there was cross-collaboration between the groups.
3. **Dress Rehearsal.** During the dress rehearsal, each lab section presented together the selected lesson. The dress rehearsal was critical for success of the actual lesson when visiting the schools. Although the instructor provided some advice, most of the lesson corrections came in the form of self-correction by the students. Importantly, the rehearsal allowed the students the opportunity to determine appropriate

timing and create a plan if the lesson was substantially shorter or longer than the designated 50 minutes. We found a good back-up plan was to have the undergraduate students be prepared to talk about what it is like to study science in college and/or revisit some of the studies they learned about during the subway speeches if there was time remaining at the end of the actual lesson in the high school.

4. **Presentation Day.** Before visiting the classroom, students were reminded to take charge of the classroom and not to stand idly, but instead interact with the high school students as much as possible. Students arrived early enough to be able to resolve any technical issues with their lesson. Once the lesson began, the undergraduate students took the lead, while the faculty became part of the audience. Afterwards, students were allowed time to reflect on the activity through discussion of the major achievements of the lessons and the talents of the student teachers (Appendix 7). Students were tasked with giving each other a review of their participation. Discussion was framed much like is described in the elementary service-learning section.