INQUIRY & INVESTIGATION

Use of Crime Scene Investigations in Anatomy and Physiology: Potential for Going Beyond Knowing in NGSS Dimensions

CATHERINE L. QUINLAN

Abstract

To create and implement meaningful tasks that go beyond the cognitive processes of understanding and that integrate all three dimensions of the Next Generation Science Standards (NGSS) is challenging for both educators and curriculum makers. This issue is compounded when considering a content-rich biology course such as anatomy and physiology that requires first familiarity and understanding before engagement in higher-order thinking. The use of crime scene investigations that encourages students to examine evidence even as they learn specific biology concepts can encourage meaning making about scientific practices and science content. This paper deconstructs the implementation of a crime scene investigation titled the "Jewel Heist," created by the New York Hall of Science and implemented in twelfth-grade anatomy and physiology classes in a diverse urban high school in the northeastern United States. The NGSS, the Framework for K-12 Science Education*, along with Bloom's taxonomy and Krathwohl's revisions, are implicated in this process.*

Key Words: *scientific practices; crime scene investigation; blood; inquiry; NGSS; anatomy and physiology.*

○ Introduction

Rationale and Connection to Taxonomy of Objectives

One of the challenges to teaching anatomy and physiology is that in this content-rich biology course students are being introduced to the structures and functions of the various parts of the body. Thus, it is easy for students to spend most of their time in the knowledge and comprehension cognitive domains of taxonomy, rather than engage in higher-order thinking. Knowledge focuses on the learning of specific facts, terminology, functions, and methodologies, whereas comprehension includes interpreting, drawing conclusions, and making immediate inferences from statements made (Bloom et al., 1956).

This paper explores and analyzes an attempt to take students beyond the traditional anatomy course by including what could be equated to a real-life dilemma.

Going beyond Bloom et al.'s (1956) knowledge and comprehension cognitive domain can be challenging for the biology content that forms the foundation of the structure and function of the human body. This is because the application domain, which comes immediately after knowledge and comprehension, not only requires knowledge and comprehension but additionally means taking principles, theories, or ideas, and applying them to new problems (Bloom et al., 1956). Even less likely to happen in the traditional biology classroom is opportunity for analysis, which according to Bloom et al. goes beyond application; analysis takes information apart to understand its organization, structure, and relationship between the parts. Synthesis, in turn, goes beyond analysis with implications for the use of creativity to reorganize and restructure information (Bloom et al., 1956). Going beyond knowledge and comprehension has implications for functional scientific literacy, which involves the application of scientific knowledge that could be useful to a member of society (Ryder, 2001).

Even though Bloom's taxonomy provides insights into the anatomy and physiology biology curriculum, Krathwohl (2002) proposes that his revised taxonomy provides even more insights into what is missing in a curriculum. Krathwohl's (2002) revised taxonomy contains two dimensions instead of one, the Knowledge Dimension and the Cognitive Process Dimension. Here, Bloom et al.'s (1956) taxonomy of educational objectives is reconfigured into the Cognitive Process Dimension to emphasize verbs such as Remember, Understand, Apply, Analyze, Evaluate, and Create, and each of these are further described by the Knowledge Dimension to determine if the objectives attend to Factual Knowledge, Conceptual Knowledge, Procedural Knowledge, or Metacognitive Knowledge.

The American Biology Teacher, Vol. 80, No 3, pages. 221–226, ISSN 0002-7685, electronic ISSN 1938-4211. DOI: https://doi.org/10.1525/abt.2018.80.3.221.

Thus, Krathwohl's revision of Bloom's taxonomy shows us that what can be further lacking is an opportunity to go beyond Factual or Conceptual Knowledge or an opportunity to Create, even as one gains understanding of one's own knowledge processes.

Recently, the National Academies of Sciences, Engineering, Medicine (2017) convened a two-day workshop that was open to the public to address the challenge to create curriculum materials that addressed all three dimensions of the Next Generation Science Standards (NGSS): Scientific and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas. Even curriculum stakeholders are baffled by the challenge, and the workshop showed that most teachers are implementing materials that they themselves have created or that have been created by other teachers.

The Goal of this Paper

This paper explores and analyzes an attempt to take students beyond the traditional anatomy course by including what could be equated to a real-life dilemma. This report is a reflection on the implementation that took place, and considers the challenges and successes experienced by a high school teacher who taught an anatomy and physiology course for the first time for an entire academic year. The paper documents salient outcomes, advantages and disadvantages, and the challenges encountered in hindsight, to provide insights into its implementation, with possible implications for development of tasks that consider all dimensions of the NGSS (Burnette, 2005). To provide structure to this report, questions from design thinking are used for guidance to align the intentions of the investigation with the descriptions and observations. The taxonomy of objectives along with the NGSS are also used to analyze the investigation.

○ Deconstruction of the Crime Scene Investigation

About the Crime Scene Investigation

This paper describes the implementation of a crime scene investigation in three twelfth-grade elective anatomy and physiology classes in a northeastern urban school where about 30 languages are spoken, and with over half the students receiving free or reduced-price lunch. Crime Scene Investigation Technology (CSIT) was a professional development curriculum designed by the New York Hall of Science (NYSCI). The NYSCI CSIT modules consist of forensic science investigations in various subject areas that align with the NGSS. This particular CSIT was titled the "Jewel Heist" and was implemented in a culturally, linguistically, and cognitively diverse classroom that included honors, general education, and special needs students. The reports are taken from students with signed consent forms allowing the teacher, who is also the researcher, to use their final assignments.

Use of Design Thinking and the NGSS to Deconstruct the Implementation Process: What was the dilemma?

Students were presented with a dilemma: a scenario in which they would help to solve the case of the Jewel Heist by helping the detective to gather evidence. The evidence gathering phase consisted of several stages. Moreover, the gathering of the evidence focused on the scientific practices that students were to carry out. Students had to determine whether or not the evidence gathered matched a list of fictitious suspects that carried some identifying features or had specific blood types or phenotypes, and arriving at their conclusions required sifting through various types of evidence. These included emails that were sent to them by the detective, from which blood types or other identifying features such as tattoos could be inferred. Furthermore, making these inferences required implementation of scientific practices in which students designed an experiment to determine the blood type.

What Were Students Expected to Know? What Were Students Expected to Do?

In this dilemma, students could not simply look for right or wrong answers. They had to revisit certain concepts in biology, such as genetics (Punnett squares), even as they were learning new concepts in their anatomy and physiology course, in this case, blood and blood typing. Thus, this provided opportunities to combine concepts that would not otherwise carry over from an introductory biology course, to give a more holistic view of the connected nature of biology.

How Did They Go About Doing This?

The students were given guiding questions created by the NYSCI CSIT that enabled them to determine the epistemic nature of their inquiry. They were first required to distinguish facts from inferences and facts from assumptions so that when they began to interpret the evidence, they could hopefully be better aware of the nature of their interpretations; that is, whether they were making assumptions rather than inferences. The NYSCI CSIT curriculum was interpreted and translated into a PowerPoint format and shared through googleclassroom, so that the students could work from at their own pace.

What Did I Hope to Accomplish with This and Why?

The goal of this task was to enable students to engage in inquiry and to provide a context in which they can learn the concepts as they engage in inquiry. Thus, the inquiry became a means to an end that would provide engagement and disrupt what could be monotonous as students simply move from one anatomy topic to another. The goal was for students to engage meaningfully in the investigation by asking questions and to make the learning of the biology concepts more interesting and relevant. Overall the goal was to have students talk science and engage in interesting discussions about science, more specifically about the science concepts of crime scene investigations that they are familiar with through television shows like *CSI (Crime Scene Investigation)*.

What Resources Were Students Provided?

Students were provided with resources that included witness statements from emails, photos of the crime scene, a security video clip that quickly captured the tattoo on the perpetrator, and an online criminal database. Students were also given a video clip about blood typing. This crime scene investigation was done after students were introduced to a unit on blood and while they were learning about blood. Students were expected to create a digital portfolio to present to the class (NYSCI CSIT).

Figure 1. Jewelry counter. Image courtesy of Michaela Labriole, Manager of Special Projects. New York Hall of Science.

Due to classroom constraints, and the exploratory nature of this scenario, the teacher left out some of the scientific applications that were indicative of more detailed chemistry understanding and required out-of-pocket purchases of materials for implementations. Thus, sifting through the dilemma, which is the crime, also meant addressing biology concepts such as genetics (Punnett squares) and blood typing. The luminol reaction was not addressed even though this would have been an interesting addition. Some of the crime scene photos used are shown in Figure 1 with permission from NYSCI CSIT.

○ Emergent Themes and the NGSS

Advantages of This Approach

The guiding questions asked students to distinguish a fact from an assumption, and a fact from an inference. Then students were asked to point out the facts from the information given, along with possible assumptions and inferences they could make. This provided opportunity for students to pay attention to form and structure in information, more specifically, in the evidence given. Consequently, the evaluative nature of the task could lead to increased comprehension.

The process enabled systematic interferences that Dewey defines as "the recognition of definite relations of interdependence between considerations previously unorganized and disconnected, this recognition being brought about by the discovery and insertion of new facts and properties" (Dewey, 1910, p. 81). Pieces of information that prior to examination would not have seemed relevant were brought to bear when connections were sought between them; the eyewitness testimonies and descriptive phenotypes of individuals were combined with other scientific information that took the genotypes and possible phenotypic descriptions of eyewitness testimony into consideration. This meant retrieving information from prior knowledge, or if the information was unfamiliar because it was not previously learned, it was revisited by the students; comprehension of this information was necessary in order to apply it during the investigation. Thus, the various types of evidence presented meant that students engaged in what Dewey (1910) defines as critical reflective thought as they sifted through the evidence to determine what was relevant and what was not. Judgment was suspended in favor of reasoning and reflection, and inferential thinking, which Dewey (1910) notes, defines "thinking" in and of itself.

Possible Role of Inferential Thinking

When attending to the information offered as evidence, many questions could be used to guide inferential thinking. The description that follows was generated by the engagement of both the researcher and a nonscience adult to indicate the possible questions that might drive thinking to comprehend the facts given as evidence. For example, the evidence indicated that "this was the third in a string of recent robberies that fit the same pattern." A student could either accept this information as fact, or could ask whether or not this reference to pattern was a fact or an inference. How do we know? How do police detectives determine if something was a pattern? What mechanisms are used for pattern finding? Can we deduce patterns in the data that we observe? If so, how do we go about determining a pattern? These were in fact questions that the researcher asked while pondering the evidence, and students might ask various types of questions as they reason, or simply accept the evidence as fact. The task has the potential to engage different students differently.

Students would need to ask questions of the observations they made in order to distinguish between a fact, an inference, or an assumption. Students who are metacognitively aware would distinguish whether or not they themselves were making inferences or assumptions, or even ask that question of each other. According to the *Framework for K-12 Science Education*, students should be asking various types of questions as they examine a text—in this case, the various types of evidence: "Ask probing questions that seek to identify the premises of an argument, request further elaboration, refine a research question or engineering problem, or challenge the interpretation of a data set-for example: How do you know? What evidence supports that argument?" (2012, p. 55). These questions could include but are not limited to: How do you know it's a "she" and not a "he"? Is that her real hair color or is it dyed? Is this an inside job? Was there a robbery? What was used to smash the glass? Why this pane and not the top one? Which way is easier to scoop up jewels? Why smash, if the tray of rings was taken out already?

This investigation also enabled students to orient themselves toward the evidence for which their own preexisting knowledge structures already exist, thus making different information salient to different students. This idea is supported by studies on schema that define schema as an "active organization of past reactions" (Bartlett, 1932). The significance is that within any group, students attended to information dependent on their own prior knowledge (Marshall, 1995). This means that some might orient themselves mainly toward the scientific evidence, whereas a non-science-oriented individual might attend to the non-scientific facts first. For example, someone concerned with the scientific evidence might ask, How do we test to see if X is true? This might include initially jumping into using Punnett squares or using the information to mentally determine a cross to see if there was a match. The chain of reasoning might look like this: "Her blood type is A+; what is Joe's (her father)? What was the blood type found on the scene?" Knowing the possible alleles for the mother who provided a statement, and the exact blood type at the crime scene, assuming it was the daughter's, could lead to deductions about the possible blood type of the father, if in fact this was a father-daughter job. Some students did actually make these types of deductions and looked for someone with the father's blood type, after finding out what blood type was found at the scene.

Patterns

Students used pattern finding to examine the evidence most salient to them. This included separating the facts from the nonfacts, as the task required. For some, this was the actual events that occurred: "The girl who came in was looking for a ring, the store was robbed in Queens … they rushed out, she fell on the glass and cut herself." When this same group was asked what the evidence was, they noted: "The woman posed as a customer to get the diamond before the man busted through the door and robbed everything else." Thus, for most students it was only until prompted for "evidence" instead of "facts" that they talked about the biological evidence. One group indicated the "faint shoe print in the blood, the blood belongs to a female who cut herself while getting away, the male has a tattoo in his right hand." Only one group combined the information about the blood with their prior understanding of patterns of inheritance to work out the blood type at the beginning of the investigation, and prior to being asked to determine what the blood type was: "She cut her hand before leaving and left a trace of blood behind; from the blood left we figured out she was B blood type." Others simply seemed to look for similarities in phenotypic description, based on the information they learned about what oxygenated versus deoxygenated blood looked like in the video clip. Two other responses are shown below for different groups:

1. The blood from the woman was oxygenated, so we can tell this was not staged blood.
2. The blood found at the crime scene is oxygenated because it is bright red in color, and this is one of the most important pieces of evidence.

Thus, even though students sought comparisons between what they knew and the evidence, the extent to which they used prior understanding of patterns were different.

Cause & Effect

For the remaining students, it was only after they were prompted to investigate the blood type that they worked out what it was. According to the NRC's *Framework for K-12 Science Education*, scientists use causal relationships to determine patterns in nature and sometimes use patterns to deduce cause-and-effect relationships. The students were asked to design and carry out an investigation to determine the blood type, which provided an additional opportunity to learn for those who might not have predetermined the blood type. This required an understanding of the types of chemical and biological interactions that would give a positive test for particular outcomes—a process that students simulated as instructed by the NYSCI CSIT module. Here are some of students' responses to this task. The italics are the questions and instructions derived from the NYSCI CSIT:

> We will determine the blood type of the perp by preforming a blood typing experiment. We know that antibodies and antigens do not mix with every blood type; each blood type has specific antibodies and antigens. We place a sample of the perp's blood that was left at the scene into a small dish with four different sections. We added different types of serums to determine which blood type will clump and eventually figure out the blood type of the perp. The perp's blood type is B+, and she is female.
>
> *What is the perp's blood type? Explain your conclusions.*
> The perp's blood type is B+ because those were the only two samples that did clump the blood sample we found.
>
> *Explain your process by elaborating on these terms: antigen, antibody, agglutination.*
> Because antibodies attach themselves to the antigens, we were able to clearly see which blood types collect clumps and agglutinate.
>
> *What do we know about antigens and antibodies in blood to help us with our test?*
> The antibodies put into the blood will either clump it or leave it alone. Determining which blood does that or doesn't do it will determine the blood type. The blood clumps if antibody A is added and antigen A is present. If RH clumps, then it is positive.
>
> *How can we design an experiment with this information?*
> We add 3 to 5 drops of blood to three separate holes in the blood tray. Then you add 3 drops of antibody A into the first one, Antibody B into the second one, and Antibody RH into the last one.
>
> *What might we expect to see during the experiment?*
> We might expect to see clumping.
>
> *How will we know what [his] or [her] blood type is at the end of the test?*
> The clumping with antibody A or B will determine the blood type. If RH clumps then it is positive, if it does not then the blood type is negative.

Thus, given a simulation for each blood type and antigen, and using their new understandings or most recently acquired prior knowledge, they deduced from the effect of adding the reagent, what blood type caused a positive outcome or agglutination. Thus, students had a second chance through further investigations to explore mechanisms by which certain biological processes occurred, in this case, the patterns of outcomes from combining antigens with antibodies, using simulated blood and reagents.

Nature of Science: Opportunities & Limitations

The NRC *Framework* notes that the emphasis on practices rather than experimental procedures is to bring the focus away from simply using experimental procedures as the main aim, as opposed to using various methods to construct meaning, which they note is much more central to science. Applied to this activity, students' investigations would have benefitted from going beyond their initial conclusions by extending the investigation into an evaluation of their own conclusions. Thus, their attempts at comprehension, application, and synthesis provided the backdrop for their initial analysis. Using the practices to evaluate their synthesis of the situation could have implications for higher-order skills as they examined and evaluated their own thought processes. For example, even though all groups indicated that the tattoo was evidence, they all interpreted the tattoo differently after watching the security video clip footage. Here are five student reports:

1. On the footage the male has a tattoo on his right hand that could be a dragon.
2. The male has a tattoo in his right hand.
3. The male has a tattoo on his left hand seen in the security video.
4. The person who was taking the jewelry has a tattoo on his arm.
5. The male suspect has a tattoo on his right hand that resembles some type of animal, possibly a type of lizard.

The tattoo from the video surveillance took on many life forms and locations on the suspect, including a gecko, lizard, and dragon on either the left or right hand. The discrepancies in their outcomes provided an opportunity for a class discussion and analysis of how they came to different conclusions. In their small group setting, they could have developed a model for creating the best match or best interpretations of the tattoo. Thus, model building and theory building would extend this activity and allow them to come together and have the types of discussions scientists might engage in before accepting the best model: "The focus here is on important practices, such as modeling, developing explanations, and engaging in critique and evaluation (argumentation), that have too often been underemphasized in the context of science education" (NRC, 2012, p. 44). This opportunity to engage in modeling using real world scenarios in biology also means that further work would be needed on how to encourage emergent model building. Thus students would engage in explicit theory building and revisions of theories, which Kuhn (2010) notes is one way that children make sense of their world.

This investigation also provided an opportunity to engage students in more systematic approaches to determining how and why their conclusions and claims were correct. That different groups examined the same evidence and came to different conclusions indicated one of two things: either the investigation was flawed, or perhaps there was no single best answer that fitted the evidence. Thus, this provided a teachable moment for the interpretive and creative, yet systematic, nature of science. Instead of debating the final conclusion—who was the perp?—students could have debated their methods and use of the scientific practices, thus making the nature of science explicit. Here are a few examples of the claims students made and the rationale for their conclusions:

- "We can conclude it was these two because Iris matches the blood type, and if the witness let her try the ring on, she would have noticed the tattoo. Also, Junior has a tattoo of a gecko which is identical to the tattoo seen in the video."
- "While looking through the database, I kept an eye out for tattoos on the male's right hand, height and weight. For the female, I kept an eye for outstanding features because the witness stated the female had red hair. However, because there was not any description of red hair on the online criminal data base. In that case, I moved onto looking at the type of occupations the females had and I singled out suspects by occupation. Due to the fact that the witness statement described the female vaguely, we cannot rule out many females. We also cannot rule out many male suspects because the surveillance video was pixilated, the tattoo is distorted."
- "We chose these suspects based on a accumulation of the witness statement, evidence, and facts. Ms. Soze and Ms. Feldman both have type B positive blood and both have high paying salary jobs. Mr. Luistro is the only male suspect because he has type B positive blood as well, he also has a tattoo on his right hand of a tiger. Mr. Luistro fits the height and weight category given by the witness."
- "The two possible suspects are Iris Breuger and Junior Lorio. We believe our male perp was Lorio because, while watching the security cameras, we observed he has a lizard looking tattoo which we found out he has. Iris was B+ and had an unknown profession, which made her stand out a bit more. There was no clear description on her physical appearance but more on her apparel. In conclusion, with the limited evidence we have, we believe these two suspects are the robbers."

Thus, this investigation has implication for the use of the principles of argumentation to examine evidence. Osborne (2010) and the NRC *Framework* (2012) note that it is just as important for students to know why something is wrong as it is to know why it is right. Moreover, the NGSS define argumentation as follows: "Argumentation is a process for reaching agreements about explanations and design solutions … Argument in science goes beyond reaching agreements in explanations and design solutions" (NGSS Lead States, 2013, App. F, p. 13). Although a large classroom setting presents challenges in engaging all students in debate all the time, communication across the groups could have provided an opportunity to discuss scientific practices. The activity could have been extended to allow students to create a model for determining what would have provided the best sound judgment for the predictions, claims, and outcomes. This was not explored, and would be an important next step as putting it all together in the end takes students beyond the synthesis stage and into the evaluative stage in Bloom et al.'s (1956) knowledge taxonomy. Moreover, this could encourage students to examine their own thought process as they went about the investigation.

○ The Challenges and Outcomes

Creating

Putting it all together in the end to present a case was challenging for students. Since little to no time was spent in helping students to create a presentation to present a case, students simply created a PowerPoint presentation that addressed the guiding questions that were given to them. No one began from where they ended by indicating that this was the guilty person and here was how they went about proving it. However, during their presentation in the mock trial, they did attempt to put it all together by indicating the various evidence that was drawn from the scene. Since their talk was not recorded, the only thing that can be said is that they argued with each other briefly. However, the disadvantage of this process—having them address the evidence first in small groups, then present it, but without specific directions on how to put it all together for that presentation—is that the presentation became redundant and probably not as meaningful as the students' engagement in the process itself. Perhaps the entire activity could be combined with class talk rather than waiting until the end to present, even though students did engage in a great deal of talk, although in small groups. Therefore, one should expect a very brief presentation only of the final outcomes, without reference to the process, if the exercise were replicated as it was here.

In closing, extending the learning to Bloom et al.'s (1956) synthesis and Krathwohl's (2002) creation was challenging, and additional opportunity would need to be provided for students to creatively reconstruct information after taking it apart so that they can present a case that is not confined by the guiding questions. This would require students to reflectively understand and document how they went about knowing, comprehending, applying, analyzing, and synthesizing the information. This means evaluating or making judgments about the value of the evidence, or even using metacognition, knowing about knowing.

○ Acknowledgments

Special thanks to Michaela Labriole, Manager of Special Projects at the New York Hall of Science, for permission to use the materials in this publication.

Reference

Bartlett, F. C. (1932). *Remembering: A study in experimental and social psychology*. London: Cambridge University Press.

Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. R. (1956). *Taxonomy of educational objectives: The classification of educational goals*. A Committee of College and University Examiners. New York and London: Longman.

Burnette, C. (2005). IDesign. Seven ways of design thinking. A teaching resource. Available at http://www.idesignthinking.com.

Dewey, J. (1910). *How we think*. Boston: D.C. Heath & Co. Publishers.

Dewey, J. (1933). *How we think: A restatement of the relation of reflective thinking to the educative process*. Boston: Houghton Mifflin Company.

Krathwohl, D. R. (2002). A revision of Bloom's taxonomy: An overview. *Theory Into Practice*, *41*(4), 212–218.

Kuhn, D. (2010). What is scientific thinking and how does it develop? In U. Goswami (Ed.), *Hand of Childhood Cognitive Development* (2nd ed.) Hoboken, NJ: Blackwell.

Marshall, S. P. (1995). *Schemas in problem solving*. New York: Cambridge University Press.

National Academies of Sciences, Engineering, Medicine (NASEM). (2017, July). *Workshop on the design, selection, and implementation of instructional materials for the next generation science standards (NGSS)*. Public workshop sponsored by Carnegie Corporation of New York and Schusterman Family Foundation.

National Research Council (NRC). (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Idea*. Washington, DC: National Academies Press.

New York Hall of Science (NYSCI). (2015). *Crime Scene Investigation Toolkit Curriculum*. New York: NYSCI.

NGSS Lead States. (2013). *Next Generation Science Standards: For States, By States*. Washington, DC: National Academies Press. Appendix F: Science and Engineering Practices in the NGSS. Appendix H: Understanding the Scientific Enterprise: The Nature of Science. Available at http://www.nextgenscience.org

Osborne, J. (2010). Arguing to learn in science: The role of collaborative, critical discourse. *Science*, *328*(5977), 463–466.

Ryder, J. (2001). Identifying science understanding for functional scientific literacy. *Studies in Science Education*, *36*, 1–44.

CATHERINE L. QUINLAN is an Assistant Professor in STEM Education in the Department of Curriculum and Instruction at Howard University School of Education; email: drcatherinequinlan@gmail.com