An inquiry driven interdisciplinary approach to teaching bone decomposition in the high school classroom

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Abstract: In this inquiry-based lab**,** students are provided with the opportunity to apply their knowledge of physiology, forensic science, and chemistry to aid in the decomposition of a simulated body. The students are provided a chicken bone ("body") and are tasked with trying to develop the best method to dispose of the body. Throughout the course of the lab, students will research, design, and conduct a series of experiments which culminate with a gallery walk where students present their experiments and the class decides which method is the best way to dispose of a body. All the materials for the lab are readily available for teachers in high school and college classrooms. This real-world problem engages the students to think about the roles of chemicals, insects, and the environment in the decomposition of biological matter. The method of disposal, experimental design, and testing procedures makes this lab extraordinarily relevant to the lives of students, which is supported by students' reactions to the lab. Students reported that the lab was like being in a television episode in the classroom; it aided them in understanding the interdisciplinary nature of forensic science, and how to design an experiment without a specific outcome. The lab also emphasizes an area of forensic science which is in need of effective laboratory activities especially at the high school level.

Keywords: decomposition, active learning, high school, interdisciplinary, scientific phenomena

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Introduction

The application of scientific concepts learned in the classroom to real world situations can be challenging for many students. The Next Generation Science Standards (NGSS) (1) were developed in part to address this concern, as well as to provide a national document centered on best practices in science classrooms. Having students address real world problems in the classroom also increases engagement (2) and has the potential to introduce students to the interdisciplinary nature of science. This multidisciplinary approach has multiple benefits, such as increasing higher order and critical thinking skills, improving communication, and fostering student creativity (3). This, in turn, leads to deeper conceptual understanding and the ability to apply information, versus simple rote memorization or step by step cookbook labs.

Utilizing an interdisciplinary approach does have drawbacks. Students can find it challenging to connect specific aspects of science without explicit instructional guidance. Many educators are specialized in a specific discipline of science, facilitating student learning in this multifaceted approach puts more pressure on the instructor to be well versed in how the various aspects of science, and possibly industry, complement one another.

One method that educators can use to increase student engagement with the material is centering a lesson or unit around a phenomenon (4). A phenomenon is a natural event that students can use their scientific knowledge to explain. The phenomenon does not need to be flashy but should include a hook to garner student interest. The benefit of using a phenomenon is that it aids in student application of science knowledge and can motivate them to explain a concept. An added benefit of using a phenomenon is that many events are interdisciplinary, and students can draw upon their entire science knowledge, versus a single discipline, to explain them.

This inquiry-driven laboratory activity was developed with the aim of addressing these issues. Our aim was to create an activity that focused on student interest, students planning and conducting investigations collaboratively, generating data, and investigating the effects of different methods of disposal on body decomposition. The questions and experiments developed by the students lend themselves implicitly to the interdisciplinary aspects of science, because students must synthesize ideas from multiple disciplines to answer their questions. The central phenomenon of the project is, "how would the students dispose of a body?" This phenomenon is flashy, and it gets students' attention because a multitude of crime dramas revolve around body disposal to get away with a crime.

Activity Description

The activity is the culmination of a unit of instruction about entomology, anthropology, and autopsy. The unit would take approximately 15 50-minute class sessions, with the lab taking three of the 15 class sessions. The students begin the unit by reading excerpts from the book *Death's Acre: Inside the Legendary Forensic Lab* (5) and *Dead Men Do Tell Tales* (6). These readings introduce the students to the scientific practices utilized by medical examiners to help identify bodies and the science of bone decomposition. Students then spend the next class periods exploring entomology and anthropology. Once an understanding of these concepts is developed, students watch a documentary over the University of Tennessee's Forensic Anthropology Center, i.e., the "Body Farm (7)."

Next, the classroom is transformed into a research facility where students are tasked with designing their own experiments to break down bone tissue. The students are divided into groups to begin discussing possible questions or methods to investigate how to dispose of a body simulated with chicken bones. The activity is student-driven, which means students may propose a variety of questions or scenarios dependent on the individual class. To aid in the creation of a proposed research question, students are guided by a worksheet (see https://tinyurl.com/Bodydecomp). This also allows the teacher to center student thinking on testable hypotheses based upon materials that are readily available, and to dissuade students from using dangerous materials and methods in their classrooms as students can get creative in how they want to dispose of their "bodies." The student groups then begin designing and conducting experiments that revolve around their specific research question. The total time investment will vary based on the experiment, with some experiments taking longer than others. For example, a group that wants to investigate how strong acids break down bones will take less time than a group wanting to drown their "body" in the pond water. The instructor should encourage the students to revise and elaborate on their proposed questions and materials to help generate usable data to make comparisons between controls and experimental conditions. One possible revision of the research question pertaining to acid decomposition is to compare the speed of decomposition or amount of the body that was disposed (broken down).

Materials and Methods

Materials for the Activity

The materials for the proposed research questions will vary for the individual class and developed hypotheses. **TABLE 1** includes the materials that were used for our student questions. All materials are readily available through school chemical supplies or a local market, but it is important to check the availability of some materials or guide students away from materials that are construed to be too hazardous. It is also beneficial to modify the guided worksheet to reflect the materials available, so students do not propose research questions and experiments that they are unable to conduct.

TABLE 1 *Suggested material list from student questions*

- Acid- we used 8M HCl
- Beakers
- Blankets cut into small pieces
- Bleach
- Blender
- Buckets with lids
- Chicken leg bones - we used chicken thighs with as much of muscle and connective tissue removed as possible
- Environmental materials – leaves, snow, rainwater, etc.
- Fire
- Glass containers with lids
- Household cleaners
- Lye
- Markers
- Plastic bags - grocery sacks and trash bags
- Ruler
- Scale
- Shovel/Trowel- one of our groups buried their bones on school grounds
- Soda
- Soil
- Water- saltwater, pond water
- Ziploc bags

Hazards and Safety Precautions

General safety precautions for laboratory activities in a high school setting will provide protection from the majority of chemicals used in the students' proposed investigations. The specific designs of student experiments could lead to the use of potentially hazardous materials i.e., lye, bleach. Students should use proper PPE when handling these materials such as safety goggles, lab coat, and gloves. All hazardous materials should be kept under a vent hood. Teachers should monitor student groups to ensure that proper safety measures are being followed, especially in groups using strong acids or bases. Care must be taken not to combine household cleaners to avoid the creation of dangerous gases i.e., bleach and ammonia.

Teacher Setup & Additional Notes

Before the lab, the instructor must acquire enough chicken bones for the class. It is recommended to provide at least two bones for each group, plus extra. The bones should be stripped of meat and cartilage as best as possible, wrapped in Saran Wrap, and then stored in an air-tight container in the freezer. The bones should be taken out of the freezer a few days prior to the day of the lab to thaw.

The setup of the lab will vary greatly depending on the students' experimental design. We suggest that students design their lab in one class period and the teacher should set the lab up for the next class period. A summary of some questions from our class can be seen in **TABLE 2.**

TABLE 2 *Student generated research questions and materials needed*

Example research question	Materials needed
-How does water affect the rate of decomposition?	- 2chicken bones, bucket with lid, water, Ziploc bags
-How do plastic trash bags and blankets affect the rate of decomposition after drowning?	- 3 chicken bones, plastic, blanket, pond water
-How does incineration affect the decomposition of a body?	- 2 chicken bones, blowtorch
-How do dismemberment and acid affect the decomposition rate	- 6 chicken bones, hydrochloric acid, blender
- What are some factors that cause adiopocere in a body?	- 4 chicken bones with fat, lye, glass container

During the day of experiment planning, it is helpful to have all materials, aside from harsh chemicals, available for students. You should have MSDS sheets for all chemicals available for reference, which helps students to hypothesize the effect of treatments on bone decomposition. Remember to advise students against mixing harsh chemicals to avoid hazardous reactions. You should also advise students to use glass containers if they are using harsh chemicals which may break down plastic containers. Some experiments are fragrant; therefore having a vent hood available is helpful to keep smells at bay.

Some of the experiments will take longer than others to yield visible results. Our students took anywhere between one class period to two months to see results. The quickest experiment involved burning the body, while some of the acid and pond water reactions took much longer. Students used qualitative analysis to see monitor the progress of their experiments at multiple points during the duration of their experiments. We suggest two-week intervals to gauge the progress of the decomposition if students used chemical means to dispose of their "body." Qualitative and quantitative analyses are possible, such as color, mass, and volumetric changes, but more advanced analyses can require equipment that is usually unavailable in a high school classroom. However, networking with local agencies could allow for more sophisticated analysis or having local agents visit the classroom to demonstrate the equipment and analyses.

Results

The complex bone matrix serves as the target of the students' research. Collagen, a fibrous protein, and hydroxyapatite, or bone mineral, comprise the bulk of dry bone mass. Small amounts of other materials like inorganic salts and proteins are also present. Living bone contains a significant amount of water as well. The success of proposed pathways of degradation will be dictated by how the proposed research questions correlate with the integrity of the matrix. Experimental observations will be a result of how the study design impacts the bony structure and assessment of such may be impacted by resource availability.

Depending on laboratory supplies and instrumentation, experimental designs can be qualitative or quantitative, and range from visual examination to quite technically detailed assessments of molecular and cellular structure. **TABLE 3** builds from the exemplar student generated research questions outlined in **TABLE 2** to aid the instructor through in the interpretation of potential experimental results. In general, the degradation pathways will result in both qualitative and quantitative data, which students must interpret to address their research questions. The instructor may need to guide students in their evaluations based on their academic background and knowledge of chemistry, physiology, and microscopy.

TABLE 3 *Expected experimental results and basic interpretation of observations*

Hypothesis Focus	Variables to Examine	Expected Results	Interpretation of Results
Deterioration in aqueous solution (e.g., water, soda, boiling water)	-Visual color and texture changes -Mass and volume change -Length of time submerged	Decomposition of remaining soft tissue; change in bone color	Bones do not chemically breakdown through this process well
Decomposition in acidic solution (HCl, H_2SO_4)	-Visual color and textural changes -Changes in mass -Microscopic evaluation of "body" with dissection or light microscope	-Bones becomes porous and pitted initially, erosion at edges -Intermediate stages present softer, gelatinous, viscous material -Dark discoloration -Steady decrease in mass -Final stages present material that is amorphous and translucent	Effective at very low pH's because the calcium apatite is more soluble
Decomposition in a basic solution	-Visual color and textural changes -Changes in mass -Microscopic evaluation of "body" with dissection or light microscope	-Specimen may appear whiter over time -Soft tissue and marrow absent or dissolved -Bone may be crumbly texture	Alkaline hydrolysis breaks up proteins by cleaving disulfide bonds Adding lime (CaO) or slaked lime (CaOH) would raise pH and accelerate collagen loss
Effects of fire or a high temperature environment	-Visual color and textural changes -Changes in mass -Microscopic evaluation of "body" with dissection or light microscope	-Bone may appear gray, brown, black	Discoloration is a function of oxygen availability Histological structure is preserved at high temperatures (800-1200°C)

Student Reactions

Our students were incredibly interested in this lab and came up with innovative bone treatments. They thought the lab was "very enjoyable, a lot of fun, and very interesting. It was like TV, but in our classroom!" They appreciated they could work their way through the scientific process and that they had the leeway to design their own experiment. One student stated, "This lab helped me understand how you would go about setting up an experiment given a general goal. Within our teams, we decided exactly our plan, and then we got to follow through and see if our plan would work. The aspect of being able to set up our own experiment instead of hearing a lecture over how to set up an experiment made this lab so much more worthwhile." The students also thought the lab helped them synthesize areas of science, and said, "I believe that this lab helped to create a well-rounded understanding of not only bone decomposition, but also how chemistry, biology, and forensics work together." In fact, students from years past still remember this lab!

Our students both enjoyed and learned much from this lab. They were not only interested in the decomposition of their own bones but were excited to know the results of other groups' experiments. We highly recommend doing a gallery walk or presentations at the end of this lab so students may learn from one another. Students will be motivated to develop a robust hypothesis to test if a gallery walk is used as a summative assessment since the class can potentially vote on which method developed in the class was the best at disposing of a body.

Discussion and Conclusion

There is a multitude of research and activities at the post-secondary level (8–11), but the same cannot be said for high school classrooms. Resources for the high school classroom are centered on relatively few texts (12,13), some peer-reviewed activities (14,15), curriculum repository websites (16), and Pinterest boards of activities. Many of these sources, especially Pinterest boards, do not align with current national science standards. This activity

addresses this gap by giving secondary educators an activity framed by national standards that can easily be implemented in classrooms using readily available materials.

Students can generate very creative ways to dispose of their "bodies" but limitations can arise with the availability of materials and access to equipment needed for quantitative analysis. Some veteran teachers may have networked with local agencies in their community while novice teacher may struggle to make connections. We encourage any high school teachers to reach out to local labs, law enforcement agencies, local colleges and universities with forensic science programs to aid in the use of equipment. Many of these agencies are more than willing to provide outreach opportunities into local high schools.

One recommendation for modifying this activity is how to present the phenomenon itself, disposing of a body. We framed the phenomenon in the context of disposing of a body to get away with murder but in some districts this may not be the most appropriate way to present the activity. High school teachers should use caution and consider the multiple stakeholders in their district and how to best frame the activity when presenting it to their students.

Additionally, this lab activity meets several of the calls from Botch-Jones et al. (17) needs assessment of current forensic science education laboratory activities. First, this activity aligns with national science education standards (1,4) using a phenomenon, in this case, the disposal of a body. This phenomenon will garner the attention of the students and help facilitate a student-centered approach to learning. Second, the activity uses common materials that are found in many high school classrooms, and the "bodies" can be purchased from the grocery store. It is not necessary to purchase expensive equipment if the instructor uses qualitative data generated from the students' designed experiments but limitations can occur with quantitative analysis due to availability of equipment. This can potentially be remedied if a strong network can be established with local agencies. Lastly, many of our students proposed experiments that involve chemistry which Botch-Jones and her colleagues emphasized as an area that needs effective laboratory activities.

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